California Energy Commission

STAFF REPORT

THE NATURAL GAS RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

Proposed Program Plan and Funding Request for Fiscal Year 2011-12

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ABSTRACT

The California Energy Commission's Public Interest Energy Research (PIER) program was created in 1996 when the State Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring legislation. This law shifted the administration of public interest energy-related research, development, and demonstration (RD&D) from California's investor-owned utilities to state government; a major change intended to ensure the continuation of public interest energy RD&D.

Similar legislation was enacted in 2000 with Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000), which required the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California to fund public interest research and development activities specific to natural gas. In 2004, the CPUC designated the Energy Commission as the administrator for the natural gas research program over a five-year period beginning in 2005.

The Energy Commission manages the electricity research program and the natural gas research program through its Energy Research and Development Division. Countless California stakeholders, research institutions, and governmental partners have collaborated on and participated in the Energy Commission's public interest energy research projects. The success of this state research program depends upon this ongoing partnership.

The CPUC requires the Energy Commission to submit an annual proposed program plan and funding request regarding the program's administration. This staff report is the seventh annual proposed plan, which details the current and future areas of research relevant to California's natural gas ratepayers and stakeholders as well as the Energy Commission's strategic vision for future natural gas RD&D needs. The report covers the 12-month fiscal year 2011-12 (July 1, 2011 through June 30, 2012).

Keywords: California Energy Commission, California Public Utilities Commission, Air Resources Board, CPUC, ARB, natural gas research, PIER, energy research, RD&D, energy efficiency, ARRA, climate science, advanced electricity generation, renewable energy, infrastructure, buildings research, distributed generation, smart grid, carbon sequestration, carbon storage, transportation research

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EXECUTIVE SUMMARY

Background

The Public Interest Energy Research (PIER) Program was created in 1996 when the state Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring legislation. This law shifted the administration of public interest energy-related research, development, and demonstration (RD&D) from California's investor-owned utilities to state government – a major change intended to ensure the continuation of public interest energy RD&D.

Similar legislation was enacted in 2000 with Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000), which required the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California to fund public interest research and development activities specific to natural gas. In 2004, the CPUC designated the Energy Commission as the administrator for the natural gas research program for a five year period beginning in 2005.[1] The Energy Commission manages the electricity research program and the natural gas research program through its Energy Research and Development Division (ERDD).

The CPUC requires the Energy Commission to submit an annual proposed program plan and funding request regarding the program's administration. This is the seventh annual proposed plan, which details the current and future areas of research relevant to California's natural gas ratepayers and stakeholders, as well as the Energy Commission's strategic vision for future natural gas RD&D needs. The report covers Fiscal Year (FY) 2011-12 (July 1, 2011, through June 30, 2012).

Research Policy Guidance

The Energy Commission's natural gas research is driven by CPUC energy policies identified in Decision 04-08-010 and *California's Long-Term Energy Efficiency Strategic Plan*, as well as *Energy Action Plans*, *Integrated Energy Policy Reports* (*IEPR*), the *Bioenergy Action Plan*, and the *State Alternative Fuels Plan*.[2] Collaborative research efforts between the Energy Commission and the Air Resources Board identify technologies that can help reduce greenhouse gas emissions and achieve the policy goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006). In addition, the Energy Commission seeks input from experts in energy and environmental research,

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[1] California Public Utilities Commission, Decision 04-08-010 (August 19, 2004), <http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/39314.htm> (January 27, 2010).

[2] *California's Long-Term Energy Efficiency Strategic Plan*, (September 2008), <http://www.californiaenergyefficiency.com/docs/EEStrategicPlan.pdf> (January 28, 2010).

State Alternative Fuels Plan, (December 2007), <http://www.energy.ca.gov/2007publications/CEC-600-2007-011/CEC-600-2007-011-CMF.PDF> (January 28, 2010).

research organizations, the state's investor-owned gas utilities, and other interested parties during the development of natural gas research priorities.

The Energy Commission integrates its natural gas and electricity research programs to leverage and increase the effectiveness of research for its overall ratepayer-funded RD&D portfolio. This reduces the potential of duplicative research in areas that affect both gas and electric use.

Fiscal Year 2011-2012 Research Plan

The proposed annual FY 2011-12 funding divides primary research activities into four major objectives:

- Improve industrial, commercial, residential, and transportation energy efficiency.
- Accelerate the adoption of clean alternatives to conventional fossil resources and technologies.
- Improve natural gas system and infrastructure performance, reliability and safety.
- Reduce the environmental footprint of California's natural gas system.

The research plan follows the state's "loading order" for new energy resources, led by energy efficiency and renewable and clean distributed resources. Table 1 displays the proposed allocation of the FY 2011-12 budget by research area.

Table 1: Natural Gas Budget Plan Summary FY 2011-12

Budget Item	FY 2011-12 Budget
Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency	$8.75 million
Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies	$7.25 million
Improve Natural Gas System Infrastructure Performance, Reliability and Safety	$1 million
Reduce the Environmental Footprint of California's Natural Gas System	$3 million
Energy Innovation Small Grants	$1.50 million
Program Administration	$2.50 million
TOTAL	**$24 million**

Source: California Energy Commission

The following sections describe specific research activities proposed for FY 2011-12. Before they can begin, individual projects are subject to the Energy Commission's review and approval process for all RD&D research.

Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency

Reflecting the State's energy loading order, the Energy Commission considers natural gas process and end-use efficiency as its highest priority research objective. Research will identify and develop opportunities to achieve greater energy efficiency benefits with existing or market-ready technologies to provide near-term and long-term benefits for California residents and the state economy. The CPUC established a specific state goal of reducing natural gas demand by 290 million therms from investor-owned utility customers between 2005 and 2014 from a 2004 baseline of 13,436 million therms.[3]

The proposed budget plan would support research on energy efficiency through seven core areas: improved efficiency of the hot water distribution system; improved efficiency of food service operations; improved efficiency of industrial and institutional natural gas use; demonstration of emerging technologies for industrial applications; development of advanced distribution systems for heating homes; development and demonstration of advanced fuel-efficient transportation technologies that result in cost-effective reduction of on-road and off-road petroleum fuel use in the short and long term; and development of next generation models.

Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies

Consistent with the loading order, the proposed budget plan also assigns priority to reducing dependence on imported natural gas by diversifying supplies. Ongoing research into renewable technologies and the eventual deployment of market-ready renewable natural gas alternatives could substantially reduce natural gas demand. This is one of the Energy Commission's most prominent research goals.

Key research projects include the development of energy-efficient, cost-effective, safe, clean, durable, and reliable combined heat and power and distributed energy resources technologies; development of commercial heating systems and cooling solutions, biogas, and biomass gasification systems augmented by renewable resources; and RD&D of alternative fuels that reduce petroleum consumption and transportation-related greenhouse gas emissions while assisting economic development within California.

Improve Natural Gas System and Infrastructure Performance, Reliability and Safety

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

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[3] California Public Utilities Commission. *Interim Opinion: Energy Savings Goals for Program Year 2006 and Beyond.* D.04-09-060. http://docs.cpuc.ca.gov/Published/Final_Decision/40212.htm.

- Assess the current state of technology and practices, and identify emerging technologies that can enhance natural gas pipeline integrity and safety.
- Assess residential customer behavior toward advanced customer technologies.

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 effect of a 33 percent renewables portfolio standard that may lead to additional gas-fired generation.

Reduce the Environmental Footprint of California's Natural Gas System

To achieve the long-term greenhouse gas emissions reduction targets mandated by Assembly Bill 32, California must establish an environmentally sound natural gas system. Key targets include efficiency and optimizing the use of natural gas.

The three core initiatives in this research area include assessing the impacts of global climate change; developing strategies to reduce direct and indirect greenhouse gas emissions associated with natural gas; and developing solutions to reduce the impacts of natural gas production, distribution, storage, and use on air quality, biological diversity, land use, public health, and water quality.

Energy Innovations Small Grants Program

The Energy Commission's Energy Innovations Small Grants Program provides research grants to businesses, nonprofit organizations, individuals, national laboratories, utilities, academic institutions, and other qualifying entities for research that establishes the feasibility of innovative natural gas energy concepts.

Beginning in FY 2009-10, the Energy Commission created a separate solicitation process for small grants research focused specifically on transportation. These grants will support the Energy Commission's alternative fuels research and complement the natural gas research areas by funding projects that reduce the consumption of petroleum-based fuels by promoting and advancing renewable and non-renewable alternative fuels using innovative tools and methods.

Program Administration

This budget plan allocates 10 percent of the total budget to administrative expenses, which includes personnel expenses and non-research technical support.

Economic Benefits from Natural Gas Research, Development and Demonstration

Due to PIER's national reputation for RD&D, the program has established a network of strategic partners that enables it to attract millions of dollars in matching funds to California from private and public sources. This is demonstrated with match funding of 66 percent of the natural gas budget.

Economic benefits also occur through PIER-funded projects that directly reduce natural gas costs for end users through efficiency improvements or more economical alternatives that allow

natural gas ratepayers to reduce consumption and realize cost savings. The PIER Natural Gas Program provides additional economic benefits in terms of public interest RD&D funding by committing research funds 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.

Highlights of Natural Gas Research Activities

Public interest RD&D delivers tangible ratepayer benefits, acts as a catalyst for innovation, provides next generation solutions, stimulates the economy, and informs policy. The following projects are highlights of PIER's ongoing efforts to fund natural gas projects that provide tangible ratepayer benefits.

Advanced Heat Recovery Boosts Industrial Efficiency

Recently the Gas Technology Institute issued a press release lauding the successful deployment of the PIER funded Transport Membrane Condenser (TMC) technology at L. & N. Costume and Linen Service, an Anaheim, CA industrial-scale laundry facility that serves a large portion of Disneyland's laundry needs. The TMC is installed above the facility's steam tunnel to recover sensible heat, latent heat and water, which helps to reduce natural gas and water consumption. This demonstration project marks the first non-boiler application of TMC technology. When used with industrial and commercial boilers, the TMC is the cornerstone of an advanced heat recovery system that boosts fuel-to-steam efficiency to as high as 95 percent on a higher heating value basis while recovering usable, clean water from the natural gas combustion products.

The TMC technology is also being used at Baxter Healthcare in Thousand Oaks (an existing boiler retrofit) and at Clement-Pappas & Company, a juice bottler in Ontario (a new Super Boiler installation). Both are experiencing increased efficiency, fuel cost savings, lower emissions, and water savings. Baxter has seen reduced fuel costs and carbon emissions by more than 12 percent. The Clement-Pappas installation has shown comparable efficiencies and reductions in fresh water needs while also achieving stable nitrogen oxides (NOx) emissions below 9 parts per million by volume (ppmv).

GTI and Cannon Boiler Works commercially launched the technology under the brand name Ultramizer®.

ConAgra Demonstrates Efficiency for Food Processing

The Energy Commission collaborated with the Gas Technology Institute and California garlic processor, ConAgra, to develop a gas-fired drum dryer for commercial food production. California consumes an estimated 14.4 trillion British thermal units of natural gas energy for drying, dehydrating fruits and vegetables, and milk processing. The conventional dryers have metal drying cylinders, which are heated from the inside by steam. The use of steam requires the drums to meet pressure vessel codes, which limits the steam pressure and the efficiency of the associated drying capacity. When using the gas-fired drum dryer, ConAgra demonstrated immediate improvements in efficiency at its Gilroy, California facility. This innovative PIER funded technology successfully increased energy efficiency from 60-70 percent (steam-operated)

to 75-85 percent (gas-operated). This represents a potential savings of $21 million in natural gas costs to California industry.

California Steel Demonstrates Large Efficiency Savings

The Energy Commission collaborated with the Gas Technology Institute and North American Manufacturing Company, Ltd. (NAMCO) to develop the Reverse Annulus Single-Ended Radiant Tube (RASERT), a heating tube for use in the metals smelting industry. By using a more efficient design that maximizes heat transfer efficiency, the new burners produced a 25 percent improvement in thermal efficiency. Additional benefits are the reduction of greenhouse gas (GHG) emissions and better air quality for the host site, California Steel's Fontana facility. At California Steel, RASERTs have saved about 2 million cubic feet of natural gas, which is worth approximately $24,000 annually, a direct benefit to California industry. The State uses approximately 5,200 heating units that could be replaced by the RASERT technology. If adopted statewide, this PIER funded technology has the potential to save $8.6 million in natural gas costs.

A Pore-Flow Reactor for Landfill Gas Cleanup Increases Renewable Potential From Landfills

This Energy Innovations Small Grant project demonstrated the feasibility of using a catalytic pore-flow reactor to remove toxic components typically found in landfill gas. California's landfills represent a significant source of methane for use in electric production or as pipeline gas. However, much of the gas from these sources contain various non-methane organic compounds, which limit the use of this resource. Successful removal of such contaminants could increase the use of landfill gas in lieu of flaring or escape into the atmosphere. Researchers at the University of Southern California successfully demonstrated the ability to deposit a platinum nanocatalyst on membranes designed to function in pore-flow mode. These membranes were used to treat a simulated landfill gas containing six representative non-methane organic compounds (NMOCs) in a typical mix of methane, oxygen, nitrogen, and carbon dioxide. Complete destruction of these compounds was demonstrated at temperatures ranging from 200° to 290° Celsius. The researchers provided preliminary estimates of the cost/volume of treated gas and a detailed proposal for further work toward commercialization, including industrial and commercialization partnerships with Media and Process Technology Inc. and GC Environmental, Inc.

Cleaner Biogas Production

The purpose of this Energy Innovations Small Grant project with CHA Corporation was to determine the feasibility of a cost-effective, carbon-based, microwave treatment system that removes hydrogen sulfide from dairy digester biogas and nitrogen oxides from biogas engine exhaust, while meeting California Air Resources Board (ARB) emission standards. Hydrogen sulfide is the most significant contaminant in biogas produced in dairy farm anaerobic digesters. The sulfur in hydrogen sulfide causes corrosive deposits and severe wear on combustion equipment, and poisons catalysts used for post-combustion treatment of exhaust gases. Traditional treatment methods do not remove all the hydrogen sulfide from biogas, and newer removal methods are too costly. Even a small amount of hydrogen sulfide in the biogas

means the methane produced by anaerobic digestion will not meet ARB emission standards while being economically used for electric generation or heat recovery.

After receiving PIER funding for this project, the CHA Corporation then obtained utility funding. This led to a successful field demonstration of the microwave technology. These research and funding opportunities motivated CHA to relocate its operations from Wyoming to California, providing both environmental and economic benefits to the State.

Production of Syngas from Dairy Manure to Replace Natural Gas

The Energy Innovations Small Grant program is currently funding a research project to investigate the potential for extracting energy from farm waste. This study explores the potential of combining dairy manure with various amounts of straw, as well as integrating three processes; biodrying, gasification and gas conditioning to produce medium heating value gas from a dairy manure-wheat straw mixture. The preliminary results of this research have reached some exciting conclusions that will benefit California both economically and environmentally. Assuming that 50 percent of dairy cow manure (750,000 tons/year) produced in California can be utilized via this technique, a vast reduction in natural gas use could occur. 1.5 cubic meters of gas can be produced by gasifying 1 kilogram of dried manure, and the energy content can reach 6 Mega joule per cubic meter of producer gas. Therefore, about 6.75 billion Mega joule can be produced in California only from the manure. In other words, 6.1 billion cubic feet of natural gas equivalent could be produced. This vast amount of producer gas can reward dairy producers by $24 million annually based on a natural gas price of $4 per cubic foot. By gasification and utilization of this vast amount of dairy manure, California can reduce carbon dioxide emission from natural gas by 412,000 tons.

Reducing Natural Gas Consumption by Modifying Water Heaters

Research is nearing completion under an Energy Innovations Small Grant award to determine whether there are easily attainable efficiency gains to be had in residential and commercial gas-fired hot water heaters. Early results indicate that by using a simple and inexpensive baffle inside the tank, natural gas consumed for hot water heating can be reduced by 5 percent. Final verification under this research grant indicates that this slight tweak in the manufacturing process will not cause water heaters to operate outside of manufacturers specifications. The estimated cost of this baffle modification is $3 and the forecasted savings are $10.50 per year for residential and $99.50 per year for commercial consumers. With full implementation going forward, this simple breakthrough could save California as much as $15 million per year.

ARB 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 the general population, including the aggravation of heart and lung disease, and premature mortality. To mitigate this concern, the ARB and the U.S. Environmental Protection Agency adopted the emission standards of 0.20 g/bhp-hr NOx 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, PIER funded research with Westport Power, Inc. to

develop a High Pressure Direct Injection liquefied natural gas engine, and adapt that technology to a premium Cummins 15 liter ISX diesel engine that is being commercialized as the Westport GX engine.

The purpose of this research was to increase the use of natural gas as a transportation fuel by developing advanced natural gas engine technologies that will address regulatory and economic barriers. As a transportation fuel, natural gas could offset over 750 million gallons of diesel per year by 2022. In 2011 dollars, that would be a savings of about $1.35 billion per year, while reducing greenhouse gas emissions 4 million metric tons per year.

On July 6, 2010, Westport's GX natural gas engine successfully met the ARB 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.

American Reinvestment and Recovery Action of 2009 (ARRA)

The federal government's American Reinvestment and Recovery Act of 2009 (ARRA) included more than $62 billion in energy-related grants. This federal legislation presented an opportunity to improve California's energy infrastructure faster than would otherwise have been possible using only state funds. Although no PIER natural gas program funding was allocated to any of these ARRA-related efforts, technology advancements and research lessons are expected to be learned from these California-based projects that will significantly benefit natural gas ratepayers.

To date, the Energy Commission has committed $20.6 million in PIER electricity program cost-share funds to California companies, resulting in the award of more than $500 million in U.S. Department of Energy ARRA funds. The State's $20.6 million in cost-share is leveraging more than $900 million in additional federal and private funding for clean technology implementation in California.

Carbon Capture and Storage Research

The West Coast Regional Carbon Sequestration (WESTCARB) partnership, one of seven regional electricity partnerships funded by the U.S. Department of Energy, is expected to lead to advanced natural gas-fired electricity generation technologies. The partnership consists of more than 80 organizations with the common goal of characterizing regional carbon capture and storage opportunities and conducting technology validation field tests. Slowing and ultimately reversing atmospheric carbon dioxide buildup will require deep reductions in man-made carbon dioxide emissions. Carbon capture and storage is one method to reduce these emissions. Due to the current high costs of implementing carbon capture and storage with conventional power generating systems, advanced electricity generation must be developed that will minimize the costs to ratepayers in a carbon-constrained environment. In addition to the PIER

electricity program match funding provided by the Commission, the WESTCARB program is managing more than $51 million in U.S. Department of Energy funding. In 2010, the Commission initiated research funded by WESTCARB to determine the cost-effectiveness of adding carbon capture and storage technologies to existing natural gas power plants.

Identify and Achieve Long-Term Natural Gas Goals for California's Energy-Smart Development

The Energy Commission will continue to evaluate and calibrate its natural gas research portfolio to maximize the benefits to California's natural gas ratepayers. Central to this effort is a renewed focus on measuring the benefits of the Energy Commission's research activities. While the costs and benefits of most commercially available products and technologies can be quantified, the same cannot be said for premarket emerging technologies. Calculating benefits associated with energy technology research can be especially challenging because not all benefits are readily quantifiable, such as the environmental impact of greenhouse gas reduction.

Nevertheless, the Energy Commission continues to identify and pursue research projects that provide significant and measurable benefits to California's ratepayers. Three primary benefit categories have been identified that accrue to California ratepayers from the activities of the PIER NG program: economic, environmental, and security. The research program results also provide Californians with important benefits that include reduced impact from global climate change, reduced health risks related to poor air quality, lower bills, reduced volatility of transportation fuel prices, and reduced economic impact from dependence on petroleum.

The Energy Commission also focuses on identifying and addressing emerging long-term natural gas-related themes and trends that are important to California's energy-smart future. To assess the benefits of the PIER NG program and identify emerging research trends, the Energy Commission obtains direct feedback, "gap" analysis, and recommendations from utilities, other state agencies, academic experts, industry associations and technology experts. 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. The Energy Commission will continue to conduct more workshops and other activities with the public and stakeholders to identify program improvements.

Looking beyond the next fiscal year, several recently emerged themes in California's energy sector promise to have a profound effect on the Energy Commission's current and proposed natural gas research program. The Energy Commission intends to shape and prioritize its long-term research goals to reflect these themes, which include pipeline integrity and safety, Zero Energy Homes and Buildings, and customers' behavior effects on energy use.

CHAPTER 1: Introduction

The Public Interest Energy Research (PIER) Program was created in 1996 when the State Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring law. Recognizing the benefit of natural gas research to California, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California 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 Research program (PIER NG program). In Decision 04-08-010, the CPUC designated the Energy Commission as the administrator of these research dollars for a five-year period beginning in 2005.

The Energy Commission's natural gas research program has 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; and Senate Bill 76 (Committee on Budget and Fiscal Review Energy, Chapter 91, Statutes of 2005), which added transportation research as an integral element of natural gas research.

This report is the seventh annual *Proposed Program Plan and Funding Request* (*NG Budget Proposal*). It details current and future areas of research relevant to California's natural gas ratepayers and stakeholders, as well as the Energy Commission's strategic vision for future research, development, and demonstration (RD&D) needs related to natural gas research. Covering the 12-month period of Fiscal Year 2011-12, this report complies with the requirements set forth in the CPUC decision and subsequent legislation.

This year's annual budget proposal contains four sections:

- Chapter 1 *Introduction* outlines the history of the Energy Commission's stewardship of ratepayer funded natural gas research and the proposed funding for FY 2011-12.
- Chapter 2 *Research Policy Guidance* highlights the Energy Commission's strategic vision of public interest natural gas research and development. The FY 2011-12 Budget Proposal is allocated according to this vision.
- Chapter 3 *Fiscal Year 2011-12 Research Plan* details the Energy Commission's proposed research solutions within each natural gas research objective, as well as the funds allocated toward those objectives. Examples of completed and ongoing natural gas projects that support the Energy Commission's research objectives are also provided.
- Chapter 4 *Energy Innovations Small Grants Program (EISG)* establishes the plan for the FY 2011-12 EISG solicitation and summarizes the results of the EISG solicitation from FY 2010-11.

Highlights of Natural Gas Research Activities

Public interest RD&D delivers tangible ratepayer benefits, acts as a catalyst for innovation, provides next generation solutions, stimulates the economy, and informs policy. The following projects are highlights of PIER's ongoing efforts to fund natural gas projects that provide tangible ratepayer benefits.

ConAgra Demonstrates Efficiency for Food Processing

The Energy Commission collaborated with the Gas Technology Institute and California garlic processor, ConAgra, to develop a gas-fired drum dryer for commercial food production. California consumes an estimated 14.4 trillion Btus of natural gas energy for drying, dehydrating fruits and vegetables, and milk processing. The conventional dryers have metal drying cylinders, which are heated from the inside by steam. The use of steam requires the drums to meet pressure vessel codes, which limits the steam pressure and the efficiency of the associated drying capacity. When using the gas fired drum dryer, ConAgra demonstrated immediate improvements in efficiency at its Gilroy, California facility. This innovative PIER funded technology successfully increased energy efficiency from 60-70 percent (steam-operated) to 75-85 percent (gas-operated). This represents a potential savings of $21 million in natural gas costs to California industry.

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Advanced Heat Recovery Boosts Industrial Efficiency

Recently the Gas Technology Institute issued a press release lauding the successful deployment of the PIER funded Transport Membrane Condenser (TMC) technology at L. & N. Costume and Linen Service, an Anaheim, California industrial-scale laundry facility that serves a large portion of Disneyland's laundry needs. The TMC is installed above the facility's steam tunnel to recover sensible heat, latent heat, and water, which helps to reduce natural gas and water consumption. This demonstration project marks the first non-boiler application of TMC technology. When used with industrial and commercial boilers, the TMC is the cornerstone of an advanced heat recovery system that boosts fuel-to-steam efficiency to as high as 95 percent on a higher heating value basis while recovering usable, clean water from the natural gas combustion products.

The TMC technology is also being used at Baxter Healthcare in Thousand Oaks (an existing boiler retrofit) and at Clement-Pappas & Company, a juice bottler in Ontario (a new Super Boiler installation). Both are experiencing increased efficiency, fuel cost savings, lower emissions, and water savings. Baxter has seen reduced fuel costs and carbon emissions by more than 12 percent. The Clement-Pappas installation has shown comparable efficiencies and reductions in fresh water needs while also achieving stable NOx emissions below 9 parts per million by volume (ppmv).

GTI and Cannon Boiler Works commercially launched the technology under the brand name Ultramizer®.

Waste Heat Recovery Through the Recovery of Condensate Water (DOME Technology).

The PIER grant solicitation under which this project was developed was a competitive solicitation sponsored by the Industrial, Agriculture, and Water Program to solicit technologies and/or scientific advances that will significantly reduce energy and water use in California's food processing and dairy processing industries. The DOME technology uses a distillation vessel to capture waste heat that is then used to evaporate and recover food processing wastewater. The distillation vessel is designed such that the clean condensed recovered water created by the vessel is drawn down by gravity and creates a slight vacuum in the vessel space behind it. This lowers the boiling point of the wastewater in the DOME device and improves the efficiency of the distillation process. The potential savings to the state with 100 percent market penetration of DOME are significant, totaling some 440 million gallons per year of clean water from state water supplies, 30 million therms of natural gas per year, 185 million kilowatt-hours (kWh) of electricity and associated greenhouse gas carbon dioxide (CO_2) emission savings estimated at 155,000 tons per year. The project will be conducted at the Gill's Onions processing facility located in Oxnard (Ventura County), California.

Production of Syngas From Dairy Manure to Replace Natural Gas

The Energy Innovations Small Grant program is funding a research project to investigate the potential for extracting energy from farm waste. This study explores the potential of combining dairy manure with various amounts of straw, as well as integrating three processes: biodrying, gasification, and gas conditioning to produce medium heating value gas from a dairy manure-wheat straw mixture. The preliminary results of this research have reached some exciting conclusions that will benefit California economically and environmentally. Assuming that 50 percent of dairy cow manure (750,000 tons/year) produced in California can be used via this technique, a vast reduction in natural gas use could occur. 1.5 cubic meters of gas can be produced by gasifying 1 kilogram of dried manure, and the energy content can reach 6 megajoule per cubic meter of producer gas. Therefore, about 6.75 billion megajoule can be produced in California only from the manure. In other words, 6.1 billion cubic feet of natural gas equivalent could be produced. This vast amount of producer gas can reward dairy producers by $24 million annually based on a natural gas price of $4 per cubic foot. By gasification and use of this vast amount of dairy manure, California can reduce carbon dioxide emission from natural gas by 412,000 tons.

Reducing Natural Gas Consumption by Modifying Water Heaters

Research is nearing completion under an Energy Innovations Small Grant award to determine whether there are easily attainable efficiency gains to be had in residential and commercial gas-fired hot water heaters. Early results indicate that, by using a simple and inexpensive baffle inside the tank, natural gas consumed for hot water heating can be reduced by 5 percent. Final verification under this research grant indicates that this slight tweak in the manufacturing process will not cause water heaters to operate outside of manufacturers specifications. The estimated cost of this baffle modification is $3, and the forecasted savings are $10.50 per year for residential and $99.50 per year for commercial consumers. With full implementation going forward, this simple breakthrough could save California as much as $15 million per year.

A Pore-Flow Reactor for Landfill Gas Cleanup Increases Renewable Potential From Landfills

This Energy Innovations Small Grant project demonstrated the feasibility of using a catalytic pore-flow reactor to remove toxic components typically found in landfill gas. California's landfills represent a significant source of methane for use in electricity production or as pipeline gas. However, much of the gas from these sources contain various non-methane organic compounds, which limit the use of this resource. Successful removal of such contaminants could increase the use of landfill gas in lieu of flaring or escaping into the atmosphere. Researchers at the University of Southern California successfully demonstrated the ability to deposit a platinum nanocatalyst on membranes designed to function in pore-flow mode. These membranes were used to treat a simulated landfill gas containing six representative NMOCs in a typical mix of methane, oxygen, nitrogen, and carbon dioxide. Complete destruction of these compounds was demonstrated at temperatures ranging from 200° to 290° Celsius. The researchers provided preliminary estimates of the cost/volume of treated gas and a detailed proposal for further work toward commercialization, including industrial and commercialization partnerships with Media and Process Technology Inc. and GC Environmental, Inc.

Cleaner Biogas Production

The purpose of this Energy Innovations Small Grant project with CHA Corporation was to determine the feasibility of a cost-effective, carbon-based, microwave treatment system that removes hydrogen sulfide from dairy digester biogas and nitrogen oxides from biogas engine exhaust, while meeting ARB emission standards. Hydrogen sulfide is the most significant contaminant in biogas produced in dairy farm anaerobic digesters. The sulfur in hydrogen sulfide causes corrosive deposits and severe wear on combustion equipment, and poisons catalysts used for post-combustion treatment of exhaust gases. Traditional treatment methods do not remove all the hydrogen sulfide from biogas, and newer removal methods are too costly. Even a small amount of hydrogen sulfide in the biogas means the methane produced by anaerobic digestion will not meet ARB emission standards while being economically used for electric generation or heat recovery.

After receiving PIER funding for this project, the CHA Corporation then obtained utility funding. This led to a successful field demonstration of the microwave technology. These

research and funding opportunities motivated CHA to relocate its operations from Wyoming to California, providing both environmental and economic benefits to the State.

Engine CHP Emission Control Technology

Reciprocating engines have been the preferred prime mover for CHP applications less than 3 megawatts, and because they are relatively low cost and have high efficiency, reciprocating engines are projected to be the choice for a large majority of CHP applications through 2020. The inconsistent ability of engine emission control technology to comply with tightening emission requirements impedes the adoption of CHP in California. Indeed, a major deterrent for new CHP implementation in the State is the failure to cost-effectively achieve and sustain compliance with the ARB 2007 emission regulations and the amended South Coast Air Quality Management District (SCAQMD) Rule 1110.2 emission standard and real time emission monitoring protocols.

The *Engine CHP Emission Control Technology* project is developing and testing ultra clean emission technology for small to medium (60 – 1,000 kW) engine CHP systems that will address the emission level and monitoring requirements while keeping a favorable cost. The emission technology will have the following attributes: (1) emission of criteria pollutants below the ARB 2007 emission guidelines; (2) real-time monitoring and control to sustain operations within ARB 2007 emission guidelines without the need for frequent hand-held emission analyzer tests; and (3) a cost premium less than 10 percent of existing CHP systems. Completed tests demonstrated the capability of developed emission technology to achieve the emission targets, while a breakthrough finding in emission design and strategy is being refined for possible patenting of the technology, subsequent coupling with specific engine CHP, and marketing.

ARB 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, including the aggravation of heart and lung disease, and premature mortality. To address this concern, the ARB and the U.S. Environmental Protection Agency adopted the emission standards of 0.20 grams per horsepower-hour (g/bhp-hr) of NOx for 2010 and newer heavy-duty engines. Heavy-duty natural gas engines 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, PIER funded research with Westport Power, Inc., to develop a high pressure direct injection liquefied natural gas engine, and adapt that technology to a premium Cummins 15 liter ISX diesel engine that is being commercialized as the Westport GX engine.

The purpose of this research was to increase the use of natural gas as a transportation fuel by developing advanced natural gas engine technologies that will address regulatory and economic barriers. As a transportation fuel, natural gas could offset more than 750 million gallons of diesel per year by 2022. In 2011 dollars, that would be a savings of about $1.35 billion per year, while reducing greenhouse gas emissions 4 million metric tons per year.

On July 6, 2010, Westport's GX natural gas engine successfully met the ARB 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.

Algae OMEGA (Offshore Membranes for Growing Algae)

Renewable diesel and gasoline have the potential to offset more than 530 million gallons per year of petroleum derived fuels by 2022, also reducing greenhouse gas emissions by at least 4 million metric tons per year. Compared to conventional fuel production, however, algaeculture remains up to 100 times too expensive to make into commercially viable biofuels that are necessary to reduce GHG emissions. [4] 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. PIER funded NASA Ames' Offshore Membrane Enclosures for Growing Algae (OMEGA) system to develop the technologies and methods needed to make sustainable, large molecule gasoline and diesel replacements cost-competitive. 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 is composed of municipal effluent, accomplishing the additional goal of enhanced wastewater treatment while cultivating algae for fuel.

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.

Funding Priority Overview

Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) directs the Energy Commission to meet new research investment goals while performing a full range of RD&D not supported by competitive markets. The natural gas research program includes energy efficiency, advanced electricity generation, renewables, transmission and distribution, transportation and energy, and climate science.[5]

Table 2 and Figure 1 display the proposed allocation of the FY 2011-12 natural gas program budget for each research objective.

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[4] The agrarian process of growing and harvesting algae for its many by-products.

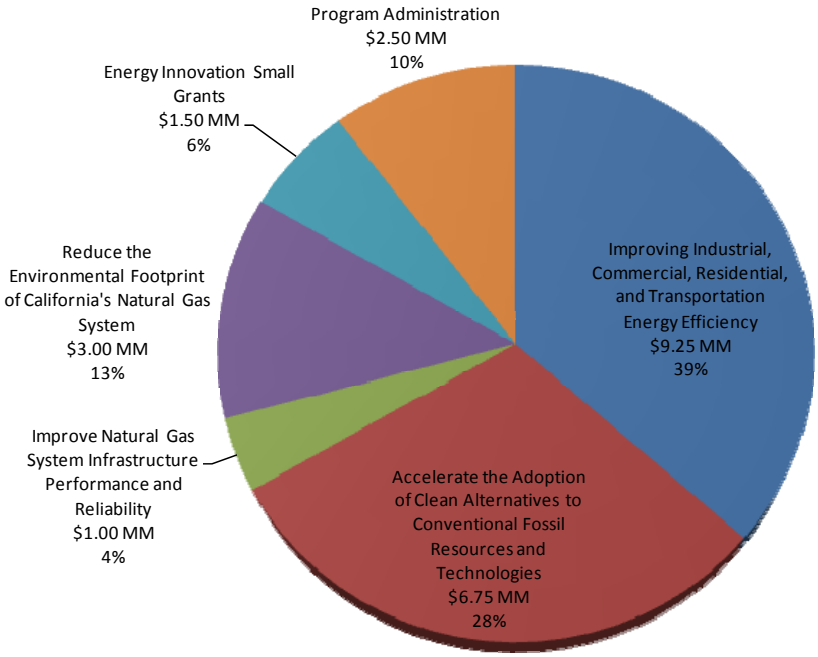
[5] *California Energy Commission Public Interest Energy Research Program 2008 Annual Report: Investing in California's Future Today*, CEC-500-2009-064-CMF, (March 2009), <http://www.energy.ca.gov/2009publications/CEC-500-2009-064/CEC-500-2009-064-CMF.PDF> (January 27, 2010).

Table 2: Natural Gas Budget Proposal Summary

Budget Item	FY 11-12 Budget
Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency	$8.75 million
Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies	$7.25 million
Improve Natural Gas System Infrastructure Performance, Reliability and Safety	$1 million
Reduce the Environmental Footprint of California's Natural Gas System	$3 million
Energy Innovation Small Grants	$1.50 million
Program Administration	$2.50 million
TOTAL	**$24 million**

Source: California Energy Commission

Figure 1: Proposed Natural Gas RD&D Budget for FY 2011-12



Source: California Energy Commission

CHAPTER 2:
Research Policy Guidance

Natural Gas Research Vision

The Energy Commission's natural gas research is governed by energy policies identified in the CPUC's Decision 04-08-010 and *California's Long-Term Energy Efficiency Strategic Plan*, as well as *Energy Action Plans*, *Integrated Energy Policy Reports (IEPR)*, *the Bioenergy Action Plan*, and the *State Alternative Fuels Plan*.[6] Additionally, Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) recognized the transportation sector as an integral area of natural gas research. The CPUC's Decision 04-08-010 not only authorized the Energy Commission to administer the natural gas program, but also defined public interest gas RD&D activities as those that "are directed towards developing science or technology, 1) the benefits of which accrue to California citizens and 2) are not adequately addressed by competitive or regulated entities."[7] The decision also directs that natural gas RD&D projects meet the following criteria:

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

In addition, the CPUC established a specific state goal of reducing natural gas demand by 290 million therms from investor-owned utility customers between 2005 and 2014 from a 2004 baseline of 13,436 million therms.

The Energy Commission supports these goals and advocates increasing the energy efficiency of existing building systems, industrial processes and transportation end uses. Examples include reducing and optimizing hot water use in residential, commercial, and industrial operations and developing more efficient natural gas-fueled medium- and heavy-duty vehicles. The Energy Commission is also working to develop and advance more energy-efficient end-use technologies and strategies for unique California conditions and industries. During the development of the Energy Commission's natural gas research priorities and budget proposal, the Commission sought input from experts in energy and environmental research, research organizations, the state's investor-owned gas utilities, other interested parties, and CPUC staff.

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[6] *California's Long-Term Energy Efficiency Strategic Plan*, (September 2008), <http://www.californiaenergyefficiency.com/docs/EEStrategicPlan.pdf>.

State Alternative Fuels Plan, (December 2007), <http://www.energy.ca.gov/2007publications/CEC-600-2007-011/CEC-600-2007-011-CMF.PDF>.

[7] CPUC Decision 04-08-010, p. 24.

Research Objectives

The priorities of the state energy "loading order" for new energy resources are reflected in the proposed natural gas projects for energy efficiency and renewable and clean distributed resources. Other research has strategic significance for energy-smart growth and is guided by key policy mandates and directives, such as Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) and the *State Alternative Fuels Plan*.[8] The Energy Commission pursues strategic investments in RD&D that recognize the central role natural gas plays in meeting the state's energy needs and helping achieve its emission reduction targets.

The budget proposal identifies four research objectives that support this vision:

1. *Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency*. Research in this area seeks to reduce the daily energy consumption practices for California natural gas ratepayers by addressing energy efficiency for industrial operations, the commercial food services sector, heating systems in residential and commercial buildings, and the transportation sector.
2. *Accelerate the Adoption of Clean Alternatives to Conventional Fossil 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, Reliability and Safety*. This area includes research that develops guidelines to reduce geo-hazards for natural gas pipelines and assesses residential customer behavior toward advanced customer technologies. 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 effect 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 nonstandard gas supplies (for example, liquefied natural gas and shale gas). The area also includes methodological research to improve analytical methods for measuring pollutants.

These objectives are consistent with direction provided by the CPUC. Upon reviewing and approving the FY 2009-10 proposed research budget, the CPUC staff recommended that future natural gas research plans increase their focus on the use of renewable energy to offset natural gas applications and on direct natural gas ratepayer benefits.

[8] <http://www.energy.ca.gov/2007publications/CEC-600-2007-011/CEC-600-2007-011-CMF.PDF>

The proposed research objectives also reflect three high-level research objectives established by the Energy Commission: stimulate economic growth in California, identify and achieve long-term natural gas goals, and capture the benefits of integrating electricity and natural gas research. The selection of past natural gas projects reflects the Commission's core research vision and has resulted in numerous successful results, including valuable research that would otherwise not have been funded. Furthermore, the Energy Commission remains flexible to rapidly changing new and emerging energy technologies. The research highlights for 2010 included at the end of this chapter offer concrete examples of how PIER manages the Natural Gas Program through its vision and flexibility.

Strategic Partnerships

The Energy Commission relies on strategic partnerships to help carry out its RD&D activities. Partnerships are used to avoid duplication, build on successful RD&D work, generate new ideas, leverage public and private investments, and ensure that the RD&D portfolio provides benefits to the state's electric and natural gas customers. Such partnerships make interagency research coordination easier and often include other state agencies, local and regional entities, industry, utilities, and researchers. For example, one of the major organizing principles in the creation of the *2007-2011 Natural Gas Research Investment Plan* was that Senate Bill 76 (Committee on Budget and Fiscal Review Energy, Chapter 91, Statutes of 2005) required planning with the California Air Resources Board (ARB) to coordinate energy and environmental research priorities.[9] The investment plan represents co-planning by the ARB and the Energy Commission at the strategic level and creates a forum for achieving consensus between ARB and the Energy Commission on natural gas strategic research issues and their respective priorities. ARB staff plays a key role in implementing the natural gas research program. As with the Energy Commission's electricity research, ARB staff provides advice and insights in workshops, the development of research roadmaps, defining the scope of research projects, and, in some cases, management of specific research projects on behalf of the Energy Commission.

The Energy Commission also works closely with CPUC staff to coordinate PIER NG research efforts. For example, after the 2010 San Bruno pipeline explosion, coordination between the two agencies led to $1 million of the FY 2011-12 budget proposal being allocated to research on natural gas pipeline integrity and safety. Also, Energy Commission goals and policies follow along with the CPUC's. As the CPUC's *California's Long-Term Energy Efficiency Strategic Plan* is updated, the PIER Program will adjust its RD&D activities to meet these updated goals.

Additionally, the Energy Commission taps into California's diverse and substantial research capabilities at state universities, national laboratories, utilities, and high-tech companies.

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[9] *2007-2011 Natural Gas Research Investment Plan,* (August 2006), <http://www.energy.ca.gov/2006publications/CEC-500-2006-017/CEC-500-2006-017-CMF.PDF> (January 28, 2010).

Creating and sustaining these partnerships help leverage RD&D investments and are essential to performing the right research for the greatest benefit to California's ratepayers.

Stakeholder Outreach

Energy policies provide guiding principles for stakeholders during the creation of collaborative roadmaps. Natural gas roadmaps are a planning mechanism and a communication tool that establish a clear link between the priorities of natural gas research and key California energy policy goals. The Energy Commission's Research Development and Demonstration Roadmap (RD&D Roadmap), which includes energy resources and technologies that deal directly with natural gas replacement with renewable energy, was developed through internal workshops with ERDD staff, meetings with other Energy Commission program staff, and extensive interviews with external stakeholders from government, utilities, industry companies, advocacy groups, and research organizations.[10]

The Energy Commission's *Natural Gas Vehicle Research Roadmap (NGV Roadmap)* identifies initiatives and projects that research, develop, demonstrate, and deploy advanced fuel-efficient natural gas powered transportation technologies and fuel switching strategies that result in a cost-effective reduction of on-road and off-road petroleum fuel use in both the short and long term.[11] The *NGV Roadmap* represents a broad range of views, with the participation by more than 100 stakeholders in the natural gas vehicle market. More than 35 in-depth interviews were conducted with stakeholders representing the interests of the natural gas vehicle industry, government, advocacy groups, fleet users, and utilities. The interviewed representatives and other stakeholders also provided feedback on drafts of the *NGV Roadmap*. Finally, at the Roadmap Asilomar Workshop, stakeholders were asked to review, refine, and prioritize the many natural gas vehicle RD&D ideas collected during the process. The results of the workshop were offered to a wide group of stakeholders for comment.

Energy Commission staff and external stakeholders participating in roadmapping activities also have the chance to identify both electricity and natural gas research needs where they overlap by program area. Collaborative thinking about energy solutions that cut across policy boundaries is integral to maximizing the research dollar value to the ratepayer. The end users of electricity and natural gas face a complex array of regulatory issues in which savings from one energy source is often offset by increased usage from other sources. Bringing natural gas and electricity stakeholders together in the roadmapping process minimizes resource shifting, encourages innovation, and yields outcomes that are more likely to successfully address challenges that involve both areas.

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[10] *PIER Renewable Energy Technology Program: Research Development and Demonstration Roadmap*. August 2007. CEC-500-2007-035. <http://www.energy.ca.gov/2007publications/CEC-500-2007-035/CEC-500-2007-035.PDF>

[11] *Natural Gas Vehicle Research Roadmap*. May 2008. CEC-500-2008-044-D. <http://www.energy.ca.gov/2008publications/CEC-500-2008-044/CEC-500-2008-044-D.PDF>

Stimulate Economic Growth in California Through Advanced Natural Gas Technologies

Given California's current economic environment, energy research also should focus on projects that help fuel near-term economic growth. For example, projects that directly reduce natural gas costs for end users through efficiency improvements or more economical alternatives allow natural gas ratepayers to reduce consumption and realize cost savings.

Identify and Achieve Long-Term Natural Gas Goals for California's Energy-Smart Development

The Energy Commission will continue to evaluate and calibrate its natural gas research portfolio to maximize the benefits to California's natural gas ratepayers. Central to this effort is a renewed focus on measuring the benefits of the Energy Commission's research activities. While the costs and benefits of most commercially available products and technologies can be quantified, the same cannot be said for premarket emerging technologies. Calculating benefits associated with energy technology research can be especially challenging because not all benefits are readily quantifiable, such as the environmental impact of greenhouse gas reduction.

Nevertheless, the Energy Commission continues to identify and pursue research projects that provide significant and measurable benefits to California's ratepayers. Three primary California ratepayer benefit categories have been identified from the activities of the PIER NG program: economic, environmental, and security. The research program results also provide Californians with important benefits that include reduced impact from global climate change, reduced health risks related to poor air quality, lower bills, reduced volatility of transportation fuel prices, and reduced economic impact from dependence on petroleum.

The Energy Commission also focuses on identifying and addressing emerging long-term natural gas-related themes and trends that are important to California's energy-smart future. To assess the benefits of the PIER NG program, and identify emerging research trends, the Energy Commission obtains direct feedback, "gap" analysis and recommendations from utilities, other state agencies, academic experts, industry associations and technology experts. 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. The Energy Commission will continue to conduct more workshops and other activities with the public and stakeholders to identify program improvements.

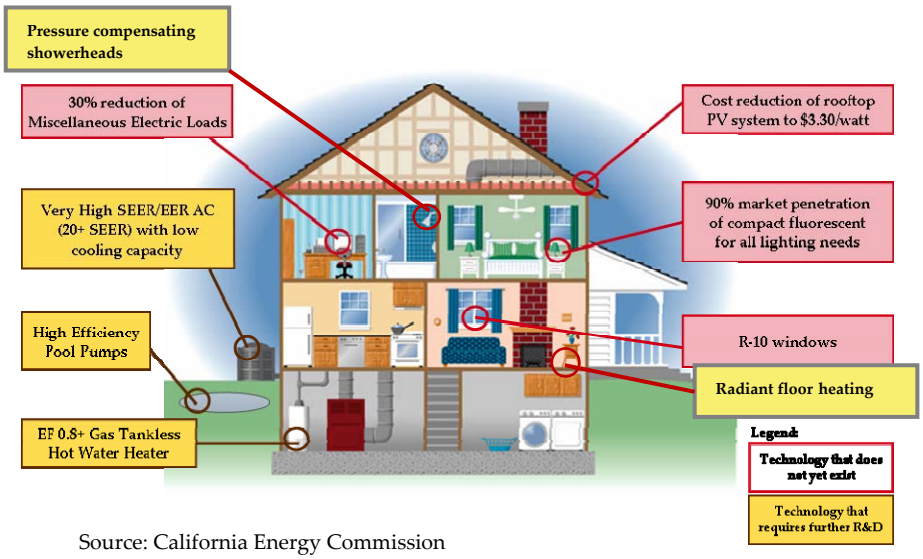
The Energy Commission also supports the goals targeted in Governor Jerry Brown's recent Clean Energy Jobs Plan to increase renewable generation in California. Technology breakthroughs will be required if the state is to meet the Governor's goal to increase cooling, heating, and power (CHP) production by 6,500 MW over the next 20 years. Green jobs, localized energy and the funding of projects that explore the development of compatible renewable energy facilities on farmland have also been identified as important to meeting goals outlined by Governor Brown.

The Energy Commission believes that California's natural gas system will be transformed over the next decade as the state pursues its goal of energy-smart and community-oriented development. The Energy Commission envisions the following developments and opportunities for California's natural gas industry: 1) non-traditional supplies, alternatives such as domestic shale gas production, biogas, liquefied natural gas and other renewables, will become a larger part of the natural gas portfolio; 2) natural gas and clean alternatives will become larger components of California's transportation fuel mix; 3) statewide natural gas consumption could be dramatically reduced by implementing community-level natural gas efficiency measures, such as integrated CHP systems and district heating and cooling. The Energy Commission will shape and prioritize its long-term research goals to reflect these themes, which include pipeline integrity and safety, the Zero Energy Homes and Buildings policy mandate, and customer behavior's effect on energy use.

Zero Energy Buildings and Communities

CPUC Decision 07-10-032 directs that all new residential construction in California be zero net energy by 2020 and new commercial construction by 2030. [12] In addition, the *2008 IEPR Update* brings additional policy attention to the goal of zero net energy communities. Achieving net-zero energy in California quickly will require concerted research effort on both the natural gas and the electricity sides of the state's energy system (Figure 2).

Figure 2: RD&D Needs for California's Zero Energy Residential Homes



Source: California Energy Commission

Natural gas research must enable widescale adoption of energy efficiency and renewable thermal energy solutions, while electricity research will be required to reduce the cost of technology options to improve the viability of zero net energy buildings and communities. The Energy Commission's natural gas research proposes focusing on technology solutions that would enable the state to successfully meet the zero net energy buildings targets.

Capture Benefits of Integrated Electricity and Natural Gas Research

Through administrative and research synergies, the Energy Commission provides unique benefits to California natural gas ratepayers. Administrative synergies derive from managing

[12] http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/74107.PDF

the Public Interest Natural Gas Program within the existing public interest electricity research program using overlapping staff resources. This cost savings is important and has a much bigger effect on the value of the program by achieving low operating margins over the long term. Research synergies contain even greater benefits and come from several sources:

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 for resources between the two areas. One of the qualitative benefits from administrating both natural gas and electric research includes 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.

For example, the Industrial, Agriculture, and Water program identified research areas that applied to electricity, natural gas, and some that applied to both areas during the 2008/2009 Food Processing roadmapping process. The research areas were identified by stakeholders that actively contend with multiple regulatory hurdles and recognize that resource substitution was a viable strategy in many cases. This enabled the Energy Commission to elicit multiple project ideas while minimizing the potential for resource switching.

Researcher Engagement — Researchers and developers who respond to Energy Commission Requests for Proposals (RFPs) are then 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. RFPs that are written broadly to address both areas typically garner a higher quality response. The qualitative benefits from administering natural gas and electric research stem from RFPs that reflect the two sources, which are geographically distributed over the entire state.

The ERDD's Renewable Energy Secure Communities (RESCO) program provides a successful example of efforts to cross-leverage between natural gas and electricity research funding sources. RESCO was launched in 2008 with a solicitation that attracted more than 50 proposals. Most of the proposals awarded applied electricity research funds to address opportunities for development of technical integration solutions related to the deployment of community scale renewable energy supply. The project specifications require an overarching approach that integrates and optimizes the interplay of renewable energy sources, electricity and natural gas demand response measures, energy efficiency measures, sourcing of bulk energy, and use of

community waste streams to generate biogas to generate electricity and, otherwise, displace natural gas consumption in the community. Natural gas research funds were applied to three specific RD&D projects that enable community energy system integration, that is, projects targeting cleaner, more efficient ways of exploiting local renewable energy resources that displace natural gas consumption.

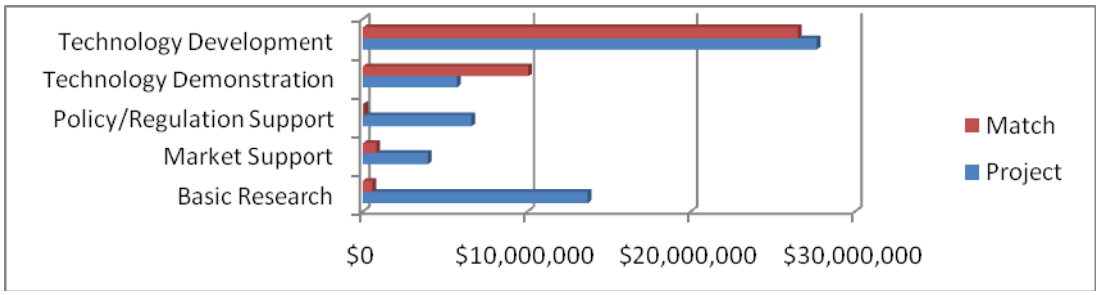
Interdependent Research Progress — RD&D processes are often nonlinear and depend on multiple research elements to bring a technology to the market. Energy Commission staff are often made aware of the need for improvements in natural gas technology through efforts made in the electricity sector, and vice versa; this interdependence supports collaboration. The qualitative benefits from administering natural gas and electric research include those that stem from addressing the RD&D cross-cutting interdependencies of technology, science, economics, and end-user applications.

An example of interdependent research progress can be seen in a project that combined advances in solar-thermal technologies originally intended for the electricity sector with natural gas-specific technology development. Cooling Technologies, Inc., developed, adapted, and tested a new dual-fired (gas-solar) generator for its 5-ton ammonia-water air-cooled absorption chiller. The generator is a simple adaptation of the company's standard gas-fired chiller generator, which minimizes the extra cost associated with the solar/gas product. With dual-fire capability, the need for thermal storage or backup systems is eliminated because the cooling system is able to operate on either or both solar energy and natural gas or propane.

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 spans 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 nonrestricted 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.

The PIER NG Program has contributed significantly 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 3 illustrates the match funding obtained over the five-year period that the Energy Commission has administered the PIER NG program.

Figure 3: Match Funding for PIER Natural Gas Projects 2005-2010



Source: California Energy Commission

These PIER NG projects benefit California's residents and businesses today and in the future. Projects within the PIER NG Program are evaluated periodically 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. 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.

Research Policy Guidance

Energy Action Plan Loading Order

The *2008 Energy Action Plan Update* articulates a unified approach to meeting California's electricity and natural gas needs by emphasizing that meeting California's energy policy goals "requires the cooperation and teamwork of multiple sectors of the California economy, including the electricity, natural gas, and transportation sectors."[13]

The *2008 Energy Action Plan Update (2008 EAP Update*) also identifies next steps that guide the Energy Commission's natural gas research effort and that are addressed in the FY 2011-12 research program. These major action areas include:

- Energy efficiency
- Renewable energy
- Climate change

2009 Integrated Energy Policy Report

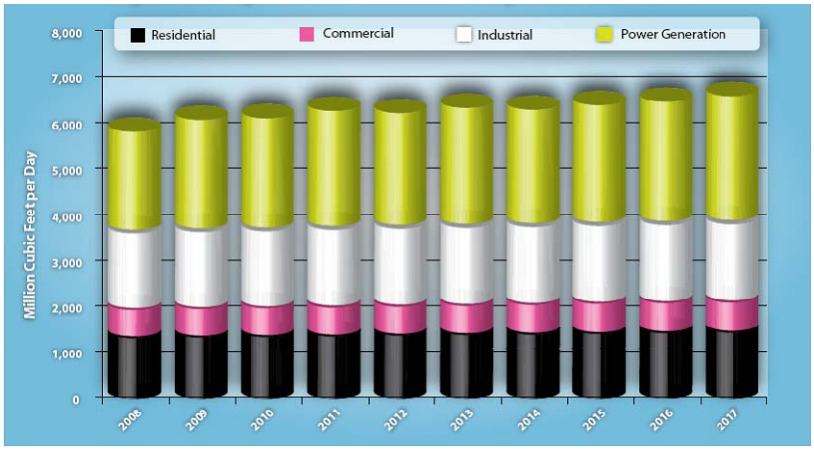
The Energy Commission's *2009 Integrated Energy Policy Report (2009 IEPR)* is California's key energy policy document.[14] The *2009 IEPR* reflects input from numerous public and private stakeholders, as well as federal, state, and local agencies. The inclusive process included nearly 50 public workshops and hearings and approximately 70 supporting reports.

[13] http://www.energy.ca.gov/2008publications/CEC-100-2008-001/CEC-100-2008-001.PDF

[14] http://www.energy.ca.gov/2007_energypolicy/index.html

The *2009 IEPR* details natural gas resource constraints in California and outlines several major issues facing the state's natural gas sector including growing demand, dependence on imports, price fluctuations, and AB 32 policy goals. Figure 4 displays the state's growing demand for natural gas. In response, the proposed natural gas research budget addresses energy efficiency, renewable energy resources, and greenhouse gas emissions reduction targets.

Figure 4: Projected California Demand by Sector 2008-2017



Source: California Energy Commission

State Alternative Fuels Plan

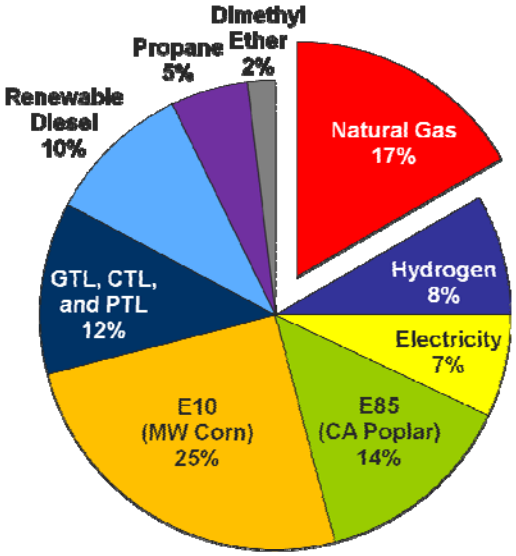
The joint Energy Commission and ARB *State Alternative Fuels Plan* establishes the following policy goals for California's transportation fuels:[15]

- Petroleum reduction
- Greenhouse gas reduction
- In-state biofuels production and use
- Improved air quality

The plan also states that as a transportation fuel, natural gas could account for the largest percentage (6.7 percent) of GHG reductions from the nine alternative fuels studied.

The transportation research component of the PIER NG Program develops alternative fuels and vehicle technologies to help achieve the goals of the plan.[16] Research results target market implementation through the *Alternative and Renewable Fuels and Vehicle Technology Program (ARFVT).*[17]

Figure 5: State Alternative Fuels Plan Projection of Alternative Fuel Breakdown in 2022 (total volume = 5.3 billion gal. of gasoline equivalent, natural gas-derived solutions in red)



Source: California Energy Commission

[15] CEC-600-2007-011-CTD

[16] Excluding electric drive technology, the Energy Commission's electricity RD&D program will support electric drive RD&D.

[17] http://www.energy.ca.gov/proceedings/2008-ALT-1/

Natural Gas Research Program Research Objectives

By focusing on the following four research objectives, the Energy Commission's natural gas research program supports a range of issues and concerns critical to California's economic growth and the state's effort to meet its natural gas demand in environmentally sensitive ways.

Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency

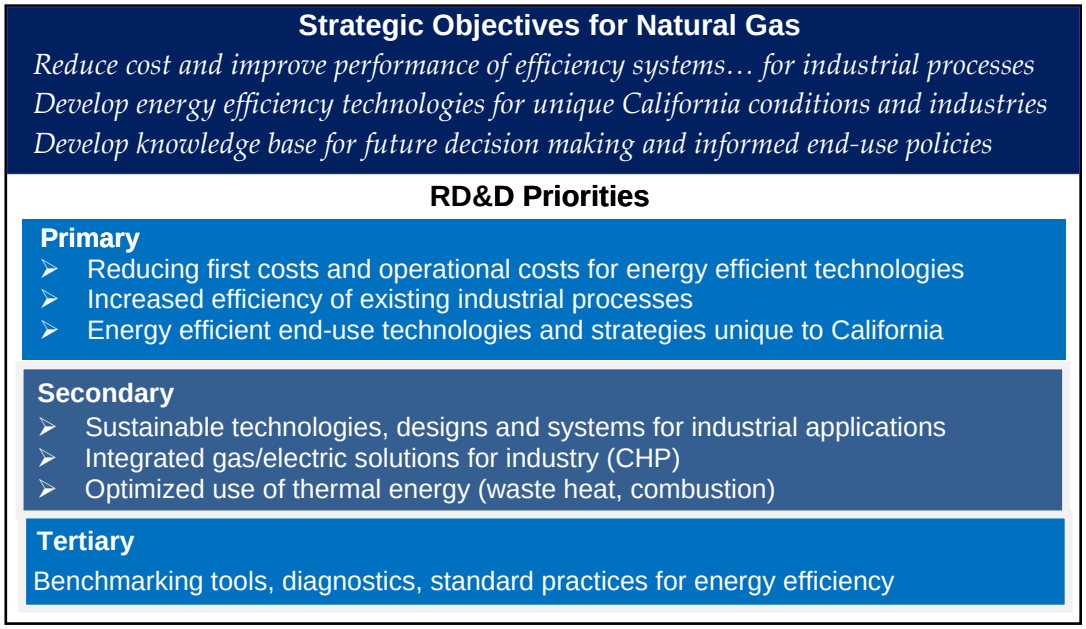
Natural gas end use and process efficiency is the Energy Commission's highest priority research topic area and one that provides significant near-term benefits to California residents.

Industrial Efficiency

The Energy Commission's Industrial, Agriculture, and Water (IAW) research program focuses on improving energy efficiency in the natural gas sector and ensuring the availability of reliable energy supplies. In particular, the industrial sector is a major energy consumer and one of the largest users of natural gas in the state, accounting for approximately 34 percent of total use in 2009. Consequently, industry represents a logical target for improving the efficiency of natural gas use through the adoption of new technologies and improved energy management practices.

Recognizing the importance of industrial end uses in reducing natural gas demand, the research program has defined strategic objectives that directly affect these sectors (Figure 6). Preliminary solutions identified as being relevant to the industrial sector range from reducing first costs and operational costs for energy efficiency technologies to unique and innovative technology development and sustainable processes.

Figure 6: Strategic Objectives for Natural Gas



Source: California Energy Commission

Commercial and Residential Efficiency

Approximately one-third of California's natural gas consumption today is on-site gas use (for example, water heating, space heating, and cooking). Another 30 percent is used for electricity generation for residential and commercial buildings. Energy consumption in California's residential and commercial buildings accounts for more than 60 percent of the total natural gas consumed in the state annually.

The PIER Buildings Natural Gas Program focuses on addressing technology gaps hindering the achievement of efficiency and reduced natural gas use in buildings. The program works in conjunction with the Energy Efficiency Buildings Standards (California Code of Regulations, Title 24, Part 6,) and with the Appliance Energy Efficiency Standards (California Code of Regulations, Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608: Appliance Efficiency Regulations) to ensure close staff communication and coordination in identifying important future research needs to support regulations that reduce natural gas consumption.

Reducing natural gas use in residential and commercial buildings is essential to decreasing GHG emissions and reaching state energy efficiency goals. The Energy Commission's future building research investments include improving the efficiency of building envelopes; thermal distribution systems; food service equipment, such as dishwashers, gas ranges, and refrigeration; residential testing of tank and tankless condensing water heaters; and showerhead research.

Transportation Efficiency

Senate Bill 76, the legislation that led to the formation of the Energy Commission's Transportation Research Program, provides guidance on determining the areas of transportation research that are appropriate for public interest funding. This law requires that public interest research done for transportation also provide benefits to California's natural gas and electricity ratepayers. SB 76 further lays out broad areas of ratepayer benefits to be realized by transportation research, summarized as:

1. Direct benefits specific to making gas or electrical service:
    - Safer, more reliable

      or
    - Less costly
2. Activities that benefit ratepayers and that promote ALL of the following:
    - Energy efficiency
    - Reduction of health and environmental impacts from air pollution
    - Reduction of greenhouse gas emissions related to natural gas and electricity production and use
    - Increased use of alternative fuels

The Energy Commission's method for investing in transportation energy research ensures that the research investments comply with SB 76, account for energy system linkages, address transportation energy policy priorities, and provide ratepayer benefits. This method:

- Incorporates the requirements of statutes governing public interest energy research, including SB 76.
- Uses energy system linkages to better understand how transportation research affects electric and natural gas ratepayers.
- Uses California transportation policy in combination with statutes and system linkages to identify strong, moderate, or weak ratepayer benefit potential of research initiatives.

A more complete discussion of the method can be found in the *Public Interest Energy Research Program 2007 – 2011 Natural Gas Research Investment Plan*.[18]

To reduce petroleum fuels use and greenhouse gas emissions, the *2007 IEPR* and *State Alternative Fuels Plan* set goals to increase alternative fuels use to 9 percent by 2012, 11 percent by 2017, and 26 percent by 2022. The plan notes that natural gas use in heavy-duty vehicles alone could represent about 36 percent of the freight and off-road vehicle fuel use by 2050. Significant investment in this research area is necessary if California plans to meet such emission targets. Moreover, the *2008 EAP Update* defined transportation fuels and vehicles as a priority natural gas research area for the Energy Commission's Transportation research program and the Alternative and Renewable Fuels and Vehicle Technology program. These programs take strategic guidance from the *2008 EAP Update*, so that technology development direction for the research is coordinated with the deployment abilities of the ARFVT.

Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies

The Energy Commission believes renewable natural gas alternatives and highly efficient applications of natural gas, such as combined heat and power (CHP) systems, require immediate and continued research to ensure significant long-term benefits for California's natural gas ratepayers. The demand for natural gas for electricity generation and commercial and residential heating applications, as well as for industrial processing and transportation-related uses, is increasing and expected to rise. Renewable technologies and resources that could displace conventional natural gas are abundantly available in California, although many of these options require long-term research to support their development and market entry. The transportation sector, which is expected to rely more on natural gas for important niche applications, benefits from research into renewable alternative fuels and technologies that could substitute for conventional natural gas.

California energy policies and directives place a high priority on reducing the state's dependence on imported natural gas through diversification of its gas supplies. For instance, the *2008 EAP Update* recognizes the need for additional research to establish or improve the viability of these natural gas alternatives, including solar thermal technologies. Similarly, the

[18] http://www.energy.ca.gov/2006publications/CEC-500-2006-017/CEC-500-2006-017-CMF.PDF

2009 IEPR encourages utility preference for low-carbon fuels, including various renewables for electricity generation and alternative resources that directly displace natural gas, such as solar for water and space heating, industrial process heating and cooling, or pipeline-quality injected biogas. Already working to expand the market acceptance of CHP and combined cooling, heating, and power (CCHP) systems to reduce natural gas and electricity costs, the Energy Commission continues to pursue research that will reduce the cost and improve the performance of solar thermal, biogas, biomass gasification technologies, and geothermal technologies. Another important research initiative is the development of renewable natural gas alternatives, such as fuel produced from landfill gas, wastewater treatment systems, and anaerobic digesters.

Improve Natural Gas System and Infrastructure Performance, Reliability and Safety

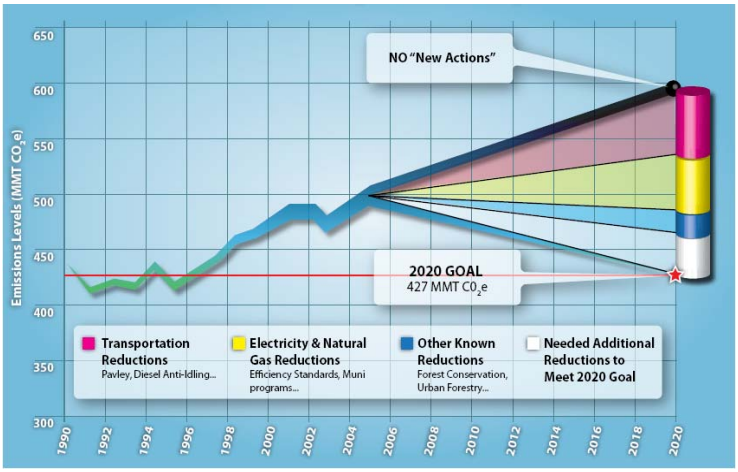
The safety and security of California's natural gas infrastructure are priorities. The growing demand for natural gas and the aging natural gas transportation infrastructure pose significant challenges for the state's natural gas users. The State's natural gas supply is conveyed through a robust system of pipelines that run throughout the state, including underneath areas of high population. The safety and security of the natural gas system are important priorities for California, especially the prevention of catastrophic events on the natural gas pipeline. In the interest of enhancing the safety and operation of the overall natural gas pipeline system, public interest research is needed to explore issues related to natural gas pipeline integrity and safety. A critical element of this needed research is an assessment of technologies that are used or could potentially be used to monitor pipeline integrity and safety.

Reduce the Environmental Footprint of California's Natural Gas System

The Energy Commission believes research efforts that reduce the environmental footprint of California's natural gas system are critical to the successful adoption of emerging natural gas technologies. California's natural gas system must be expanded and improved to comply with state and federal regulations that protect natural resources and minimize environmental, health, and safety hazards. Established by CPUC Decision 07-01-039, the Power Plant Greenhouse Gas Emissions Performance Standards heighten the importance of natural gas in meeting the state energy policy goals. An environmentally sound natural gas system is crucial for California to achieve the long-term GHG emissions reductions target mandated by AB 32 (Figure 7).[19]

[19] http://docs.cpuc.ca.gov/published/FINAL_DECISION/64072.htm

Figure 7: State GHG Emissions Projection and Needed Reductions to Meet AB 32



Source: California Energy Commission

The *2008 EAP Update* supports collaboration among the CPUC, the Energy Commission, and ARB to determine how electricity and natural gas sectors should be included in AB 32 framework. The Proposed Final Opinion on Greenhouse Gas Regulatory Strategies provides directions and priorities on how to achieve these AB 32 reduction goals.[20] AB 32 places reducing greenhouse gas emissions at the center of California's government and business agendas and highlights additional research needs that must be addressed to meet its goals. Furthermore, the Energy Commission's natural gas research program is evaluating and characterizing the impact of California's natural gas system on the climate and other environmental impacts associated with various natural gas technologies, such as environmental concerns with the development of shale gas deposits.

[20] http://www.energy.ca.gov/2008publications/CEC-100-2008-007/CEC-100-2008-007-D.PDF

CHAPTER 3:
Fiscal Year 2011-12 Research Plan

Overview

The Energy Commission's *Proposed Program Plan and Funding Request for Fiscal Year 2011-12* reflects current state energy policy, particularly the loading order introduced in the *2008 EAP Update*. The four major research objectives developed by the Energy Commission to carry out these goals address energy efficiency, renewables and clean alternatives, and the science of energy and climate. Policy guidance for these initiatives extends from the loading order, the *State Alternative Fuels Plan*, CPUC Decision 04-08-010, and AB 32.

The $24 million *Natural Gas Budget Proposal* includes research project funding, small grants, and program administration. Approximately $21.50 million is proposed to spend on specific research areas, $2.50 million on program administration, and $1.50 million would be allocated for Energy Innovations Small Grants, which funds feasibility studies for emerging natural gas technologies. Table 3 displays a summary of the *Natural Gas Budget Proposal*.

Table 3: FY 2011-12 Natural Gas Budget Proposal Summary

Research Objectives	Proposed Budget
Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency	$8.75 million
Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies	$7.25 million
Improve Natural Gas System and Infrastructure Performance, Reliability and Safety	$1 million
Reducing the Environmental Footprint of California's Natural Gas System	$3 million
Energy Innovations Small Grants Program	$1.50 million
Program Administration	$2.50 million
TOTAL	**$24 million**

Source: California Energy Commission

Proposed Research Solutions

Improve Industrial, Commercial, Residential and Transportation Energy Efficiency

The *2008 EAP Update* states that energy efficiency is the first priority under the state energy loading order. Efficiency improvements through improved building codes, appliance standards, utility energy efficiency programs, and smart growth strategies account for nearly one-quarter

of the emissions reductions identified in the *California Climate Action Team Report*.[21] Also, transportation energy efficiency will be increasingly necessary to achieve proposed carbon dioxide emissions reductions. Therefore, the Energy Commission proposes to focus heavily on natural gas RD&D that will improve energy efficiency in California's industrial, commercial, residential, and transportation sectors.

In FY 2011-12, the Energy Commission proposes to leverage knowledge gained from its past and ongoing research to target energy efficiency opportunities with strong potential for significant natural gas savings. Table 4 provides the energy efficiency budget for FY 2011-12.

Table 4: Budget Breakdown for Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency

Research Solution	Budget
Natural Gas Efficiency Research for Industrial Use	$2.25 million
Natural Gas Efficiency Research for Residential and Commercial Facilities	$4 million
Research and Develop Advanced and Fuel-Efficient Natural Gas Engines	$2.5 million
TOTAL	**$8.75 million**

Source: California Energy Commission

Natural Gas Efficiency Research for Industrial Use

Nearly every industrial sector in California relies on natural gas. The use of natural gas in California industry is dominated, however, by a relatively small set of industrial sectors. The largest users include food processing, printing, electronics manufacturing, transportation equipment, fabricated metals, furniture, chemicals, plastics, and machinery. These sectors represent prime areas of opportunity for reducing industrial natural gas use.

The following industrial research areas were identified through existing roadmaps and stakeholder input gained through membership in the Emerging Technologies Coordinating Council (a stakeholder organization with a membership that includes the Energy Commission and the major investor-owned utilities).

Heat Recovery: Industrial processes produce heat, much of which is wasted. Research opportunities into reusing waste heat include very low-grade (-40 to 250 degrees Fahrenheit) heat recovery, low-grade (250 to 500 degrees Fahrenheit) heat recovery, and mid- to high-grade (500 to 1400 degrees Fahrenheit and higher) heat recovery. Research opportunities also exist in the areas of heat loss reduction, enhanced heat transfer, combustion systems improvement, and advanced natural gas burners.

Process Measurement, Diagnostics, and Optimization: Research opportunities include optimization of energy management technologies, energy metering and monitoring, energy

[21] http://www.climatechange.ca.gov/climate_action_team/reports/index.html

efficiency assessment and analysis tools, financial analysis tools, process/product innovation and optimization, advanced controls, innovative processes, and nonthermal energy alternatives.

The Energy Commission proposes to fund technologies such as high-efficiency, low-emission burner designs; burners with integrated heat recovery systems; individual components to optimize heat recovery (valves, intelligent cycling system); combustion control systems; flexible-fuel boilers; new techniques for process heating; and software tools for process optimization and monitoring.

Research solutions in these areas are:

- Glass production industry improvements: additives for glass, high efficiency furnaces.
- Research opportunities for substitution of gas fired drum dryers for existing, less efficient steam pressure vessels.

Some Sector-Specific Research: PIER will also seek out energy-efficient technologies (emerging or commercially available) that can increase reliability, reduce emissions, heighten product quality, and improve productivity in natural gas-intensive industries.

Cement Industry

The production of cement is an energy-intensive process. The cement industry spends more than $1 billion in energy purchases annually. Producing cement results in the emission of carbon dioxide from both the consumption of fuels and from the calcination of limestone. With 11 cement plants, California is the largest cement-producing state in the United States, which accounts for between 10 percent and 15 percent of national cement production. Areas of potential innovation in this industry include:

- Improvements to raw materials preparation.
- Clinker process improvement.
- Waste heat recovery.
- Advanced additives for the cement.

Food Processing Industry

The food processing industry in California is highly diversified. It comprises more than 3,000 plants, which process commodities that are sourced from more than 75,000 farms. About 240 commodity and trade associations represent food and agricultural interests in California. Although agricultural and food processing activities occur throughout the state, these industries are concentrated in the Central Valley. The Central Valley is home to more than 3,000 factory sites, including the world's largest factory site for processing fluid milk (California Dairies, Inc.), cheese (Hilmar Cheese Company), milk powder/butter (California Dairies, Inc.), wine (E. & J. Gallo Winery), and poultry (Foster Farms). California ranks 5th in the world in agricultural production, spending $36.6 billion in 2007, or 12.8 percent of total United States production. In

2006, the total value of shipments was $73 billion, 11.2 percent of the United States total, which made California first in the United States for total food processing output. Areas of potential innovation in this industry include:

- Blanching
- Drying and dehydrating
- Evaporation
- Frying
- Pasteurization and sterilization
- Peeling

Glass Industry

The United States glass industry includes establishments engaged in manufacturing flat glass, container glass, specialty glass, and fiberglass. These four primary industry segments produce more than 20 million tons of glass per year, with a value of more than $16 billion. Glass manufacturing in the United States is one of the most energy-intensive industries. In 2009, natural gas consumption was 93 million therms. Primary energy consumption by the glass industry is approximately 1 percent of total United States industrial energy use. California has approximately 13 major glass plants, each unique, yet together they have a significant potential for natural gas reduction by employing energy efficiency measures. Areas of potential innovation in this industry are:

- Batch preparation
- Glass melting, refining, and conditioning
- Oxy-fuel furnaces
- Forehearths and forming
- Annealing and finishing
- Submerged combustion melting (new combustion technology)
- Oscillating combustion (new combustion technology)
- Segmented melter
- Waste heat recovery (oxy-fuel, regenerative and recuperative furnaces)
- Innovative CHP technologies

Chemical Manufacturing Industry

The United States has the world's largest chemical industry. Within that industry, more than 70,000 diverse compounds are produced, with production volumes ranging from a few grams to billions of pounds. In 2009, California chemical and allied products manufactures consumed 98 million therms. The chemical manufacturing industry has a large variety of opportunities to

reduce energy consumption while maintaining or enhancing the productivity of the plant. Areas of potential innovation in this industry are:

- Energy management programs and control systems
- Distillation process (vacuum and atmospheric)
- Heating, cooling and process integration

Pharmaceutical Industry

The manufacture of pharmaceuticals and medicines is a key industry in the United States, and particularly in California, which is the headquarters for Amgen. Using the most recent numbers available, the United States pharmaceutical industry generated more than $140 billion in output in 2002, which was up from $108 billion in 1999. California was responsible for 7.5 percent ($10.5 billion) of the total output and employed 23 percent of the total industry employees (249,000). Areas of potential innovation in this industry are:

- Energy management systems
- Fume hoods
- Cleanrooms
- Heat and steam generation and distribution
- Waste heat recovery

PIER NG funds will also be used to revise the natural gas related sections of the existing 2009 Industrial, Agriculture, and Water program's research roadmap. The roadmap contains sections dealing with natural gas sector specific research, including natural gas pipelines, the petroleum industry, data centers, electronics, food processing and water-energy. The chapter regarding PIER cross-cutting will also be updated, as some research activities present RD&D opportunities to IAW (for example, digester gas, lighting and renewable integrations) that are also of interest to other PIER research areas. Future solicitations will utilize the updated IAW roadmap to develop and guide RD&D efforts.

An upcoming solicitation will include possible research topics on industrial energy efficiency, controls, data centers, demand response, distributed generation, food processing, chemical and pharmaceutical industries, cement processing and metallurgy.

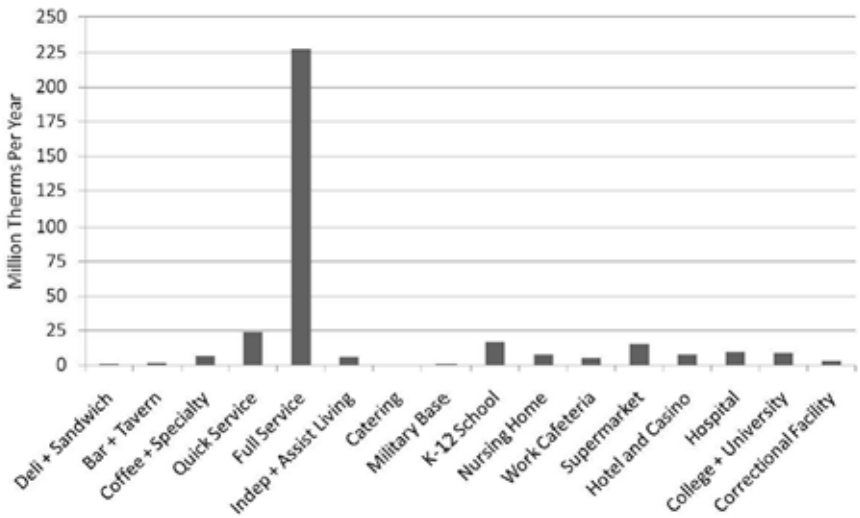
Natural Gas Efficiency Research for Residential and Commercial Facilities

Residential and commercial buildings account for more than 60 percent of California's natural gas use, of which more than 30 percent is used for space and water heating, and cooking in residential and commercial buildings. As a result, research focuses on technologies and strategies that can help reduce usage in these areas.

Food Service – Natural gas use in full-service commercial food facilities is an area that could greatly benefit from efficiency improvements. Full-service facilities in California collectively

account for more than 60 percent of natural gas use by all of the State's food service facilities, including hospitals, universities, and hotels (Figure 8). Much of the potential efficiency gain would come from improvements in hot water heating and range-top cooking. Each of California's 34,400 full-service facilities uses an average of 2,000 gallons of hot water, daily. As much as 90 percent of the energy used to heat water literally goes down the drain.

Figure 8: Annual Food Sector Gas Load by Service Facility Types



Source: California Energy Commission

The PIER Program has funded research aimed at improving the energy efficiency of food service appliances, including:

Under-fired broiler – A lid was developed and installed in commercial kitchens to keep broilers hot when not in use and keep heat in when cooking. This device also has the benefit of keeping the kitchen cooler, so working chefs and cooks are motivated to use the lid.

Over-fired broiler – This research is investigating the use of a recuperator, which uses hot flue gas to preheat incoming air. The project contractor has created parts and is working with the manufacturer to build a prototype and explore how to control the technology properly.

Conveyor oven (pizza oven) – A new model of conveyor oven was developed for commercial kitchens that reduces energy use by turning off the blower fan and one of the flames when the oven is idle. This new model is nearly two times more efficient than previous ovens.

Convection ovens – PIER is investigating changes to flue, fans, and door seals.

Range top – A flame sensor was developed that turns off the range when no pot is present. Pilotless ignition technology is also being investigated.

Wok – Woks require very high temperatures to achieve the desired cooking style. At the same time, they use water to cool the appliance structure that surrounds the wok. PIER-funded research developed a design that eliminates water usage and is up to three times more efficient.

The project contractor is working with the manufacturer to create field test prototypes of the technology.

Future research will continue to look for opportunities in the commercial food service industry, including commercial dishwashers; commercial range tops; restaurant-specific, refrigeration heat-recovery systems; and tankless and high-efficiency condensing water heaters. The following are examples of that research:

Dishwashers – This appliance has high potential for increased energy efficiency. Research opportunities include the development of a water-to-water and air-to-water heat exchanger for dishwashers (preheating domestic water using energy from gray water and exhaust air). The energy from the heated wastewater can be used to preheat the incoming cold water used by the dishwasher. Research is needed to develop an integrated heat recovery system that could reduce the gas used for heating water for the dishwasher by an estimated 50 percent, assuming daily dishwasher usage of four hours. This results in an estimated annual energy savings of nearly 50 million therms, or approximately $50 million in annual cost savings to the food service industry.

Range top – This is one of the most widely used pieces of equipment in commercial kitchens. Typically, a range-top configuration consists of six open gas burners, with a standard oven incorporated underneath. The development of a super-advanced (sealed or open-top) gas-burner range with a target efficiency of at least 70 percent is a significant area of potential savings.

A typical gas-fired range top has a cooking energy efficiency of 30-40 percent. Range tops are generally controlled by the operator and are not amenable to advanced controls. If the burners are continuously left on, as is frequently the case in busy kitchens, real-world cooking energy efficiencies are closer to 10 percent. As a result, range tops are one of the more energy-intensive appliances in a commercial kitchen. Range tops that are open to the kitchen also radiate heat, thereby requiring higher exhaust rates and more mechanical cooling of the kitchen. Research is needed to develop an advanced gas-fired range top that will meet the real-world needs of both end users and manufacturers, significantly surpassing the performance of existing range tops (in efficiency and user comfort), and provide benefits to food service operators.

Refrigeration – Research is needed to develop a restaurant-specific, refrigeration heat recovery system and demonstrate its energy efficiency potential for preheating domestic water. The research would quantify the reduction of gas used for heating domestic water and the associated reduction in compressor energy. The need exists to characterize the performance of such equipment under different operating conditions, combining both laboratory and field testing experiences. A key innovation would be a design application guideline for this technology in commercial food service.

Water heating – Another area of promising research is the testing of tankless and high-efficiency condensing water heaters to determine potential problems in restaurant applications. High-efficiency condensing water heaters may be better suited than tankless water heaters for full-

service and institutional commercial restaurants. Research is needed to determine hot water loads in commercial restaurants and to test water heaters in commercial restaurant applications and laboratory environments. This research will increase the identification of potential problems with both tankless and high efficiency condensing water heaters and their technical and economic applications in commercial restaurants.

Energy-Efficient Hot Water Generation and Distribution

The Energy Commission has found through past natural gas research efforts that heat loss in water distribution systems is one of the biggest inefficiencies in California's residential and commercial water heating systems. Various studies suggest that improvements in hot water distribution system design could increase efficiency by up to 50 percent, while reducing hot water delivery time.

The PIER Program has funded research aimed at improving the energy efficiency of hot water generation and distribution systems. These include:

Hybrid Optimized Tankless (HOT) water heater – PIER developed a medium-sized, high-efficiency burner/heat exchanger, similar to those found on a point-of-use gas tankless water heater, and combined it with a small 15-20 gallon storage tank. The biggest source of losses in storage water heaters come from the flue pipe that runs through the center of the water heater. The burner on the HOT model is external, which eliminates the source of heat loss. The product is a smaller and very efficient water heater, which provides enough, but not endless, hot water. Therefore, both gas savings and water savings are achieved. These units are now commercially available.

Multi-family hot water distribution systems (HWDS) – PIER analyzed how HWDS function in the field, and what factors lead to successful outcomes. The project identified what aspects of system design, operation, and maintenance offer the greatest opportunities for energy savings, and which can be readily achieved given cost constraints, typical design practice, available technologies and cultural factors. Project results include:

- 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 utility programs.
- Developing a hot water simulation model. This model was developed to better understand water distribution system performance by delivering an integrated water heating and water distribution (TANK+HWSIM) model, and testing 18 water heaters in three IOU territories.

Future research will focus on the following areas:

Water heaters – Support field assessment and testing of tankless water heaters in both residential new construction and retrofit applications. Specific research includes:

- Testing heat exchangers that use second-story shower grey water to preheat incoming cold shower water and assess flow and pressure.
- Determining potential technical problems in both new construction and retrofit situations. Tankless water heaters have difficulty supplying enough hot water for simultaneous uses such as showers and laundry, and have a problem known as a "cold water sandwich." A cold water sandwich occurs where a section of piping contains hot water that has since cooled off. The cold water is sandwiched between the initial hot water from the tap and the hot water that follows the cooled water. If there is no modulating temperature control, the water temperature could fluctuate at different flow rates and water pressure. Research is needed to identify potential solutions to these technical problems.

Showerhead research – Assess performance and energy benefits of pressure compensating and non-pressure compensating showerheads by reducing the amount of water, these showerheads can reduce the energy used for heating hot water. The research will evaluate customer or end-user satisfaction regarding minimum acceptable performance over a range of flowing pressures and the effect of flow rate on temperature control. Performance parameters would include: flow rate, force, spray area or pattern, temperature, efficiency (for example, removing shampoo from hair), thermal shock (hot and cold), and other end-user-defined parameters.

Natural gas project demonstrations – As indicated in previous sections, PIER has been instrumental in developing many new technologies. These technologies often languish due to lack of real world demonstration and the perceived risk to the user. To help overcome this risk barrier, partial funding would be provided for demonstrations of PIER-funded cooking, water heating, and space heating technologies in facilities with the most potential for reducing natural gas consumption. The demonstrations would:

- Demonstrate PIER-funded technologies.
- Monitor and verify savings.
- Reach out to markets and prepare case studies.
- Hold workshops for stakeholders.

Advanced energy-efficient heating systems – Space heating, particularly in residential and small commercial buildings, represents a significant end use for natural gas. Research will focus on hydronic heating systems and conventional gas furnaces:

- Hydronic heating includes all types of hot water heating. Hot water heat can be delivered to a room through a radiant floor, radiators, fan-coil heaters, fin-tube baseboard convectors, or a combination of any of these devices. There is a wide variety of possible applications using each of these methods. For instance, radiant heat can be delivered through a floor, wall, or a ceiling. Hydronic heating can provide a high

degree of temperature control within the heated area. Homeowners with radiant-floor heating are likely to be more comfortable at lower air temperatures than conventional forced-air systems. Since the floor is warm, it makes occupants in the room feel warmer than conventional forced-air heating systems. People with radiant-floor heating can keep their thermostats lower and thus realize significant energy savings, resulting in combined natural gas energy and fan electrical energy costs by 10-40 percent. Research will focus on understanding barriers and identification of cost effective solutions.

- Conventional gas furnaces – Conventional gas furnaces represent the most common method of space heating for the near term. Therefore, finding cost-effective ways to improve their efficiency to condensing levels will be the quickest way to save natural gas. One avenue to increase the energy efficiency is by improving heat transfer characteristics and reducing resistance to air flow on the air handler fan side of the furnace. Research will also focus on developing less expensive ways for heat exchangers to resist corrosive products of combustion, thereby helping to achieve cost-effective condensing natural gas furnaces.
- Advanced building envelopes – A key to reducing the use of natural gas to heat buildings is improving the performance of the shell, or envelope, of the building. Most buildings have significant air leakage to the outside and serious deficiencies in insulation, driving up natural gas use for heating these buildings.

  An important area of needed research is measuring and quantifying the performance of building envelopes, both new and existing. The majority of building stock already exists, and developing cost-effective envelope retrofits for these buildings is important to reducing natural gas use.

  Developing, evaluating, and publicizing the benefit of better construction techniques are an important potential source of natural gas savings. An additional benefit of this work is that comfort of such buildings is substantially improved due to elimination of drafts and cold spots.
- Roadmap to identify future research initiatives for buildings – The purpose of a roadmap is to identify funding priorities and guide RD&D activities associated with reducing natural gas use in buildings. The roadmapping activity will include:
  - Workshops with industry stakeholders including utilities, end users, and research organizations.
  - Evaluation of research to date.
  - Determination of research gaps.
  - Identification of research priorities in conjunction with state policy goals.

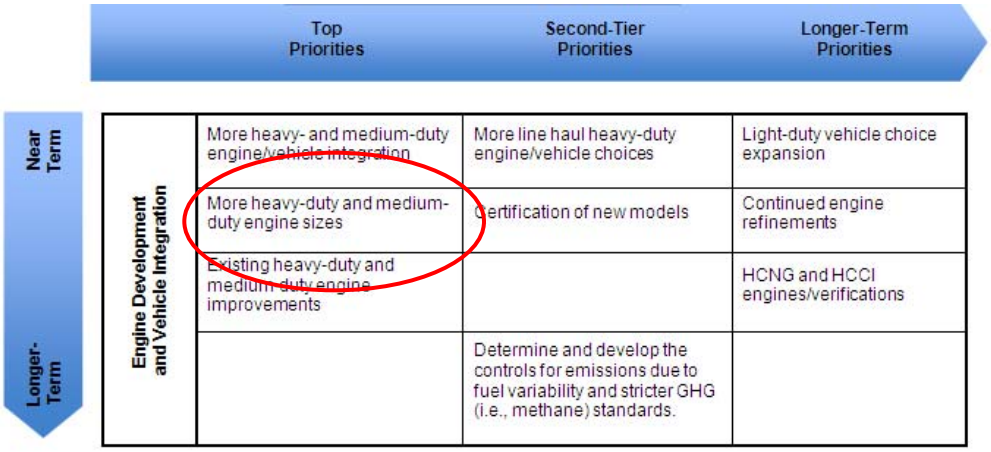
Research and Develop Advanced and Fuel-Efficient Natural Gas Engines

Fuel Efficient Transportation Technologies

The *State Alternative Fuels Plan* recommends increased use of alternative fuels and efficient vehicle advancements to reduce petroleum dependency and greenhouse gas emissions. The drive for alternative fueled vehicles now includes the U.S. Department of Energy, which recently revived its natural gas vehicle research and development program with the goal of expanding the commercial availability of fuel-efficient and low-emission natural gas-powered medium- and heavy- duty engines and vehicles. The Energy Commission will support the DOE's Advanced and Renewable Fuel and Vehicle Technologies program's focus on the deployment and commercialization of natural gas vehicles by expanding the range of natural gas engines in various sizes to strengthen that vehicle supply pool. The *Natural Gas Vehicle Research Roadmap* identifies RD&D barriers to natural gas vehicle market viability (Figure 9).[22] As focused research into natural gas engine development continues to progress, the barriers to deployment and demonstration will be addressed by more natural gas engine size availability.

Previous research and development by PIER's Transportation Program have concentrated on larger displacement engine sizes, and the results are various natural gas engine options that are nearing commercialization. However, there is still a gap in smaller displacement engines that are used in Class 3 through Class 5 vehicles. This range of vehicle classes represents the highest truck population in California and second largest population in terms of vehicle miles traveled. An example of these types of vehicles includes delivery trucks and shuttle buses. The proposed research will develop and demonstrate one or more fuel-efficient natural gas 6-8 liter engines, which would compete in both performance and cost with the equivalent conventional engines in categories widely represented in California fleets.

Figure 9: Recommended Funding Priorities From the Natural Gas Vehicle Research Roadmap (Issues addressed by FY 2011-12 research circled in red)



Source: California Energy Commission

[22] CEC-500-2008-044-F

This proposed research 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*; and the *2007 IEPR*, under which the Energy Commission seeks to maximize use of alternative fuels and advance fuels and vehicle technologies.

Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies

The state loading order ascribes the second highest priority to renewable resources and other clean alternatives, including CHP systems. California's Renewables Portfolio Standard assigns a high priority to reducing the state's dependence on imported natural gas by diversifying its gas supplies.

Renewable resources that could directly displace conventional natural gas are abundantly available in California. Renewable natural gas alternatives, such as CHP, require immediate and continued research for these resources to result in significant long-term benefit to California's natural gas ratepayers. Proposed research in this topic area addresses the following *2009 IEPR* recommendations:

- Address technical and infrastructure barriers to deployment of emerging renewable heating and cooling technologies and assess their current and future cost trajectories as well as how to strengthen the market for commercially mature technologies.
- Develop natural gas alternatives and substitutes for use within transportation applications, ideally using existing infrastructure and vehicles.

In supporting these recommendations, the Energy Commission proposes targeting three areas: buildings-scale implementation, community-scale implementation, and alternative transportation fuels. The Energy Commission is requesting an increase of $1 million over last year's funding for this area to reflect revised policy goals developed with the CPUC. Table 5 provides the proposed budget breakdown for FY 2011-12 for this research area.

PIER implements RD&D of advanced generation technologies for deployment in new applications, which exceed current performance (efficiency, environmental) and customer/user expectations (reliability, availability, affordability, maintainability, durability and usability). In the past, the primary focus areas of the program were on nonrenewable electricity generation resources, such as natural gas and cogeneration. Public forums under the *IEPR* proceedings and road mapping efforts helped identify and prioritize current and future research initiatives of the program. These efforts, supported by energy and environment policy directions, strengthened the program shift toward a focus on renewable energy. Under this budget proposal, the RD&D program will address this shift in program by focusing on hybrid generation, fuel-flexibility, and other energy-efficient and low-emission technologies for DG/CHP. The program also proposes to support and collaborate in larger cross-cutting efforts aimed at improving energy efficiency to ultimately attain net zero energy in buildings, industries, and communities.

Table 5: Budget Breakdown for Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies

Research Solution	Budget
Hybrid generation, fuel-flexible systems, and other energy-efficient and low emission technologies for distributed generation/combined heat and power/combined cooling, heating and power in industrial and commercial applications	$2.25 million
Distributed generation/combined heat and power integrated in energy-efficient and net zero energy buildings and industries	$0.75 million
Develop low-cost and thermally efficient renewable industrial heating and cooling	$0.75 million
Solar Hot Water Heating	$1 million
Research, develop, and demonstrate alternative fuels that reduce petroleum consumption and transportation-related greenhouse gas emissions, while assisting economic development within California	$2.5 million
TOTAL	**$7.25 million**

Source: California Energy Commission

Hybrid generation, fuel-flexible systems and other energy efficient and low emission technologies for distributed generation/Combined Heat and Power/Combined Cooling, Heating and Power in industrial and commercial applications

Energy-efficient, durable, and reliable distributed generation systems are a promising solution to California's need for cost-effective, safe, and clean energy technologies. In particular, CHP/CCHP offers high system efficiency (thermal and electricity) and will be a critical technology solution going forward. The *2009 IEPR* recognized CHP/CCHP as an end-use efficiency measure for commercial, industrial, and institutional facilities with identified potential "as high as 22,000 MW." Since 2003, California's energy policy has defined energy efficiency as the first priority in the loading order to meet California's growing energy demand. Under this guidance, energy efficient CHP/CCHP becomes a preferred resource in California's loading order.

Many perceived CHP/CCHP benefits, including greenhouse gas emission reductions, remain largely unrealized in California. A major deterrent for CHP/CCHP technologies in California, particularly the reciprocating internal combustion engine, is the poor emissions performance, including its inconsistent ability to cost-effectively achieve and sustain compliance with the state's stringent distributed generation emission standards. Other challenges for CHP/CCHP technologies include effective design, ability to match the load with potential end applications, and the flexibility to alternative fuels and varying operational profiles. Advanced generation technologies such as gas turbine, including microturbines, and fuel cells are less benign on emission issues, but also suffer with similar challenges at varying degrees.

The research in this area will address hardware development for reliable, energy-efficient, and low-emission technologies for CHP/CCHP applications that are market-ready or close to commercialization. In particular, this RD&D will explore integration and a combination of advanced generation technologies and fuel-flexible capability that allows the use of alternative fuels with low carbon intensity, including biogas, natural gas, and otherwise wasted fuels, such as flared gas. In addition, as part of its advanced generation research, low-emission technology will be developed for CHP/CCHP applications with inverter-based power and renewable intermittency and grid connectivity technology solutions capable of distributed energy resource aggregation. This effort will also address grid connectivity and distributed energy resource aggregation issues associated with CHP/CCHP/cogeneration units and will involve design, testing, field evaluation, and monitoring.

Distributed Generation/Combined Heat and Power Integrated in Energy Efficient and Net Zero Energy Buildings and Industries

In this research initiative, PIER will collaborate and provide funding support to a cross-cutting and game-changing effort on energy efficiency and net zero energy buildings, industries, and communities. Attaining efficiency and net zero energy goals require challenging efforts on many fronts, including energy-use efficiency measures and efficient use of available fuel resources to generate energy that matches the electricity and thermal demands. To this end, DG/CHP will be a key technology category that addresses both the generation and supply-side energy efficiency objectives. The research will not only demonstrate the critical role of DG/CHP in attaining these goals, but also examine and document the operational and parametric requirements to achieve synergy with efficiency measures and aspects such as flexible dispatchability in microgrid and smart grid systems.

Develop Low-Cost and Thermally Efficient Renewable Industrial Heating and Cooling

Based on results from the IAW program solicitation that will be released under Research Objective 1, Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency, projects will be funded under the following potential research opportunities that exist within this area:

- Preheating water in a multitude of industries (for example, breweries, wineries, and bottling operations) by using waste heat or renewable energy such as digester gas.
- Solar/thermal augmentation/replacement of existing natural gas-fired boilers in conjunction with storage systems.

Research solutions in these areas are:

- Use of natural gas or renewable methane for fuel cells.
- Fuel cells designed specifically for distributed generation.
- Research into reducing natural gas use in the paper manufacturing process through the use of advance additives and improving the bleaching process.
- Research of direct contact water heaters for industrial scale hot water generations.

Solar Hot Water Heating

Improvements in solar hot water systems could reduce equipment and operating costs and increase implementation rates. PIER's Buildings program identified the following research opportunities within this area:

Hybrid-Integrated Solar Systems for Hot Water Production and Space Heating – This research will determine the performance and technical potential of a hybrid solar system that could provide both water and space heating in residential applications. It will also develop more accurate residential hot water use profiles based on real-life California data.

Roof-Integrated Solar Hot Water Systems – This research will investigate ways to lower the cost associated with integrating solar hot water systems in a variety of roof configurations.

Drainback Optimized Controls – Most of the current controls for solar hot water systems are not optimized for drainback systems. This research would provide data to support drainback optimized controls and the resulting increase in energy efficiency.

Freezable Open-Loop Collector – Open-loop active solar hot water system design is efficient and lowers operating costs. However, it is not currently appropriate in regions with subzero temperatures. Research would focus on design of an open-loop collector for areas with subzero temperatures.

Super-Efficient Storage Array – This research would investigate options beyond traditional thermal solar storage and the feasibility of creating an array of tanks at different temperatures, each with its own solar hot water system. Options to deploy many smaller tanks to create a super-efficient storage array should be investigated, as it may reduce the cost for solar hot water systems. Each tank could be thermally stratified, or well-mixed tanks could be batched at different temperatures.

An additional area of future research is to determine how to scale tanks up and down to meet different market sectors (for example, large tanks for commercial purposes and small tanks for lower price and easier export and freight).

Research, Develop, and Demonstrate Alternative Fuels that Reduce Petroleum Consumption and Transportation-related Greenhouse Gas Emissions, While Assisting Economic Development within California

Senate Bill 76 requires the Energy Commission and ARB to jointly develop a strategic research plan for up to half of each year's natural gas funding. The *2007-2011 Natural Gas Research Investment Plan* was developed to fulfill this legislative mandate and provide a framework for coplanning. Moreover, ARB staff plays a key role in implementing the annual plans within the 2007-2011 Plan. As it does with electricity research, ARB staff provides advice and insights in workshops, the development of research roadmaps, defining the scope of research projects, and in some cases management of specific research projects on behalf of the Energy Commission. ARB participated in the production of the *Alternative Fuels Research Roadmap*. The 2007 – 2011 Plan, summarized in the *2007 Natural Gas Research Program Plan and Funding Request*, identifies benefits to natural gas ratepayers as set forth in SB 76:

- Does the research seek to improve the affordability of energy services and products?
- Does the research seek to reduce the impact on or restore the environment through energy services and products?
- Does the research seek to reduce greenhouse gas emissions related to electricity and natural gas production and use?
- Does the research seek to increase the use of alternative fuels?

The 2007 – 2011 Plan sets forth a series of transportation research initiatives that speak to state energy policy described in the *Energy Action Plan, the State Alternative Fuels Plan*, various Governor's executive orders and the 2005, 2007 and 2009 *Integrated Energy Policy Reports*. The PIER Transportation Subject Area's alternative fuels research addresses Research Solution 3b from the plan:

"Develop and demonstrate technologies for the in-state production of renewable and non-petroleum transportation fuels that can augment transportation fuel supplies, provide state economic and ratepayer benefits, reduce air pollutant and greenhouse gas emissions and increase on- and off-road transportation fuel diversity."

The PIER Transportation Subject Area has identified alternative fuels research, development and demonstration as consistent with the public benefit requirements of SB 76, and the joint Energy Commission/Air Resources Board plan required by this statute. Research into electricity as a transportation fuel is funded through the PIER electric program. While electric fuel use would displace petroleum, its potential to decrease natural gas use depends on technology developed in addition to policy and regulatory structures not yet in place. All remaining alternative fuels are combustion fuels that would displace those derived from petroleum and would also decrease the consumption of natural gas. SB 76 does not allow funding for hydrogen fuel research using natural gas public purpose funds.

Natural Gas Ratepayer Connection: Use of non-petroleum derived alternative combustion fuels will directly result in reduced consumption of natural gas in California. Large quantities of natural gas are used in petroleum production and refining. The amount of natural gas used in petroleum production varies; larger amount being used for tertiary enhance oil recovery (TEOR) of heavy crudes. California's total crude oil consumption is heavy crude; the remainder varying according to world oil market conditions. This analysis considers only the natural gas used in crude oil refining. Refineries use natural gas to provide process heat and as a feedstock for hydrogen production. In California, refineries account for more than 40 percent of all the natural gas used in the industrial sector, more than 143 trillion btus per year, enough natural gas to supply more than 300,000 homes. Each gallon of diesel or gasoline fuel produced in California uses about 7,700 btus of natural gas. State transportation energy policy has established goals to reduce the amount of petroleum-derived fuel consumed in California by increasing the use of alternative fuels, increasing vehicle efficiency, and reducing vehicle miles traveled. Increasing the use of alternative combustion fuels will displace petroleum-derived fuels and reduce the natural gas used to make them. The amount of natural gas saved depends greatly on the processes used to produce the alternative fuel. For instance, refining a seed-

derived vegetable oil to a gallon of transesterified diesel replacement can use more than 10,000 btus of natural gas, makeing it a poor choice for associated natural gas savings. However, some processes such as steam hydrogassification produce hydrogen as part of the process, thus requiring no use of natural gas to make a finished diesel replacement. This proposed scope of alternative fuels research will focus on drop-in fuel production science, such as advanced thermochemical and direct single cell synthesis that produce petroleum fuel replacements requiring minimal or no refining.

The *State Alternative Fuels Plan* established a moderate-case goal of 5 billion gasoline gallons equivalent (gge) alternative fuels market penetration by 2022. If advanced, drop-in fuel production processes supplied this fuel, the amount of petroleum displacement would result in yearly savings of more than 380 million therms, worth more than $192 million in 2011 dollars. The actual value of this savings is expected to be greater when carbon reduction benefits are applied.

In addition to conserving natural gas, alternative transportation fuels research also works on the supply side to bring technologies to market that produce affordable, renewable natural gas. Renewable natural gas has the potential to reduce the overall fossil carbon content of California's natural gas supply, thus benefiting all natural gas ratepayers. The PIER Transportation and Renewable subject areas jointly research improvements to anaerobic digestion processes that produce renewable natural gas, for example, and PIER Transportation funded a liquefied landfill gas fuel project with the Gas Technology Institute.

Alternative Fuels Research Planning: PIER's Transportation Alternative Fuels research follows the guidance of its *Alternative Fuels Research Roadmap*, which is being finalized and is expected to be publicly vetted at an Energy Commission workshop in the summer of 2011. PIER developed the roadmap with the University of California at Riverside and with a stakeholder group representing industry, research, and government, including the National Biodiesel Board (NBB), National Renewable Energy Laboratory (NREL), the ARB, and the South Coast Air Quality Management District.

Public interest research opportunities for alternative fuels were developed using statutory, regulatory, and policy criteria that can be summarized into the following crucial goals:

- Petroleum reduction
- Slowing or mitigating climate change
- Protecting California's air/environmental quality
- Promoting California's economy

This last, in particular, includes retaining and reinforcing California's preeminence as a market leader in the rapidly expanding fields of biotechnology innovation, sustainable biomass development, and market development for sustainable fuels and their coproducts. It also involves substantial potential for job creation in these new industries.

PIER exists to nurture nascent, precommercial technologies and is bounded by SB 1250, which mandates a portfolio of near-, mid-, and long-term research solutions. In accordance with this legislation, the AFRR identifies a pathway forward in the near- to mid-term to develop and implement drop in alternative fuels.

Drop in fuels, also known as fungible fuels, mimic the properties and performance of conventional petroleum fuels. They are mixtures of large molecules (as opposed to straight ethanol, which is a relatively simple 2-carbon chain), possessed of equivalent energy densities and combustion characteristics to gasoline, diesel, or jet fuels, and are functionally interchangeable with those fuels.

Such large molecule drop in fuels are key to PIER Transportation's California fuels research strategy because they would allow rapid deployment of alternative fuels in the marketplace. Fungible fuels are designed not only to seamlessly replace conventional fuels in existing applications, but also to make use of legacy infrastructure. California's fuels transportation, distribution, and storage systems, and the interstate systems with which they are linked and upon which they depend, represent enormous sunk costs and are not about to be replaced or superseded any time soon. It is a matter of both practicality and necessity, then, that the next generation of transportation fuels makes use of them.

Initial roadmap findings identify public interest research opportunities of eight alternative fuels pathways, summarized in Table 6. The most promising research opportunities lie within the large molecule (drop-in fuels) pathways.

Table 6: Public Interest Research Opportunities of Eight Alternative Fuel Pathways

Fuel Pathway	Description	Large Molecule (Drop-in) Fuel Yes or No	Research Potential High, Medium, Low
Thermochemical:			
Gasification to liquids	Uses Fischer-Tropsch synthesis to produce liquid fuels	Y	M
Hydrogasification	Potential to use wet feedstocks to produce methane or liquid fuels	Either	H
Pyrolysis	Thermal decomposition of organic matter to intermediate liquids and syngas	Either	M
Advanced direct microbial pathways	Produce large molecule fuels at much higher yields than traditional terrestrial crops	Y	H

Synthetic photosynthesis	Direct conversion of atmospheric CO2 to hydrocarbons; very long timeframe	Y	L
Cellulosic ethanol	Broader feedstock availability and lower carbon impact than grain ethanol.	N	M
Biodiesel	Usually used as a fatty acid methyl ester (FAME) derivative of plant and animal fats	Y	L
Renewable diesel	Similar to biodiesel, but uses a hydrotreating process	Y	L
Hydrogen	Not eligible for NG research funding (SB 76)	N	n/a

Source: California Energy Commission

Infrastructure Compatibility: Implementation of alternative combustion fuels will be greatly facilitated by developing those compatible with existing transportation and dispensing infrastructure. So-called "large molecule" or "drop-in" and renewable natural gas are examples of alternative fuel types that can be integrated with, or totally replace, conventional fossil fuels with little need to change existing fuel infrastructure. Liquid drop-in fuels also have the advantage of usefulness to petroleum refiners who can use them to blend directly with conventional stocks to lower the fossil carbon content of the fuels produced.

Proposed Alternative Fuels Research for the 2011/2012 Budget Plan: PIER Transportation will focus its alternative fuels research on pathways offering the benefits of large molecule and renewable natural gas alternative fuels. These research initiatives will be accomplished through competitive solicitations and interagency agreements with California universities.

1. Pathways improvement research – Research will be conducted to improve the performance and lower the cost of advanced fuels pathways processes. Some of these processes, particularly the thermochemical ones, both produce renewable natural gas (RNG) and can use that methane to create large molecule fuels. A variety of feedstocks is in play, including but not limited to municipal solid waste (MSW) and agricultural waste.

Research projects could include Phase II development of the steam hydrogasification reactor (SHR) technology. The proposed project will expand the process demonstration unit to demonstrate renewable natural gas production via further conversion of synthesis gas. The proposed project will also expand the feedstock portfolio by adding food waste. The results of this research will be used to develop and optimize the process needed to establish the engineering design basis for a commercial-scale production facility.

2. Infrastructure compatibility – Drop in fuels are designed for compatibility by definition. Between design and deployment, this compatibility needs to be ensured. Research will be

initiated to evaluate California's legacy petroleum fuels infrastructure with regard to ensuring compatibility. Pipeline and tank testing will be conducted to ensure the feasibility of seamless introduction of alternative fuels into California's petroleum fuels systems and marketplace.

3. Coproduct economic analysis – One key to making alternative fuels technology successful is making it economical. That means making the most money, not necessarily the most fuel. Research of coproducts/services will be initiated to present a current and comprehensive picture of the state of alternative fuels technology and economics for California's energy policy makers. Just as petroleum refiners also produce economically profitable chemicals, many alternative fuels technologies under development generate coproducts, both high- and low-value, as well as beneficial services such as waste disposal. These revenue streams are integral to both conventional and alternative fuels production business models and must be included in the development of post petroleum fuels.

Improve Natural Gas System and Infrastructure Performance, Reliability and Safety

California's growing demand for natural gas will have a significant impact on the State's aging natural gas infrastructure. Research to assess residential customer behavior toward advanced customer technologies is ongoing. In addition, 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 effect of a 33 percent renewables portfolio standard that may lead to additional gas-fired generation.

Pipeline safety and security are especially important, as natural gas pipelines lay beneath highly populated areas. To address this issue, the Energy Commission proposes a research approach that has been successfully used in the past. This research approach will assess both the current state of technology used for pipeline monitoring and emerging technologies that have potential to enhance the safety and operation of the natural gas pipeline system. This approach was used previously by the Energy Commission's PIER Electric Distribution Research program that completed an assessment of new and emerging technologies that could be used to assess, monitor, and report the condition and health of underground electrical cables. This effort was completed in 2009 and identified several promising technologies that are now in either the laboratory or field test phase. A similar technology assessment would be beneficial for the natural gas pipeline system. Table 7 provides the budget breakdown for FY 2011-12 for this research objective.

Table 7: Budget Breakdown for Improve Natural Gas System and Infrastructure Performance, Reliability and Safety

Research Solution	Budget
Natural Gas Pipelines	$1 million
TOTAL	**$1 million**

Source: California Energy Commission

The Energy Commission proposes funding two projects that will ensure the above approach is successful. One project will focus on the current state of technology (hardware, software, and processes) being used in California to assess and monitor the condition and health of the natural gas pipeline network. The other project will focus on innovative approaches to inspect and monitor natural gas pipeline integrity and safety. These projects will provide the State with a detailed assessment on the current state of technology and practices, and emerging technologies that can enhance natural gas pipeline integrity and safety.

Current State Technology Assessment

The Energy Commission proposes supporting an assessment of the current state of technology (hardware, software, and processes) being used in California to assess and monitor the condition and health of the natural gas pipeline network. This assessment will include developing a baseline assessment of technology currently being used in California to manage pipeline integrity and safety. It will include what is currently being done to prevent, detect, and react to incidents (leaks and/or ruptures). It will assess all the available technology that could be used in California, but is not currently being used because it is either: (a) ready for use, but not widely used on a commercial basis, (b) unknown, or (c) unproven. It will identify immediate opportunities to improve the assessment, monitoring, and integrity management program of the California pipeline network. The product of this research will be an implementation plan for currently available technologies and a set of recommendations for the further development of existing emerging technologies and for the development of new technologies that address existing technological gaps.

Innovative Approaches to Inspect and Monitor Pipeline Integrity

The Energy Commission proposes supporting research that will explore innovative technologies and approaches to inspect and monitor natural gas pipelines. Critical elements of this research will include an assessment of innovative technologies to measure gas pressure and prevent overpressure; inspect and monitor weld quality; avoid long-term corrosion and failure; and establish remaining useful life of installed gas lines to assure these assets are managed efficiently and safely. This research will include an evaluation of existing diagnostic approaches used to detect or predict incipient failure, and explore new laser-based and other sensor technologies that can be used to improve diagnostic accuracy. The product of this research will be the design platforms for new sensors and communication technologies that can significantly improve the safety and security of gas lines.

Reducing the Environmental Footprint of California's Natural Gas System

AB 32 places a direct statewide cap on GHG emissions and requires California to reduce its GHG emissions to 1990 levels by 2020. This legislation includes emissions associated with California's natural gas system. Natural gas-fired generation provides more than 45 percent of the electricity consumed within California and will continue to be an important source of electricity in the foreseeable future. AB 32 requires substantial efficiency and optimization of natural gas end uses, especially those that burn natural gas for heating and various industrial processes. Furthermore, urban development and pressures of a growing economy and population affect sensitive habitats, air quality, and water quality. Applying existing regulations and any new environmental protection regulations will have impacts on energy infrastructure constraints, energy prices, protection of the environment, public health, safety, and environmental justice. These policy and regulatory directives require that further development of California's natural gas systems will not increase its environmental footprint. The Energy Commission proposes supporting research projects that support energy-smart development of California's natural gas system without significantly impacting the state's environment and climate. Table 8 provides the budget breakdown for FY 2011-12 for this research objective.

Table 8: Budget Breakdown for Reduce the Environmental Footprint of California Natural Gas System

Research Solution	Budget
Air Quality	$ 1 million
Water and Natural Gas	$ 1 million
Climate Science	$ 1 million
TOTAL	**$ 3 million**

Source: California Energy Commission

Air Quality

State and federal comparative risk studies consistently ranked indoor air pollution among the top four environmental problems. California residents spend an average of 87 percent of their time indoors, and in many cases this air is worse than the outdoor air. Research by the ARB, the U.S. Environmental Protection Agency, and others has shown that the indoor level of some pollutants range from 2 to 50 times higher than outdoor levels. Indoor air pollution consists of gases or particles that can harm your health. These pollutants can build up rapidly indoors to levels much higher than those usually found outdoors. This is especially true if large amounts of a pollutant are released indoors. Indoor emissions have been estimated to be 1000 times more likely to result in exposure than outdoor emissions. Indoor pollution is also estimated to cost Californians a minimum of $2billion - $5 billion per year.

Measurement of time-resolved pollutant concentrations from use of unvented natural gas cooking appliances. The current magnitude and frequency of health effects associated with pollutant emissions from natural gas appliances in California homes are unknown. Recent modeling results from a PIER-funded study indicate that use of natural gas cooking appliances without exhaust routinely produces short-term nitrogen dioxide (NO2) concentrations that exceed federal outdoor air quality standards. The accuracy of the estimated scope of this phenomenon depends critically on the accuracy of emission factor data, which is currently drawn from a sample of only 12 appliances. A recent United States study found that the 1-hour NO2 standard is also frequently exceeded in homes with unvented fireplaces. In addition to unvented appliances, pollutants can enter when vented appliances are not installed or operating as designed. Examples of problem conditions include broken or disconnected flue connectors, blocked water heater air intakes, back-drafting and spillage of naturally ventilated appliances, lint-blocked dryer vents, and improper combustion conditions resulting from fuel regulator malfunction. For cooking appliances, the lack of external venting, and inefficient capture of pollutants by installed range hoods, and lack of use by residents are critical factors affecting exposures. Accurate exposure assessment and mitigation planning at the population level requires data on the frequency of occurrence of the aforementioned processes and risk factors. Improved data on emission factors, leaking rates, mitigation strategies, and so forth are also critical.

A current PIER-funded study will measure time-averaged concentrations of carbon monoxide and nitrogen dioxide in California homes, with oversampling of homes having appliances and other conditions that have been shown, or are thought to lead to, higher pollutant emissions and concentrations. In addition to direct measurement of time-integrated pollutant concentrations in a large sample of homes, complementary approaches are needed to assess the magnitude of health effects from natural gas appliances. This research would add measurement of time-resolved pollutant concentrations for model validation and assessment of acute exposures. The addition of the time-resolved concentration to the current field study was recommended by the ARB.

Develop standard test methods to determine efficiency of commercially available residential range hoods. A current PIER-funded project is examining the efficiency of available range hoods and analyzing the air quality and energy benefits of improving cooking exhaust device performance. The expected outcome of this project is a set of recommended standards for energy efficiency, pollutant capture efficiency, and noise. Improving the efficiency of range hoods will create better indoor air quality and improve health. However, there is a need to develop standard test methods for use in determining the efficiency of commercially available residential range hoods. Development of standard test methods will require coordination of stakeholders and government agencies such as the ARB.

Develop a reliable field test method to enable greater improvements in air sealing and building energy efficiency. Air tightening is one of the key strategies for improving energy efficiency in homes. If combustion appliance venting is not robust, air sealing can increase incidences of back-drafting and spillage of pollutants from venting appliances, including furnaces and water heaters.

Current field tests for proper venting do not yield repeatable results and are not determinative. They can also lead to false positives (classifying nonproblematic) or failure to identify truly problematic conditions. Since the current tests are required in some energy efficiency programs and by home performance contractor certifications, the tests drain resources without providing consistent or reliable benefits. In practice, the lack of a robust test for venting safety leads to underutilization of air sealing opportunities and a loss of energy efficiency opportunities. This project will develop more robust, repeatable, and reliable field test methods to enable greater improvements in air sealing and building energy efficiency.

Water and Natural Gas

Water is involved in almost every aspect of the natural gas system, from production and transmission to use. Given the State's efforts to reduce energy consumption and GHG emissions in the face of diminishing freshwater supplies, it is important to understand and reduce the water footprint of the natural gas sector.

One approach to this is a research program that would address the cost and performance barriers that limit the greater use of water conserving cooling technology, and would address degraded sources of cooling water (water supplies unsuitable for most other uses) without imposing additional energy costs on the State's ratepayers.

Water Conserving Cooling Technologies and Strategies. A major environmental concern regarding natural gas-fired generation is the significant freshwater use associated with the operation of conventional wet cooling (cooling towers). On average, a 500-megawatt (MW) combined-cycle power plant using wet cooling requires 3 million gallons of water per day, predominately for cooling. This is as much water as a community of 12,000 people will consume, in a day.

Methods to reduce this freshwater use include the use of water-conserving cooling technology, such as the use of air-cooled condensers (dry cooling), or the use of degraded water supplies, which include salt water and brackish or degraded groundwater or wastewater effluent. These are water supplies that are unsuitable for municipal or agricultural use without extensive treatment.

While the use of air-cooled condensers can reduce a power plant's water use by up to 95 percent, there are cost and performance penalties associated with their use. Air-cooled condensers often increase the capital cost, possibly up to 12 percent for a new gas-fired 500 MW combined cycle power plant. They also incur a performance penalty, as much as 2 to 4 percent on an annual operating basis, for a 500 MW power plant. More important, dry-cooled plants can impose a significant capacity penalty, potentially as high as 10 MW at a 500 MW combined cycle plant during the hottest hours of the year, at precisely the time when the demand for electricity is the highest.

Early PIER-funded research evaluated the use of entraining a fine mist of water into the air being blown through the air-cooled condenser. This research showed that more than 70 percent of the energy that would be lost on hot days could be regained by this approach. While spray enhancement of air-cooled condensers has been shown to be effective, concerns about mineral

deposition from evaporating water on heat transfer surfaces is a barrier to greater acceptance of this approach. Another approach, where an air-cooled condenser would use a wet-dry dephlegmator, has shown the possibility to enhance cooling performance on very hot days. A dephlegmator in an air-cooled condenser is used to remove air and other non-condensable gasses from the steam. Early evaluations show that during very hot periods, the wet-dry dephlegmator can achieve the same performance as spray enhancement at lower cost.

For degraded sources of cooling water, concerns have rose regarding worker safety from volatilization of hazardous substances, especially from using reclaimed wastewater outflow. Additional research is needed to evaluate what substances would pose such a risk, acceptable levels, and suitable water treatment methods. Another concern is particulate matter created by evaporating droplets from degraded water sources in cooling towers would exacerbate ambient air quality conditions around or near the tower. A careful laboratory investigation of droplet size characteristics and the morphology of the residual particulate matter is needed to evaluate this concern in a rational way.

Linking natural gas and water consumption in residential buildings. In 2006, residential customers accounted for approximately 12 percent of the natural gas used within California, and the vast majority (88 percent) of this was used for space and water heating. On the other hand, most indoor residential water use in California is linked to natural gas use—as needed for warm bathing and washing. These linkages, compared to the linkages between water and electricity, are often stronger and, at the same time, much less studied and understood. There is a need to understand the linkages between the residential end use of water and natural gas. This proposed research will address the issue by establishing how the relative timing and quantity of natural gas and water use changes over time, including "peak" and "off peak" periods. The research will also evaluate behavioral links between water and natural gas use in the home to provide estimates of potential savings from conservation. An example of this would be how much natural gas is conserved through implementation of water conservation, such as low flow showers and more efficient washers and dryers.

There is also a need to understand the linkages between the demand for water, natural gas, and electricity to understand how price changes in one will affect demand in the others. For example, a rise in the price of water will affect the consumption of natural gas and electricity, the price of natural gas will affect the consumption of water, and so forth. This research would establish the individual use and price patterns for each, including the price elasticity of demand, and then determine the cross elasticity for natural gas, water, and electricity.

Climate Science

Understanding the impacts of global climate change on a local level will help develop efficient mitigation strategies and will help focus on technologies that have concrete applicability. California's unique climate and geography create an ideal laboratory to study specific climate phenomena and their effect on key state sectors. The Energy Commission intends to use targeted research to better understand the impacts of global climate change on the local California environment.

For this fiscal year the PIER Program proposes to focus its research efforts on mitigation (emission reductions) that will provide information on efficient and cost-effective ways to reduce emissions from the natural gas system and the identification of environmentally sound potential sources of offsets or emission reduction credits that would be available for the natural gas sector.

Identification of options to reduce fugitive methane emissions from the natural gas system, including additional emission testing when needed. California has a large natural gas industry, which produced about 860 billion cubic feet of natural gas in 2009, which was extracted from more than 1,500 gas wells and thousands of oil wells. A vast network of pipelines and associated equipment transports the natural gas produced in California, as well as imported gas, to consumers. Those consumers include power plants, industrial facilities, commercial buildings and homes. Aside from the transportation sector, natural gas is the fuel of choice in California.

The ARB's *AB 32 Scoping Plan* includes a measure designed to reduce fugitive methane emissions from the oil and natural gas systems in California. These emissions come from wells, leaks in transmission and distribution lines, process equipment (for example, natural gas-fired dehydrators), control equipment (for example, pneumatic devices such as air-powered tools), and from the venting of natural gas during maintenance and repair operations.

The ARB and the Energy Commission are coordinating a research project designed to develop improved emission factors to estimate fugitive methane emissions from the different components of the natural gas system. The current emission estimates are believed to be highly uncertain mainly due to two reasons: 1) the existing emission factors were developed from a study conducted in 1996 and they may not apply to existing systems and practices, and 2) most of the tests conducted for the 1996 study were done outside California. Only a very small sample of components in the natural gas system will be tested under the ongoing project.

Under a follow-up project, researchers will develop proposed controlled strategies using the improved emissions estimates developed in the original research project, but would conduct additional measurements as necessary to better characterize emission reduction options. Given the lack of uniformity in regulatory requirements in different regions in California, the proposed strategies will be designed by regions in California (for example, an area under the jurisdiction of the Sacramento Air Quality Management District) and, perhaps, by utility territory. The control measures will include estimated costs, overall level of control, cost-effectiveness (dollars per ton of methane reduced), and an estimate of the economic effect to the natural gas industry and its ratepayers.

Opportunities to create offsets/Emissions Reduction Credits. To ensure that California will meet the GHG reduction requirements of AB 32, a cap and trade program is outlined in the *AB 32 Scoping Plan*. Capped sectors include commercial and residential electricity and natural gas.

Research that identifies options to reduce GHG emissions will weigh the relative costs and benefits of each option. Projects for this topic will be identified through a request for proposals.

Examples of potential projects include:

- Determine incentives to which farmers will respond to change their agricultural practices to methods that produce less greenhouse gasses. These incentives are primarily driven by the price of carbon in carbon markets and the economic feasibility of changing farming practices.
- Examine the implication of climate change on bioenergy production (and renewables in general) as required in the draft adaptation plan prepared by the Resources Agency.
- Analyze the economic feasibility and potential carbon sequestration and GHG reductions associated with wetland restoration and changes in management practices on rangelands. Wetlands occupy a small area of the world but have the greatest store of carbon due to the limited decomposition in the soil layers. Approximately 72 percent of all natural emissions worldwide occur from the anaerobic decomposition of organic matter in wetlands. Rangelands and pasture lands cover 40 percent of California. Grassland soils and grass root systems have the potential to store appreciable amounts of carbon. Unfortunately, most of California's pasture lands are overgrazed and not properly managed. Recent studies have shown that rotational management of cattle can improve soil carbon and root biomass by 50 percent.

CHAPTER 4:
Energy Innovations Small Grants Program

Planned FY 2011-12 EISG Solicitation

Some of the most important discoveries, advances, and inventions have emerged from small, innovative projects. The Energy Commission proposes allocating $1.5 million of its proposed budget for a cross-cutting natural gas research grant program to complement ongoing core research for the Energy Commission's natural gas research program. This year's funding for small grants research would be divided into two main parts: transportation-related natural gas research ($500,000), and other natural gas research ($1 million).

These solicitations would fall under the existing Energy Innovations Small Grant (EISG) program, a successful program with the objective of providing opportunities for supporting feasibility studies. Since 2006, EISG has included emerging and promising natural gas technologies. The San Diego State University Research Foundation administers the EISG program. Examples of the innovative work being done through this program can be found in Chapter 1 under Highlights of Natural Gas Research Activities.

Through EISG, the Energy Commission will carry out three solicitations every fiscal year for grant awards for natural gas projects. Table 9 describes the major activities and preliminary deadlines for the $1 million solicitation for non-transportation natural gas research.

Table 9: EISG FY 2011-12 Non-Transportation Solicitation Deadlines

Deadline	Date
Preproposal Abstracts Accepted (optional)	January, March, August 2011
Grant Applications Received	February, April, and August 2011
Energy Commission Approval of Awards	Approx. 20 weeks from cutoff date
Notification of Awards	Within 5 business days (email and website)
Begin Executing Agreements	Fall 2011

Source: California Energy Commission

The additional $500,000 would fund a grant solicitation program to target feasibility research projects with specific focus on transportation-related energy topics. Table 10 describes the major activities and preliminary deadlines for the $500,000 solicitation for transportation-related energy research.

Table 10: EISG FY 2011-12 Transportation Solicitation Deadlines

Deadline	Date
Preproposal Abstracts Accepted (optional)	January, March, July 2011
Grant Applications Received	February, April, and August 2011
Energy Commission Approval of Awards	Approx. 20 weeks from cutoff date
Notification of Awards	Within 5 business days (email and website)
Begin Executing Agreements	Fall 2011

Source: California Energy Commission

These grants would support the Energy Commission's alternative fuels research and complement the overarching natural gas research areas by funding projects that aim to reduce the consumption of petroleum-based fuels by promoting and advancing renewable and non-renewable alternative fuels using innovative tools and methods. Research examples include:

- Resources and upstream research for cost-effective production technologies for viable transportation fuels.
- Distribution and fuel infrastructure research for cost-effective technologies and strategies that solve both technical and social issues related to the introduction of new fuels.
- Transportation small grants that would continue to support PIER vehicle technologies research by funding projects that reduce vehicle energy consumption through improved vehicle efficiency, reduced greenhouse gas emissions, and enhanced viability of alternatively fueled vehicles. Many of these projects would indirectly support natural gas goals regarding fuel efficiency.

These projects would benefit ratepayers by increasing efficiency of natural gas consumption, lowering carbon dioxide and other air pollutants, and lowering natural gas prices. These grants would be designed to assess "proof of concept," with successful projects considered for substantive research funding in subsequent years. The program has already proven to be 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.

Summary of the FY 2010-11 EISG Solicitation Results

The EISG Natural Gas Solicitations for FY 2010-11 (#09-02G, 10-01G, 10-01T NG) resulted in 27 proposals being accepted. The initial screening, conducted by technical reviewers with recognized expertise in the subject areas, resulted in 10 eligible proposals that were reviewed by the Program Technical Review Board. After its review, the Program Technical Review Board recommended funding four of the proposals (listed below in Table 11).

The Program and Technical Review Board is composed of 10 to 14 individuals with recognized energy expertise and includes representatives from the Energy Commission, California State University, the University of California, private industry, and investor-owned utility companies. The Program and Technical Review Board is responsible for final scoring and preparing a ranking of the grant applications for consideration in a public meeting by the Energy Commission.

Table 11: Approved Grant Proposals FY 09-10 (Cycle 09-02G, 10-01G, 10-01T NG)

Organization	Project Title and Descriptions
Rochester Institute of Technology 09-02G	A Natural Gas-Fueled HCCI Engine for Hybrid Vehicles Project will model, design, and build a working prototype Homogeneous Charge Compression Ignition (HCCI) engine for charging a Plug-In Hybrid Electric Vehicle battery pack; the project aims to address HCCI engine control issues.
University of California, Davis 10-01G	Development of Energy-Efficient Dehulling and Drying Methods for Walnuts Project seeks to reduce agricultural natural gas use by developing an improved process for efficiently sorting, and drying walnuts.
Multispark, LLC 10-01T NG	Analysis of PowerSTAR Spark Plugs in CNG Engine Applications Project seeks to increase combustion efficiency in vehicle-based natural gas engines through spark plug advancements.
Exergy Technologies 10-01T NG	Multi-Fuel Super-Compound Engine Efficiency Analysis Project will research the feasibility of super-compound engines for use in light-truck transportation.

Source: California Energy Commission

Future Funding Strategies

To increase the success of the EISG natural gas research program, new strategies will be implemented that mirror successful strategies that were used in the Energy Commission's electricity research program. The underlying goal of these strategies is to attract a maximum number of quality applications to the natural gas research program.

The EISG program allows applicants to submit the same research proposal up to three times. First submittals often lack something minor that can easily be addressed by the applicant. Starting in 2010-2011, EISG released three natural gas research solicitations to allow applicants to resubmit their research proposals that, although failing to succeed in the first solicitation,

could easily qualify for the second or third solicitation with minor revisions. This policy is particularly helpful for individual researchers with innovative ideas, but who lack the full administrative support of a larger company.

The second 2010-2011 natural gas research solicitation closed in February 2010. As of this report, the results have not been reported. More than 80 percent of projects receiving EISG funding are either second or third submittals. This multiple-solicitation strategy will increase the quality of project proposals and ultimately result in more successful projects.

The EISG program will increase the exposure of its natural gas research program by releasing non-transportation and transportation natural gas research solicitations in parallel. This strategy will allow EISG to target a larger applicant pool because the two solicitations together will attract more diverse candidates. Additionally, this will allow EISG staff to spend less time on administrative-related work and more time on promoting the EISG program and encouraging applicants to respond.