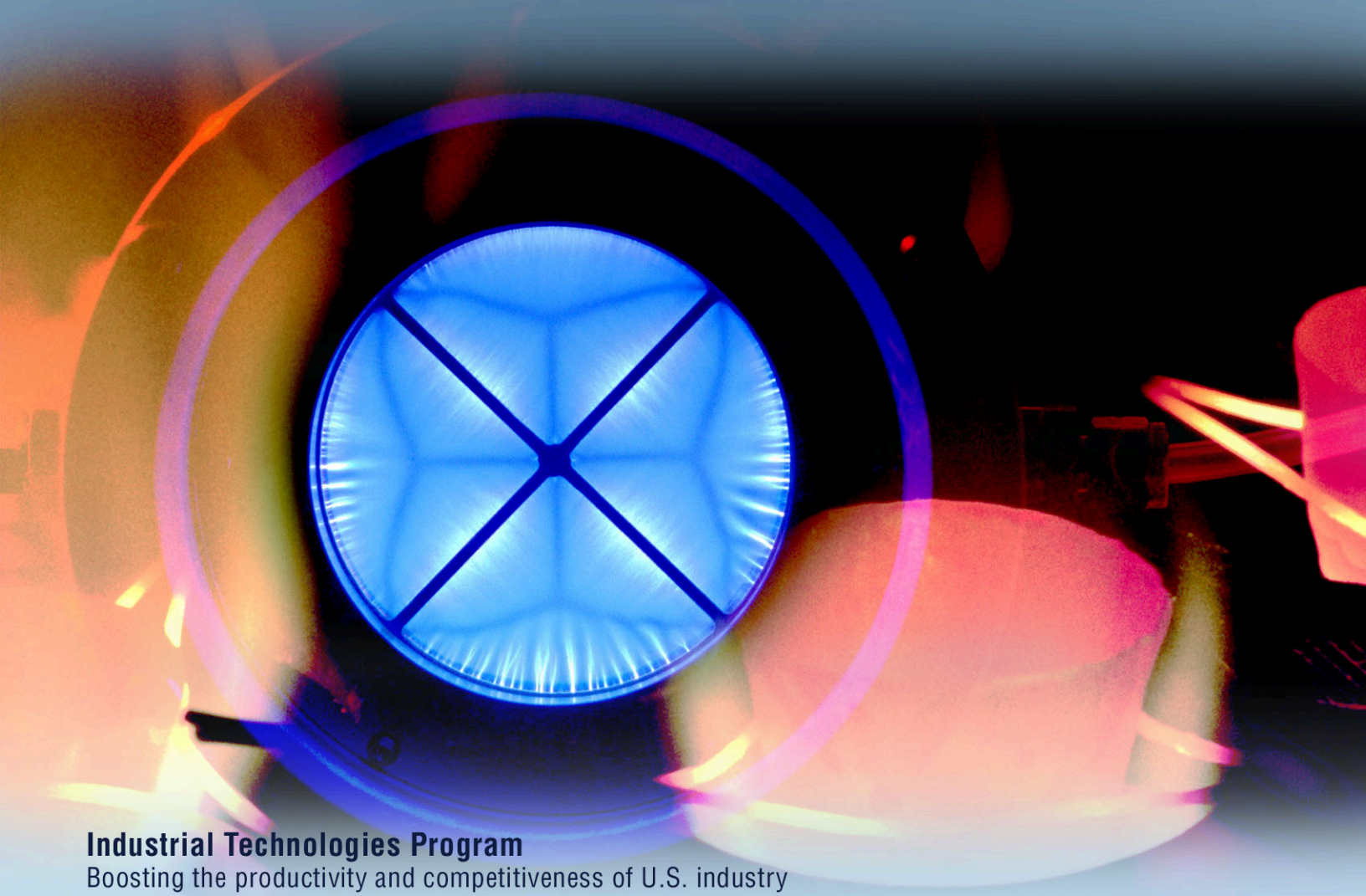
Combustion
Industry of the Future

Fiscal Year 2004 Annual Report



Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry
through improvements in energy and environmental performance

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Industrial Technologies Program — Boosting the Productivity and Competitiveness of U.S. Industry

Industry consumes 33 percent of all energy used in the United States. By developing and adopting more energy efficiency technologies, U.S. industry can boost its productivity and competitiveness while strengthening national energy security, improving the environment, and reducing emissions linked to global climate change.

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) works in partnership with U.S. industry to increase the efficiency of energy and materials use, both now and in the future. EERE's Industrial Technologies Program (ITP) is working to build the Industries of the Future through a coordinated program of research and development (R&D), validation, and dissemination of energy efficiency technologies and operating practices to reduce energy intensity in the industrial sector. ITP develops, manages, and implements a balanced portfolio that addresses industry requirements throughout the technology development cycle. The primary long-term strategy is to invest in high-risk, high-return R&D. Investments are focused on technologies and practices that provide clear public benefit but for which market barriers prevent adequate private sector investment.

ITP focuses its resources on a small number of energy-intensive materials and process industries that account for over 55 percent of industrial energy consumption.

- Aluminum
- Chemicals
- Forest Products
- Glass
- Metal Casting
- Mining
- Steel

ITP uses a leveraging strategy that maximizes the energy and environmental benefits of its process-specific technology investments by coordinating and cooperating with energy-intensive industries. By working closely with the private sector, ITP is able to effectively plan and implement comprehensive R&D agendas and help disseminate and share best energy management practices throughout the United States. The ITP public-private partnerships also facilitate voluntary efforts, such as the President's Climate VISION initiative, to encourage industry and government to reduce greenhouse gas emissions.

ITP also conducts R&D projects on enabling technologies that are common to many industrial processes such as industrial energy systems, combustion, materials, and sensors and process control systems. In addition, ITP funds technical assistance activities to stimulate near-term adoption of best energy-saving technologies and practices within industry. These activities include plant assessments, tool development and training, information dissemination, and showcase demonstrations.

New technologies that use energy efficiently also lower emissions and improve productivity. By leveraging technical and financial resources of industry and government, the ITP partnerships have generated significant energy and environmental improvements that benefit the nation and America's businesses. Energy-intensive industries face enormous competitive pressures that make it difficult to make the necessary R&D investments in technology to ensure future efficiency gains. Without a sustained commitment by the private and public sectors to invest in new technology R&D and deployment, the ability to close the gap between U.S. energy supply and demand will be severely compromised.

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EXECUTIVE SUMMARY

Combustion systems have been a crucial tool for industrial development throughout the world. The manufacturing sector continues to rely on these systems for heat and steam generation. Combustion systems include turbines, process heaters, boilers, and combined heat and power (CHP) technologies. The systems enable indispensable industrial processes, such as heating metals and chemical feedstocks, as well as the changing of the mechanical and chemical properties of materials. Major end users include energy-intensive industrial sectors, such as petroleum, metals, and forest products.

Fueled by environmental concerns such as global warming and ozone transport, emission requirements have had a major influence on the design and implementation of combustion systems. In addition, combustion energy represents almost 75 percent of the total U.S. manufacturing sector energy use. With such high energy consumption levels and emission constraints, there is a constant need for system optimization. This increases R&D needs for fundamental combustion science, as well as better heat-transfer understanding and improved system designs.

Transformational R&D, such as that funded by the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Industrial Technologies Program (ITP), is critical to maintaining the global competitive position of the U.S. manufacturing industry. DOE's goal for the Combustion portfolio is to support the ITP goal of reducing specific energy consumption in the nine energy-intensive industries by 30 percent by 2020 compared to 2002 baseline.

Successful Strategy with Industry

DOE's Office of Energy Efficiency and Renewable Energy leads the federal role in developing advanced energy-efficient and environmentally friendly industrial technologies. Industrial combustion systems R&D is a component of the overall EERE strategy, contributing to a reduction in energy intensity of industry, a goal outlined in the National Energy Policy. Improvements in industrial combustion systems can reduce energy consumption through more efficient heat transfer to the load; reduce NO_x, SO_2, CO, and particulate emissions; and improve product quality.

EERE/ITP is working to build the Industries of the Future through a strategy that is based on multi-year planning, industry involvement and input during the planning process, and careful analysis and data-based decision making. This strategy not only takes into consideration the interests of industry as described in their technology roadmaps, but also consists of an agenda of analytical studies that provide the basis for decision making. For instance, the *Combustion Technology Roadmap,* published in 1999, and revised in October 2002, has provided the basis for focusing the R&D by identifying research interests. The *Energy Use and Analysis Report*, and *The U.S. Manufacturing and Mining Energy Footprints* studies were developed using both government and industry data and information, and industry expertise to provide the next level of prioritization of the portfolio. By using these studies, the portfolio is able to design a multi-year R&D plan based on the focus area, barrier, and pathway approach. In this approach, a limited number of critical technology focus areas are identified along with the technical barriers preventing their successful implementation. A multi-year plan (called a "Pathway") is then developed that will guide the R&D activities leading to successful development of a focus area technology. The "Pathways" are then the basis for solicitations of pre-competitive R&D that address both energy efficiency goals outlined in the National Energy Policy and industrial combustion research priorities. This successful strategy has now evolved to a point where it provides focus on potentially high-impact research to make revolutionary improvements in industrial combustion systems.

There are a large number of opportunities for companies to develop and apply new combustion technologies. However, these opportunities generally involve a high capital risk, in the event that the technology might not achieve sufficient market acceptability. Additionally, the lack of technology transfer capabilities can slow down the responses aimed at addressing the U.S. industry's needs. To facilitate this knowledge transfer base, the Combustion portfolio provides cost-shared funding for crosscutting R&D projects that are of interest to a range of U.S. industries. ITP provides cost-shared funding for combustion-related projects identified as priorities by specific industries. The Combustion portfolio successfully accelerates technology transfer activities and helps the nation save energy and reduce our dependence on fossil fuels.

On August 25, 2004, ITP met with industrial combustion system users at the Ultra-High Efficiency Industrial Steam Generation Workshop. This one-day workshop aimed to identify opportunities for significantly improving industrial steam generation technology, and build upon the results being generated by the ongoing Superboiler project conducted by the Gas Technology Institute. The recommendations from the workshop and guidance from the industrial boiler community are being used to develop a solicitation for new projects that will be released in early 2005.

In September 2004, ITP held a portfolio review for the Industrial Energy Systems Program, including Combustion and Supporting Industry projects. The review process ensures that the projects are on track to achieve their technical, economic, and commercialization market goals; this is accomplished through a detailed performance evaluation and feedback by reviewers. In addition, principal investigators are also given the opportunity to present their research findings to other researchers, colleagues, and reviewers.

Achieving Energy Savings: Portfolio Strategy

The Combustion initiative aims to tackle the barriers that impede improvement of industrial combustion systems, while addressing the R&D needs of burner, boiler, and furnace systems. To satisfy long-term goals without ignoring valuable short-term opportunities that can improve energy efficiency, the strategy supports development of state-of-the-art transformational technologies, as well as the improvement of current technologies.

The FY 2004 Combustion portfolio includes four combustion projects. Additional combustion-related projects are funded by other ITP portfolios and initiatives. More information about the Combustion portfolio is available on the ITP Web site at: http://www.eere.energy.gov/industry/combustion/portfolio.html

FY 2004 Highlights

Ultra Low NO_x Burners with Flue Gas Recirculation and Partial Reformer – The goal of this project is to develop low excess air, ultra-low NO_x, natural gas-fired industrial burners that can emit less than 5 vppm NO_x. Project partners include Lawrence Berkeley National Laboratory, Coen Co., CMC Engineering, John Zink Co., Gasunie Research, Maxon Corporation, and MIT Plasma Science and Fusion Center. The low NO_x burners are currently being commercialized by Maxon Burner Corporation, for a variety of applications. The burners are characterized by a 1:6 MMBtu/hr capacity, guaranteed NO_x emissions below 7 ppm within a 10:1 turndown, exceptionally low CO emissions below 9 ppm, and maintenance and operating costs same as conventional high NO_x burners. A successful prototype that met almost all performance targets has been developed to scale up the burners to 25 MMBtu/hr. Other R&D efforts include modifying the low-NO_x burner to reduce fan power, and to adapt the burners for water heating and steam generation applications.

Process Heat Combustion System – The goal of this project is to develop designs and components for a low-cost, integrated process heater technology, with optimum system performance in terms of efficiency, emissions, flexibility, reliability, and safety. This project integrates three advanced technologies: 1) ultra-low emission burners; 2) a specially designed, fired heater with advanced heat recovery; and 3) an on-line, process-tube, temperature-sensing and burner control system to enhance heat transfer, reduce maintenance costs, and increase run lengths. The system has an energy savings potential of 84 trillion Btu/year, as well as the potential to reduce NO_x emissions by 10,000 tons and decrease capital costs by $1.5 billion by 2020. Partners for this project include TIAX LLC, ExxonMobil, and Callidus Technologies. The design of the low-emission Advanced Process Heater (APH) has been completed. A preliminary draft of the design book documenting the APH development and detailed design has been prepared. The total erected costs for the APH, as well as a conventional heater, have been estimated. This analysis shows that the expected return on investment for the high efficiency APH is attractive relative to conventional, lower efficiency process heaters. Field demonstrations of the key APH technologies, including heat transfer enhancements and tube metal temperature sensors, have been planned for FY 2005.

Superboiler – This project aims to develop ultra-low emission, ultra-high efficiency steam generation technologies that will be integrated in a package boiler. The Gas Technology Institute has teamed up with Cleaver-Brooks, a major U.S. boiler manufacturer, to design, build, and test laboratory and commercial prototype versions of a first-generation, gas-fired Super Boiler. The performance goals include 94 percent fuel

efficiency, 5 vppm NO_x and CO, and 50 percent size and weight reduction compared to a conventional firetube boiler. Potential natural gas savings are estimated at 0.5 quads per year, or more than $2 billion at current fuel prices. After successful lab testing of a single-stage lab boiler, a two-stage furnace design with an interstage convective pass, was put into operation. This boiler is even more compact than the single-stage boiler and has been tested with NO_x emissions down to 3 ppmv at low excess air and with no external flue gas recirculation. Performance of the novel heat recovery system has been confirmed with fuel-to-steam efficiency of 89% at full load; design improvements are being implemented to achieve target efficiency of 94%. GTI and Cleaver-Brooks are developing a comprehensive commercialization plan starting with demonstration of a 250-BHP (10 MMBtu/h) prototype in southern California. Plans are to begin engineering design of the boiler followed by testing in May 2005. Follow-on demonstrations are also planned for various other locations across the United States.

High-Temperature Combustion System – The innovative furnace technology of the high-temperature combustion system promises significant energy savings, emissions reduction, and increased productivity for the chemicals, aluminum, iron and steel, and metal casting industries. Over the next three years, University of Michigan and State of Michigan Department of Consumer and Industry Services will develop this technology and demonstrate its energy and emission-saving capabilities. The proposed combustion system works by capturing waste flue gases to preheat oxygen-enriched air and fuel, and at the same time, reducing NO_x production. The research team has completed cold-flow turbulent jet mixing experiments and Computational Fluid Dynamics (CFD) calculations, and 3-D hot-flow CFD calculations with chemical reactions. These experiments and calculations have been the basis of the design of a small-scale furnace for laboratory experiments. The furnace design has also been completed and it is being constructed and instrumented for a first demonstration to the Industrial Advisory Group. Continuous gas analysis equipment has also been assembled for making chemical measurements at various locations in the furnace and in the furnace exhaust. If the technology is successfully commercialized, potential energy savings of this project are estimated at 50 percent.

Other R&D Highlights

Steel Portfolio

Dilute Oxygen Combustion (DOC) – The DOC system has enabled Auburn Steel Company to increase the maximum production rate of its Auburn, New York, steel mill by 33 percent without significant capital investment. The DOC system is marketed by Praxair, Inc. and several customers have expressed interest in the technology. Another system has also been implemented at the former Bethlehem Steel Corporation. Bethlehem Steel benefited from significant cost and fuel savings, and NOx emission reductions; the company is considering the conversion of two additional furnaces.

Pulverized Coal Injection Combustion Behavior – Researchers are investigating combustion behavior of three pulverized coal injection (PCI) coals and their influence on unburned char retained in blast furnace off-gas emissions in three American steel companies. Research efforts have been conducted in a drop tube furnace at a range of temperatures and excess oxygen. The low-temperature reactivity of char and coke has been investigated by monitoring weight loss in a thermogravimetric furnace in the presence of O_2 and CO_2 respectively. Physical and chemical properties of char, reacted cokes and dust have been analyzed.

Glass Portfolio

Submerged Combustion Melter – In the first full year of this project, the Gas Technology Institute has worked with project partners to design the pilot plant unit, purchase necessary equipment, determine modeling parameters, conduct laboratory-scale testing, and finalize the consortium agreement. Currently, the design of a pilot-scale submerged combustion melter is underway. The pilot-scale unit will be constructed and tested in FY 2005.

Forest Products Portfolio

Improved Recovery Boiler Performance through Control of Combustion, Sulfur, and Alkali Chemistry – A model for aerosol formations and a theoretical model of a char bed have been completed. Preliminary parameters for a chemical structure-based devolatilization model, appropriate for black liquor, are now published. Rates and mechanisms of fume deposit formation have been fully explored, and intermediate-sized particle formation has been studied.

Improving Dryer and Press Efficiencies through Combustion of Hydrocarbon Efficiencies – Experiments have been successful in reducing formaldehyde from an airstream to levels below 1ppm. These experiments have shown that formaldehyde and methanol levels can be reduced by 95% and 75% respectively through absorption by ash in a fluidized bed. Researchers for this project will continue to study the relationship between emissions and dryer parameters, such as moisture level, temperature, dryer geometry, and other variables.

Sensors and Automation Portfolio

Tunable Diode Laser for Harsh Combustion Environments – Project partners have established the technical feasibility of developing a portable gas analyzer for petrochemical facilities based on a novel broadly tunable mid-infrared laser source. A waveguide device that detects target gas by generating broadly tuned mid-infrared radiation has been created. Future plans consist of developing a portable gas analyzer, measuring its properties, and testing its performance in a working petrochemical facility.

Aluminum Portfolio

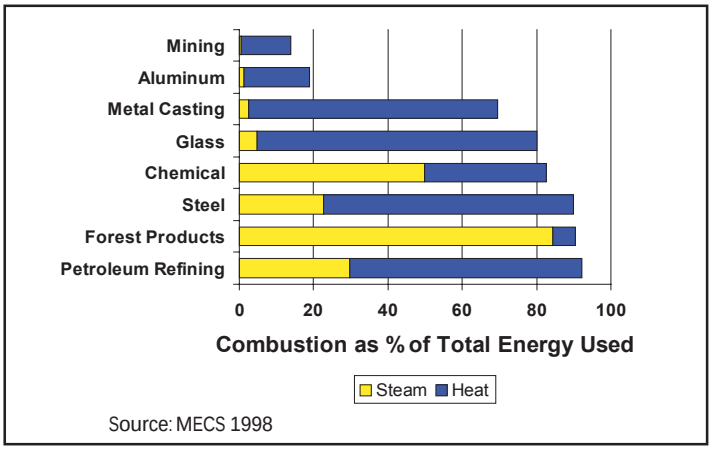
Low-Dross Combustion System – This project aims to improve burner efficiency and reduced dross formation on melted aluminum. The novel burners being developed allow control of the flame shape and oxygen distribution within the flame. Efforts have been successful in developing the flames in a laboratory environment. Future plans include testing the burners at Wabash Alloys', Wabash, Indiana plant.

INDUSTRY OVERVIEW

Industrial combustion systems are essential to the U.S. manufacturing sector and, consequently, to the U.S. economy. The total value of shipments for the top eight U.S. combustion-based industries is estimated at $890 billion. Every state with industry relies on combustion for everyday performance, and virtually every industry requires some form of combustion for operation. Exhibit 1 shows the amount of energy use for combustion as a percentage of total energy consumption for each industry.

Combustion-based industries also represent an enormous source of employment. The top seven U.S. combustion-based industries employ more than 3 million people.

Exhibit 1
Importance of Combustion to U.S. Industry

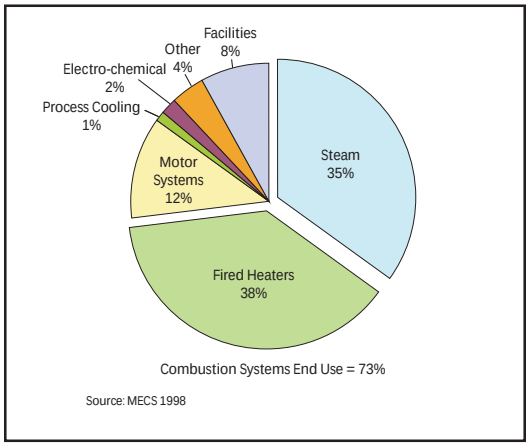


Source: MECS 1998

Energy Use

Combustion systems are used to generate steam and heat for manufacturing processes. Combustion systems account for almost 75 percent of total energy end use in the U.S. manufacturing sector. Specifically, fired heaters represent 38 percent of total energy end use, and steam systems account for 35 percent, as shown in Exhibit 2.

Exhibit 2
U.S. Manufacturing Energy End Uses

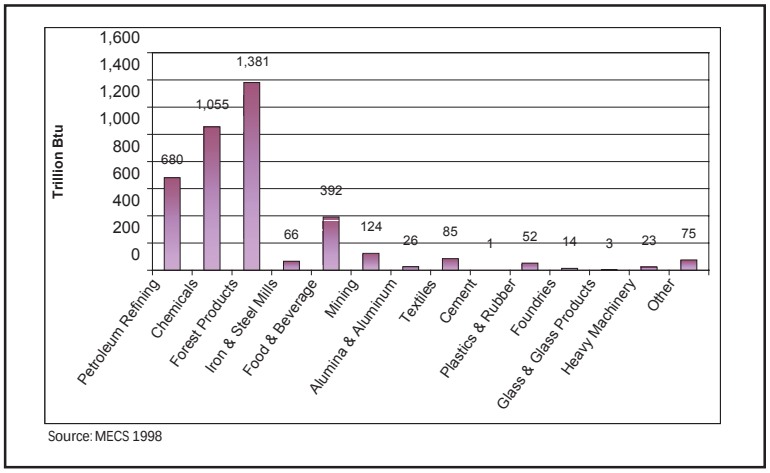


Source: MECS 1998

Steam systems consume 6,201 trillion Btu annually. The most steam-intensive industries are forest products (1,381 TBtu), chemicals (1,055 TBtu), and petroleum refining (680 TBtu). Exhibit 3 shows the amount of steam energy used by each industry.

Of the overall energy inputs for steam systems, 45 percent is lost in boilers, distribution, and energy conversion. Boilers account for the largest losses in steam systems, totaling 1,233 trillion Btu. Boiler efficiency ranges from 55 percent to almost 90 percent, and the average boiler efficiency is estimated at less than 80 percent. Almost one quad is lost in steam distribution, which represents 15 percent of the overall steam system losses. Energy conversion losses, such as losses from heat exchangers, preheat systems, and other equipment, total 597 trillion Btu. The remaining 3,380 trillion Btu are used in the various manufacturing processes.

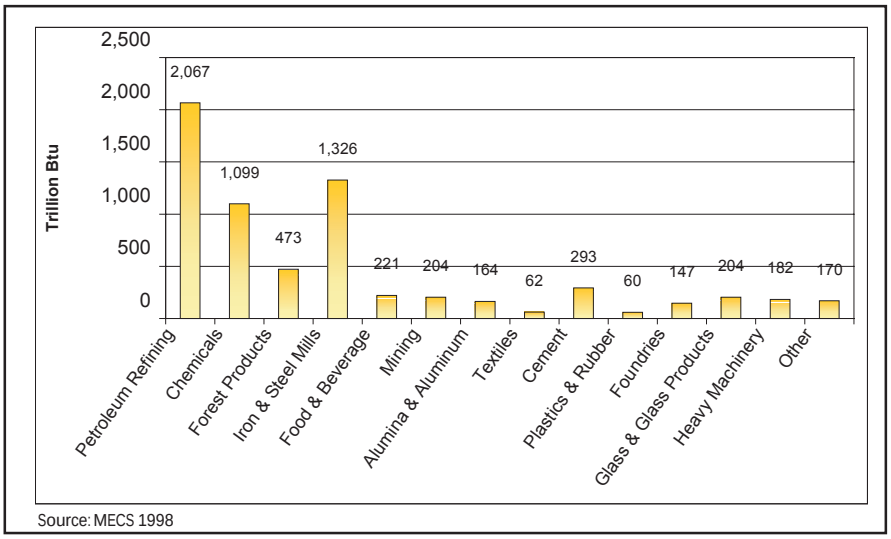
Exhibit 3
Steam Energy Use by Industry



Source: MECS 1998

Fired heaters consume 6,672 trillion Btu/year. The petroleum refining industry is the largest energy consumer, with 2,067 trillion Btu. Iron and steel mills, and the chemicals industry are also very large consumers, with 1,326 and 1,099 trillion Btu, respectively. Exhibit 4 shows a distribution of the total energy used for fired heaters by each individual industry.

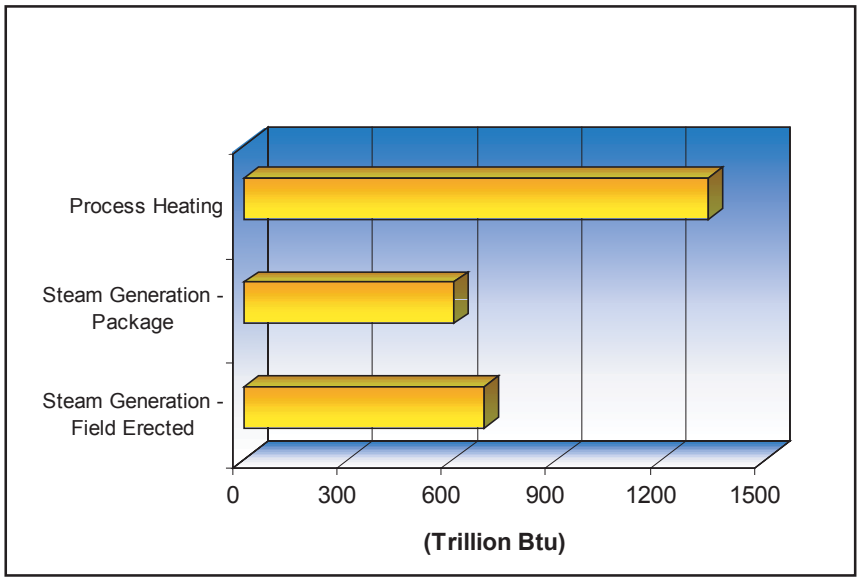
Exhibit 4
Fired Heaters Energy Use by Industry



Opportunities for Energy Savings

The Combustion portfolio identifies and addresses the opportunities for energy savings for industrial combustion systems. Because of the crosscutting nature of these systems, the opportunities for energy loss reductions are very large (in excess of 2.6 quadrillion Btu). The program's focus areas are: 1) steam generation, 2) process heating, and 3) components and design tools for both steam generation and process heating systems. Exhibit 5 shows the potential energy savings for combustion systems.

Exhibit 5
Potential Energy Savings for Combustion Systems



THE CHALLENGE

The challenges of improving combustion processes are highly complex. In recent years, combustion systems research has focused on emissions reduction and energy efficiency. The challenge has been to develop clean systems without compromising their efficiency. The combustion equipment industry is a highly fragmented, low-margin sector that has inadequate resources to tackle these R&D challenges alone. Through collaborative R&D partnerships, DOE and industry are creating the foundation for enhanced combustion performance, focusing on applications outlined as priorities by the ITP's portfolios, and identified in the combustion vision and technology roadmap.

Developments at the component level remain important. From a total systems perspective, the optimization of combustion processes depends on breakthroughs in efficiency, productivity, safety, and environmental performance. To accomplish these breakthroughs, it is imperative to attain higher levels of sophistication in computational science and systems engineering. Combustion is one of the most complex physicochemical processes known, and effective computational modeling and simulation of combustion comprise a great part of the challenge.

The overall goal of the Combustion portfolio is to support the ITP goal of reducing specific energy consumption in the seven IOFs by 30 percent by 2020 (compared to 2002 baseline).

The historical approach to combustion systems design and tuning has been trial and error. Advanced modeling and improved systems engineering capabilities can bring more predictability to combustion design, resulting in development of systems that can deliver heat to the load with unprecedented precision, reliability, and efficiency.

Improved Emissions Control

The goal of achieving low-cost solutions to criteria-pollutant emission control without sacrificing energy efficiency remains a priority for the Combustion portfolio. In the Combustion vision and roadmap, equipment end users anticipate requirements for nitrogen oxides (NO_x) emissions of under 10 ppm in the near-term, and 2 ppm over the coming decades. Presently, the scientific advances that allow for the achievement of single-digit emissions have been achieved. However, further advances in technology are required to attain acceptable cost, performance, and reliability levels.

Strategy for Improving Combustion Systems Energy Efficiency

The Combustion portfolio within the U.S. Department of Energy's Industrial Technology Program (ITP) provides crosscutting support for technology development relevant to its nine industrial portfolios. The Combustion portfolio is steered by two documents: 1) the *Combustion Industry Vision* (developed from an ITP-sponsored workshop in 1998) which describes the long-range view of industry stakeholders, and 2) the *Industrial Combustion Technology Roadmap* (developed in 1999 and updated in 2001) which establishes specific targets that will need to be met to achieve the Vision goals. Exhibit 6 (page 4) summarizes the Combustion portfolio goals.

At present, Combustion portfolio funding is fully engaged in supporting four projects. However, these projects address only a portion of the opportunities for energy savings that exist within the Industries of the Future. As part of the strategy, it is important that the projects remain on schedule and deliver the promised energy savings. Combustion portfolio managers work closely with the other ITP portfolios sponsoring combustion-related projects to maximize the impact of those projects. Simultaneously, opportunities are identified where ITP portfolios might collaborate in the development of new combustion technologies that are relevant to other portfolio goals.

Exhibit 6
Combustion Portfolio Goals Summary

Boilers	• Maximize system efficiency by achieving 150° F stack exit temperature • Improve system reliability by 50 percent • Maximize integration of steam and power production • Reduce first cost and life-cycle costs • Improve safety
Boiler Burners	• Achieve NO_x emissions below 2 vppm • Reduce CO emissions below 5 vppm • Reduce particulate emissions below 0.003 lb/MMBtu • Maximize multifuel capability
Furnaces	• Reduce the total cost of combustion in manufacturing • Reduce product loss ratio by 50 percent • Enhance system integration • Maximize system robustness • Zero accidents
Furnace Burners	• Achieve 90 percent reduction of criteria pollutants vs. 1990 baseline • Reduce CO_2 emissions per international agreements • Reduce specific fuel consumption by 20-50 percent • Maximize multifuel capability

FY 2004 HIGHLIGHTS AND ACCOMPLISHMENTS

The Combustion portfolio supports cost-shared research that addresses high-risk, high-impact needs with a broad application throughout ITP. In FY 2004, the Combustion portfolio included four active projects (see Exhibit 6). In addition, there are a number of combustion-related projects in other components of the ITP (Exhibit 7).

Exhibit 7
Active Combustion Projects in FY 2004

Ultra Low NO_x Burners with Flue Gas Recirculation and Partial Reformer – The goal of this project is to develop low excess air, ultra-low NO_x, natural gas-fired industrial burners that can emit less than 5 vppm NO_x. Project partners include Lawrence Berkeley National Laboratory, Coen Co., CMC Engineering, John Zink Co., Gasunie Research, Maxon Corporation, and MIT Plasma Science and Fusion Center. The low NO_x burners are currently being commercialized by Maxon Burner Corporation, for a variety of applications. The burners are characterized by capacities from 1:6 MMBtu/hr, guaranteed NO_x emissions below 7 ppm within a 10:1 turndown, exceptionally low CO emissions below 9 ppm, and maintenance and operating costs same as conventional burners. A successful prototype has been developed to scale up the burners to 25 MMBtu/hr. Other R&D efforts include modifying the low-NO_x burner to reduce fan power, and to adapt the burners to water heaters and steam for steam generation purposes.

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Exhibit 8
Other Projects Relevant to the Combustion Portfolio

Forest Products
- Laboratory Development of a High Capacity Gas-Fired Paper Dryer
- Improving Dryer and Press Efficiencies Through Combustion of Hydrocarbon Emissions
- Control of Emissions from Wood Waste Burners and Wood Dryers
- Development of Methane De-NO_x Reburning Process for Waste-Wood, Sludge, and Biomass-Fired Stoker Boilers

Glass
- Development and Validation of a Coupled Combustion Space/Glass Bath Furnace Simulation
- Monitoring and Control of Alkali Volatilization and Batch Carryover

Sensors and Controls
- Diagnostics and Control of Natural Gas-Fired Furnaces via Flame Image Analysis (Glass)
- Fiber-Optic Sensor for Industrial Process Measurement and Control (Glass)
- Thermal Imaging Control of High-Temperature Furnaces (Steel)
- Boiler and Furnace Efficiency Improvement with Low-Cost CO Sensor and Burner Control System
- Tunable Diode Laser Sensor for Combustion Control (Steel)

Steel
- Low-NO_x Boiler Demonstration
- NO_x Emission Reduction by Oscillating Combustion (Combustion)
- Hot-Strip Mill Transfer Bar Rapidfire™ Edge Heat Project (NICE^3)
- Pulverized Coal Injection Combustion Behavior

TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

Combustion Resources

Industrial Combustion Vision
The *Combustion Industry Vision* was developed from an ITP-sponsored workshop in 1998. The workshop combined the expertise of manufacturers and users of burners, boilers, furnaces, and other process heating equipment. The Vision provides a background on today's combustion systems, and specifies strategic targets, competitive challenges, and the industry's next steps. The Vision is available for download at: http://www.eere.energy.gov/industry/combustion/pdfs/combustion_vision.pdf

Industrial Combustion Technology Roadmap
In 1999, combustion system users and manufacturers joined forces to develop the *Industrial Combustion Technology Roadmap*. The document identified R&D priorities for the development of advanced, highly efficient combustion systems that U.S. industry will require in the future. In 2001, ITP convened industry workshops to update the roadmap. The *Industrial Combustion Technology Roadmap* (2002) lists the R&D initiatives needed for the next 20 years. The roadmap is available for download at: http://www.eere.energy.gov/industry/combustion/pdfs/combustion_roadmap2002.pdf

Guide to Low-Emission Boiler and Combustion Equipment Selection
In 2001, DOE's Industrial Technologies Program (ITP) sponsored efforts at the Oak Ridge National Laboratory (ORNL) to develop the *Guide to Low-Emission and Combustion Equipment Selection,* a guide for choosing low-emission boilers and combustion equipment. The guide addresses fundamental concerns that arise when planning a new steam or hot water boiler system to be operated in compliance with regulatory emission standards. The document became available in April 2002. The guide was developed in cooperation with the American Boiler Manufacturers Association (ABMA) and the Council of Industrial Boiler Owners (CIBO). This guide is available for download at: http://www.oit.doe.gov/bestpractices/steam/pdfs/guide_low_emission.pdf

Improving Industrial Burner Design with Computational Fluid Dynamics Tools: Progress, Needs, and R&D Priorities
In September 2001, burner designers, end users, combustion researchers, and computer code developers participated in a workshop to explore the role of computational fluid dynamics (CFD) tools in the design of industrial burners. CFD tools have the potential to significantly improve burner design. The results from the workshop, summarized in this report, show the contributions of CFD to burner design today, and identify R&D priorities. The document also describes the current progress of CFD, the benefits of CFD modeling, and future issues. This document is available at: http://www.eere.energy.gov/industry/combustion/pdfs/cfd_wkshp_report.pdf

Combustion R&D Brochure
This brochure highlights the benefits of government and industry partnership collaborations in combustion R&D. The brochure is available at: http://www.eere.energy.gov/industry/combustion/pdfs/combustion_brch.pdf

Process Heating Resources

Process Heating Tip Sheets
The tip sheets provide useful information on basic methods to improve burner efficiency. The tip sheets are available at: http://www.oit.doe.gov/bestpractices/process_heat/pdfs/et_check_burner.pdf

Process Heating Supplement to Energy Matters
This document provides information on system optimization, as well as current issues of the process-heating sector, and project specifics. The document is available at: http://www.oit.doe.gov/bestpractices/energymatters/pdfs/procheat.pdf.

Roadmap for Process Heating
The roadmap, sponsored by the Industrial Heating Equipment Association (IHEA) and DOE, became available on March 16, 2001. The document specifies the priority R&D goals and non-research goals for process heating improvement. The roadmap is available at: http://www.oit.doe.gov/bestpractices/pdfs/process_heating_0401.pdf.

Steam System Resources

Steam Tip Sheets
A series of tip sheets provide information on useful methods to improve boiler efficiency and steam system best practices. The tip sheets are available at: http://www.oit.doe.gov/bestpractices/technical_publications.shtml#steam.

Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries
Resource Dynamics Corporation developed this report with the assistance of industry, national laboratory, and best practices specialists to analyze the opportunities available for these three large steam consumer industries. The report is available at: http://www.nrel.gov/docs/fy03osti/32822CD.zip.

Improving Steam System Performance – A Sourcebook for Industry
This report provides general background on steam systems and identifies performance improvement opportunities for end users. DOE, Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation participated in a mutual effort for the development of this document. The report is available at: http://www.oit.doe.gov/bestpractices/steam/pdfs/steamsourcebook.pdf.

Steam Digest
Available directly from DOE's Best Practices Web site, Steam Digest contains a collection of articles published on steam system management and resources. Two consecutive years of Steam Digest archives are available for download at: http://www.oit.doe.gov/bestpractices/steam/tools.shtml.

Guide to Low-Emission Boiler and Combustion Equipment Selection
Oak Ridge National Laboratory developed this document to provide users with a guide for selecting low-emission boilers and combustion equipment. The guide covers topics for industrial, commercial, and institutional boilers, and presents technical and regulatory issues. The guide is available for download at: http://www.oit.doe.gov/bestpractices/steam/pdfs/guide_low_emission.pdf.

Steam System Survey Guide
Developed by Oak Ridge National Laboratory, the survey guide was prepared for steam system operational personnel and energy managers to help them identify opportunities available for energy and productivity savings. The guide is available for download at: http://www.oit.doe.gov/bestpractices/steam/pdfs/steam_survey_guide.pdf.

Review of Orifice Plate Steam Traps
Oak Ridge National Laboratory prepared this document to help end users decide when orifice plate steam traps should be used in new or existing steam systems. The report provides background information, advantages and disadvantages of using orifice plate steam traps, and final recommendations. The document is available for download at: http://www.oit.doe.gov/bestpractices/steam/pdfs/orificetraps.pdf

Technical Briefs
A series of technical reports discuss steam cost calculations, heat transfer solutions, steam system process control schemes, and the use of heat pumps for steam system fuel savings. The reports are available for download at: http://www.oit.doe.gov/bestpractices/steam/tools.shtml

Combined Heat and Power Resources
There are a series of documents and resources related to combined heat and power. Some of these resources are described below. For a complete list of resources, please visit: http://www.eere.energy.gov/de/information/info_docs_chp_tech.shtml

National CHP Roadmap
The roadmap, sponsored by the United States Combined Heat and Power Association, the U.S. Environmental Protection Agency, and DOE, became available in March, 2001. The document specifies the priority R&D goals and non-research goals for CHP. The roadmap is available at: http://uschpa.admgt.com/CHProadmap.pdf

Combined Heat and Power Market Potential for New York State
This report, created by the New York State Energy Research and Development Authority, analyzed the CHP market potential for the state of New York, and concluded very positive results. The report became available in October, 2002. The document can be found at: http://www.eea-inc.com/dgchp_reports/newyorkCHP.pdf

Integrated Energy Systems (IES) for Buildings: A Market Assessment
This report, created by Resource Dynamics Corporation, became available in August 2002. The document describes the integration of CHP and thermally integrated technologies (TAT) into Integrated Energy Systems. The document is available at: http://www.eere.energy.gov/de/pdfs/ies_report.pdf

Energy Analysis – Targeting Energy Efficiency

GPRA Analysis was completed for projects considered in the FY 2006 budget. The analysis estimates future benefits of emerging technologies in the Combustion portfolio based on market penetration, efficiency gains, and emission-reduction capabilities.

U.S. Manufacturing and Mining Energy Use and Loss Analysis details the energy use patterns of the most energy-intensive industries. This document gives valuable information on how energy is used by each industry, providing the basis to identify specific energy-saving opportunities.

Process Heating Assessment and Survey Tool (PHAST) introduces the user to process heating methods and tools capable of improving thermal efficiency of heating equipment. The tool and its fact sheet are available for download at: http://www.oit.doe.gov/bestpractices/process_heat. Training on the tool is available through DOE and a number of its Allied Partners (see http://www.oit.doe.gov/bestpractices/training for information on upcoming training sessions).

In order to help users get the most from the tool, DOE and the Industrial Heating Equipment Association (IHEA) offer the Qualified Process Heating Specialist program. Participants who successfully complete a qualification workshop exam receive the "Qualified Specialist" designation. To learn more about the PHAST qualification, please visit: http://www.oit.doe.gov/bestpractices/software/phast_cert.shtml.

Business Value of Steam Efficiency Tool allows the user to justify the economic value of system improvements and calculate benefits. The tool is available for download at: http://www.oit.doe.gov/bestpractices/steam/pdfs/justify.pdf.

Alternative Financing for Steam Efficiency is a presentation that describes the different available financing arrangements offered by energy service companies. The presentation is available at: http://www.oit.doe.gov/bestpractices/steam/docs/alt_financing.ppt.

Steam System Technical Tools are provided by members of the Steam Challenge Steering Committee. A list of tools can be accessed from: http://www.oit.doe.gov/bestpractices/steam/tools.shtml.

Steam System Assessment Tool allows the user to estimate potential savings from steam system improvements. In this tool, input data is transformed into energy, cost, and emissions savings estimates. The tool is available for download at: http://www.oit.doe.gov/bestpractices/steam/ssat.html.

Steam System Scoping Tool allows end users to evaluate their system operation against identified best practices and develop awareness of available opportunities to increase steam system efficiency. The tool is available in both Visual Basic and MS Excel formats, and can be downloaded from: http://www.oit.doe.gov/bestpractices/steam/tools.shtml.

Combined Heat and Power Tool is designed to evaluate the feasibility of using Combined Heat and Power (CHP) systems in industrial process heating systems. The heating systems include fuel-fired furnaces, boilers, ovens, heaters, and heat exchangers used by industry. The tool analyzes the technical and economic feasibility of using gas turbine exhaust gases to supply heat to fluids (air, water, heating oils, etc.), boilers or an industrial furnace or oven. The tool allows the user to determine the required amount of heat and the appropriate size of the turbine needed to meet that requirement, and it allows the user to calculate payback periods and perform "what-if" analyses for various utility costs. The tool is currently being tested as a Beta version and will be made available to the general public following incorporation of modifications suggested by the testers.

HOW TO GET INVOLVED AND CONTACT INFORMATION

Partnership Information

Public-private partnerships are the foundation of ITP's technology delivery strategy. ITP includes its partners in every phase of the technology development process to focus scarce resources where they can have the greatest impact on industrial energy efficiency. To learn more, please visit our Web site at http://www.eere.energy.gov/industry.

- Collaborative, cost-shared research and development projects are a central part of ITP's strategy. Annual solicitations provide technology development opportunities in a variety of energy-intensive industries.

- Industries of the Future Partnerships increase energy efficiency in the most energy-intensive industries. In addition to cost-shared research and development projects, industry partners participate in the development of vision and roadmap documents that define long-term goals, technology challenges, and research priorities.

- Allied Partnerships provide an opportunity for ITP to reach a broad audience of potential customers by allying with corporations, trade associations, equipment manufacturers, utilities, and other stakeholders to distribute industrial energy efficiency products and services. By becoming an Allied Partner, an organization can increase its value to clients by helping them achieve plant efficiencies.

- State energy organizations work with ITP in applying technology to assist their local industries. ITP assists states in developing partnerships to mobilize local industries and other stakeholders to improve energy efficiency through best practices, energy assessments, and collaborative research and development.

- EERE's technical programs (of which ITP is one of eleven) give manufacturers access to a diverse portfolio of energy efficiency and renewable energy technologies and bring advanced manufacturing technology to the renewable energy community. For more information, access the EERE home page at http://www.eere.energy.gov.

- The President's Climate VISION (Voluntary Innovative Sector Initiatives: Opportunities Now) effort also offers opportunities for manufacturers to pursue cost-effective actions that will reduce greenhouse gas emissions. See http://www.climatevision.gov for details.

Access to Resources and Expertise

The Industrial Technologies Program provides manufacturers with a wide variety of industrial energy efficiency resources to help your company cut energy use right away. Visit our site at http://www.eere.energy.gov/industry or call the EERE Information Center at 877-337-3463 to access these resources and for more information.

- ITP offers energy management best practices to improve energy efficiency throughout plant operations. Improvements to industrial systems such as compressed air, motors, process heat, and steam can yield enormous savings with little or no capital investment.

- Our suite of powerful system optimization software tools can help plants identify and analyze energy-saving opportunities in a variety of systems.

- Training sessions are held several times per year at sites across the country for companies interested in implementing energy-saving projects in their facilities. DOE software tools are used as part of the training sessions.

- ITP's qualified industrial energy specialists will work with your plant personnel to identify savings opportunities and train staff in the use of ITP software tools.

- Our extensive library of publications gives companies the resources they need to achieve immediate energy savings.

- Plant-wide energy assessments are available to manufacturers of all sizes interested in cutting their energy use. Cost-shared solicitations are available each year for plant-wide energy assessments. In addition, no-cost, targeted assessments are provided to eligible facilities by teams of engineering faculty and students from 26 university-based Industrial Assessment Centers around the country.

- The DOE Regional Offices provide a nationwide network of capabilities for implementing ITP's technology delivery strategy. Regional Offices are located in the Southeast, Northeast, Midwest, Central, Mid-Atlantic, and Western regions. Visit http://www.eere.energy.gov/rso.html for more information.

WHERE TO GO FOR MORE INFORMATION

Visit our Web site: http://www.eere.energy.gov/industry/combustion/

Learn about all EERE programs: http://www.eere.energy.gov

EERE Information Center answers questions on EERE's products, services and 11 technology programs, refers callers to the most appropriate EERE resources, and refers qualified callers to the appropriate expert networks. You may contact the EERE Information Center by calling 1-877-EERE-INF (1-877-337-3463) or by completing the form at this site: http://www.eere.energy.gov/informationcenter. A customer service specialist or energy expert at the EERE Information Center will respond to your inquiry.

For print copies of DOE, EERE and ITP Publications, contact the
Energy Efficiency and Renewable Energy Information Center
P.O. Box 43165
Olympia, WA 98504-3165
http://www.eere.energy.gov/informationcenter/

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and great energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new "energy carrier"

The Opportunities

Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and business

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov

Combustion Industry of the Future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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