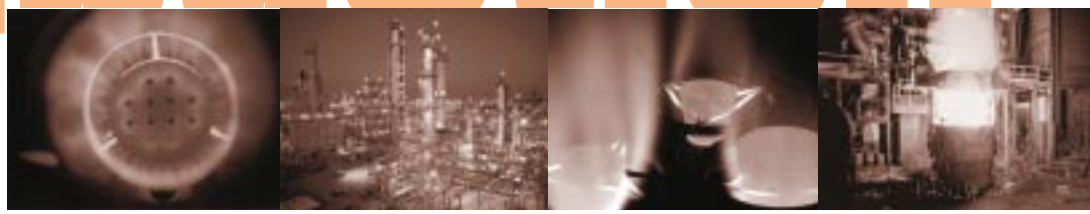
combustion

Combustion — Research and Development



Revolutionizing heat-delivery processes, for greater efficiency, productivity, and quality in U.S. manufacturing

Office of Industrial Technologies

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

Visionary goals, real-world benefits

The combustion industry's vision and technology roadmap set bold targets for tomorrow's systems. Future systems must be safe and affordable and must achieve substantial improvements in

- ***Energy efficiency:** Reducing specific fuel consumption by 20% to 50% is a long-term goal for furnaces.*
- ***Environmental quality:** A long-term goal for boilers is to reduce nitrogen oxides (NOx) emissions to 2 vppm (volumetric parts per million), a 98% reduction over typical uncontrolled levels. Other targets include reductions in carbon monoxide, particulates, and sulfur dioxide emissions.*
- ***Fuel flexibility:** Future combustion systems will maximize the use of multiple fuels, including waste and renewable fuels.*
- ***Cost-effectiveness and system reliability:** Lower life-cycle costs will be achieved through savings in operating costs and fuel use, as well as improved system reliability. (For example, one target is to double the time between scheduled boiler outages.)*

partnership

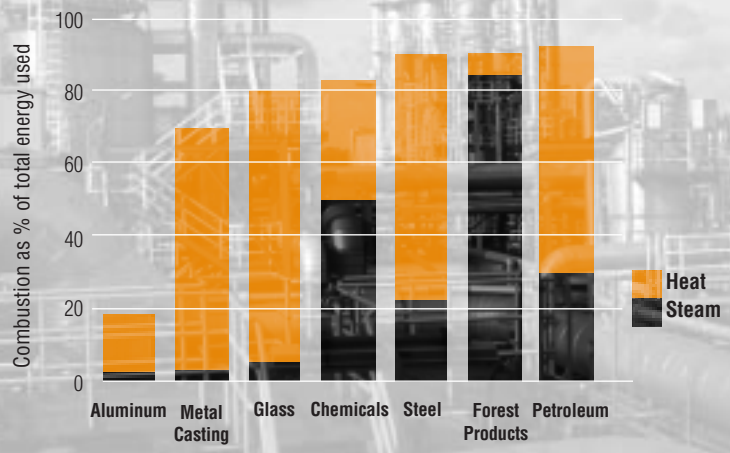
Targeting far-reaching benefits for U.S. manufacturers

Combustion poses fascinating contradictions. It is literally prehistoric, yet it remains as essential to modern life as it was to the earliest humans. It is as simple as striking a match, yet it is profoundly complex in its applications. And it is a long-established workhorse in industry after industry, yet realizing its future potential will stretch the limits of science and technology.

Combustion systems are used to generate steam and heat for vital manufacturing processes, to heat materials as diverse as metals and chemical feedstocks, and to change the mechanical and chemical properties of materials and products. New technologies can spell increasingly efficient, clean, fuel-flexible, and reliable combustion systems, capable of producing uniform, high-quality end products at high production rates, while also meeting anticipated environmental requirements.

Our nation's basic manufacturing sector stands to benefit significantly from these advances. That is why leaders in the manufacturing, combustion, and energy industries, in partnership with the U.S. Department of Energy's Office of Industrial Technologies (OIT), have joined forces to define priorities for research and development, and to co-sponsor innovative projects.

Importance of Combustion to American Industry



Virtually every manufacturing industry has a stake in improved combustion technologies. Consider the magnitude of potential energy savings. Boilers, furnaces, and other process heaters together account for about two-thirds of the total energy used by U.S. manufacturing industries. The proportion is even higher in several key sectors.

Defining industry priorities

Over the past century, great strides have been made in the fundamental science of combustion. Yet current combustion technologies will fall short of meeting the future demands of industrial users. In developing their vision and roadmap for the next 20 years, industry leaders identified environmental issues—such as emission reduction requirements—as well as productivity and competitive pressures that will drive innovation in combustion systems.

Partnerships between the federal government and industry will be essential to achieving such innovation. The challenges of improving combustion processes are extremely complex, and the combustion equipment industry—a highly segmented, low-margin sector—lacks the resources to effectively tackle them alone. Through selective co-investment in promising research and development projects, government and industry are laying the foundation for enhanced competitiveness in U.S. manufacturing, as well as improved environmental quality and energy security.

Vision

In developing *The Industrial Combustion Vision* in 1998, manufacturers and users of burners, boilers, furnaces, and other process heating equipment came together to acknowledge the challenges facing their industry and to set broad performance targets and goals for 2020.

Roadmap

Combustion system users and manufacturers joined forces to develop *The Industrial Combustion Technology Roadmap* in 1999, outlining R&D priorities for developing the advanced, highly efficient combustion systems that U.S. industry will require in the future.

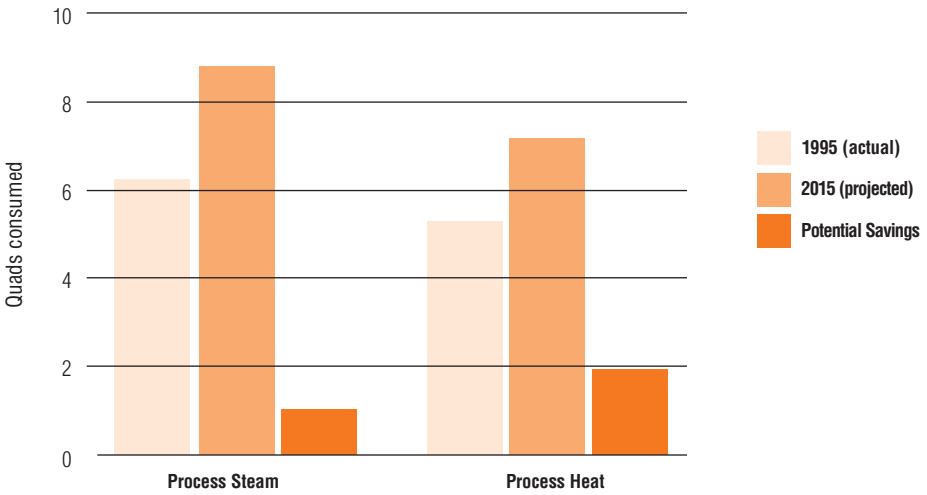
Implementation

OIT is funding cost-shared, competitively awarded combustion projects to further the R&D goals of the technology roadmap. Three projects are currently under way (see page 5). Additional combustion research projects are also being funded separately by OIT's Industries of the Future teams.

Renewal

In 2001, OIT will facilitate an industry workshop to update *The Industrial Combustion Technology Roadmap,* reflecting new developments and priorities.

Potential Energy Savings Using Currently Available Technologies



Combustion in manufacturing consumes some 15 quads of fuel, often using outdated, inefficient equipment. If all manufacturers adopted today's best technologies, almost 3 quads of energy would be saved by 2015—enough to heat nearly three-quarters of the homes in the U.S. today. With advances in technology—fostered by joint R&D now under way by industry partners and OIT— the potential savings are far greater.

Grand challenges that are reshaping the future

While developments at the component level will remain important, breakthroughs in efficiency, productivity, safety, and environmental performance will hinge on optimizing combustion processes from a total systems perspective. Such an approach will demand new levels of sophistication in computational science and systems engineering.

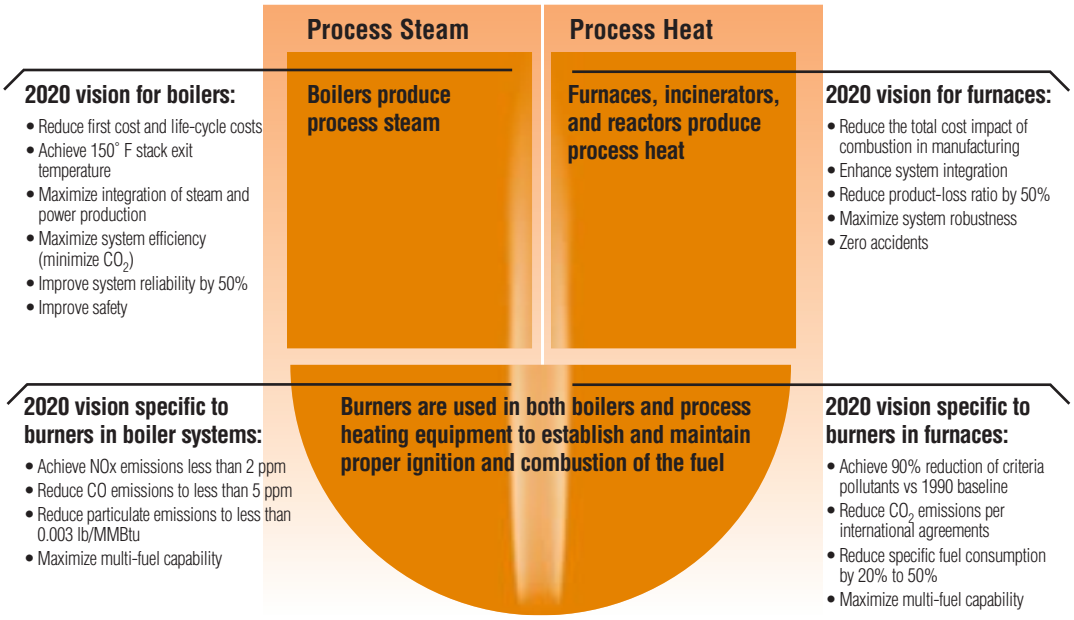
Advances in computational science are having a revolutionary impact on our world, permitting the examination of scientific and engineering problems of increasing complexity, from predicting weather patterns to mapping the human genome. Computational modeling and simulation of combustion—one of the most complicated physico-chemical processes known—hold great challenges. In fact, mathematical combustion modeling was among the original Grand Challenges designated by DOE under the High Performance Computing Act of 1991, one of nine issues whose solutions were identified as critical to meeting national needs.

Currently, new combustion systems must be designed and "tuned" using a cut-and-try approach, then custom-integrated with other process steps and equipment for a particular application. Advanced modeling and systems engineering capabilities will bring more predictability and repeatability—more science—to the art of combustion design, yielding systems that can deliver heat to the load with unprecedented precision, reliability, efficiency, and cleanliness.

Low-cost solutions

An overriding goal for future combustion systems is to achieve low-cost solutions to criteria-pollutant emission control, while simultaneously maintaining or improving process efficiency. In developing their vision and technology roadmap, industry participants anticipated requirements for NOx emissions of under 10 ppm in the near term, and 2 ppm over the coming decades. The scientific foundations for achieving single-digit emissions are in place, but advances in technology will be required to reach acceptable costs, operational performance, and reliability levels in practice. Ultra-low NOx burners—using combustion staging, premixed combustion, and advanced control capabilities to reduce peak flame temperatures—are one promising avenue for cost-effective emissions reduction.

Vision for Combustion in 2020



The Combustion Research and Development Portfolio

Forced Internal Recirculation (FIR) Burner

In field demonstrations, the natural-gas-fired FIR burner has successfully met design goals of reducing nitrogen oxides emissions to under 9 vppm, with less than 50 vppm carbon monoxide at design turndown and no loss in efficiency. To minimize peak flame temperatures, the burner employs premixed combustion and significant internal recirculation of partial combustion products in the first stage, as well as controlled second-stage combustion. Enhanced heat transfer from the first stage reduces combustion temperatures in the second stage.

Demonstrations are under way at a Detroit Stoker Company manufacturing facility, at Vandenberg Air Force Base, and at Miller Brewing Company. Sponsors for the FIR burner project include Southern California Gas Company; TetraTech, Incorporated; and Gas Technology Institute Sustaining Membership Program. Development partners include Gas Technology Institute, Detroit Stoker, the University of Illinois, and the Gas Institute of the Ukrainian National Academy of Sciences.

Fired Process Heater System

A high-efficiency, ultra-low-NOx combustion system will be the outcome of a six-year, multi-partner RD&D effort. The system integrates advanced flame ionization and air and tube temperature sensors with closed-loop control of flame shape. Designed for both natural and forced-draft operation, the burner internally recirculates furnace flue gases in order to lower flame temperature, reducing nitrogen oxides emissions to less than 9 vppm without compromising efficiency.

Callidus Technologies, a development partner, plans commercial introduction of the burner in 2001. A field demonstration retrofit is also planned for 2001 at a major Houston refinery. Sponsors for the process heat combustion system include DOE Office of Industrial Technologies, Gas Technology Institute, Arthur D. Little, Callidus, and ExxonMobil. In addition to Callidus, development partners include Arthur D. Little, ExxonMobil, and Gas Technology Institute.

Superboiler

Advanced research began in 1999 on the Superboiler concept: ultra-high-efficiency, ultra-low-emission steam combustion technologies, targeted for broad industrial applications over the next 15 to 25 years. The concept packages a suite of enabling technologies—such as a forced internal recirculation burner, high-intensity heat transfer packed media, an advanced transport membrane condenser, and a smart, integrated control system—on a standardized platform.

Envisioned as smaller and less costly to manufacture and maintain than today's boilers, the Superboiler will target goals of 94% overall efficiency and nitrogen oxides and carbon monoxide emissions below 5vppm. Potential energy savings to industry range upward of $10 billion a year in steam production costs, along with significantly reduced environmental impacts. In 1999, DOE awarded $2.37 million to the Gas Technology Institute to begin project research. Donlee Technologies is also participating in the project. Cofunders include Southern California Gas Company and Gas Technology Institute.

Making a difference today and tomorrow

The core strategy of the Office of Industrial Technologies is the **Industries of the Future,** which has engaged leaders in nine materials-intensive, energy-intensive U.S. manufacturing industries in collaborative research and development partnerships. Through the Industries of the Future, participating industries develop visions for the year 2020 and create technology roadmaps that support their visions. The Department of Energy and the private sector then partner selectively to address industry-defined R&D priorities.

Industries of the Future partnerships have invested in an impressive portfolio of R&D projects, many of which are beginning to demonstrate technical success. And while the focus of the R&D investments is generally long-term, some Industries of the Future projects already are achieving commercial success as well. Several projects related to combustion technologies are profiled below.

The R&D portfolios of the Industries of the Future teams are complemented by additional research in enabling technologies that serve multiple manufacturing sectors. The **Combustion** efforts highlighted in this document constitute one category of enabling technologies; others efforts focus on **Materials** and **Sensors and Controls.**

Industries of the Future teams are developing and demonstrating innovative combustion technologies

Combustion advances are fundamental to improving efficiency and productivity in a wide range of industrial processes. Here are a few combustion-related projects from the Industries of the Future portfolios.

Aluminum

Field demonstrations have shown that a new **oxygen-enhanced combustion melting system** provides productivity increases of 30%, energy savings of 40%, and reduced carbon dioxide and nitrogen oxides emissions.

Demonstrated combustion components are being combined for a **high-efficiency low-dross system** designed for new or existing aluminum remelt reverberatory furnaces.

A new, versatile, pilot-scale **vertical flotation melter and scrap dryer** has demonstrated thermal efficiencies of 58% and bigger yields of recycled aluminum as well as reduced emissions.

Forest Products

Proven in commercial power plants for burning municipal solid waste and coal, low-cost **methane de-NOx® reburn retrofits** will be adapted to burn high-volume biomass, wood wastes, and sludge, improving boiler energy efficiency and reducing wastes and air emissions.

Glass

Commercial demonstration is under way for a new **high-temperature burner** that increases luminosity and radiant heat transfer, resulting in improved thermal and energy efficiency and reduced NOx emissions.

Oxygen-enriched air staging technology, commercially available and in use at several container glass plants, offers 50% to 70% NOx reductions while maintaining consistent quality and productivity.

Oscillating combustion technology has demonstrated increases in productivity of 5% to 10% along with reductions in NOx emissions of up to 50% in an oxy-fuel-fired fiberglass melting furnace.

BestPractices

Today's manufacturers can realize immediate savings in energy, wastes, and costs by using the best technologies and practices currently available. Through **BestPractices,** OIT provides funding, tools, training, advice, and information to help manufacturers recognize and take advantage of these opportunities.

The program offers **plant-wide assessments** to help large manufacturers develop a comprehensive strategy for increasing efficiency, reducing emissions, and boosting productivity. Grants of up to $100,000 in matching funds are awarded through a competitive solicitation process, and case studies are then developed to help publicize the benefits. Smaller plants can take advantage of the **Industrial Assessment Centers** program, a nationwide network of 26 engineering colleges that provide no-charge assessments of efficiency and productivity improvement opportunities.

Financial Assistance

OIT offers targeted financial assistance to accelerate technology development and adoption. The **Inventions and Innovation** program awards grants of up to $200,000 to inventors of energy-efficient technologies. Grants are used to establish technical performance, conduct early development, and initiate commercialization activities. The second program, **NICE^3** (National Industrial Competitiveness through Energy, Environment, and Economics), provides cost-shared grants of up to $500,000 to industry-state partnerships for demonstrations of clean and energy-efficient technologies.

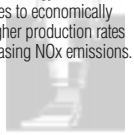
Petroleum

In the demonstration phase, a novel **rotary burner design** operates with a natural draft and uses the embodied energy in gas supply pressure, reducing fuel use by 5% while attaining ultra-low NOx emissions.

Steel

By creating fuel-rich and fuel-lean zones, **oscillating combustion** can increase heat transfer and reduce NOx emissions by up to 75% in many high-temperature, natural-gas-fired furnaces. This low-cost, simple retrofit technology demonstrated significant NOx reductions and a 5% efficiency improvement at a ladle preheater in a steel mini-mill; currently it is being demonstrated on a batch annealing furnace in a steel mill.

In commercial demonstration at a steel rolling mill site, **dilute oxygen combustion systems** require less fuel to heat steel and also give lower flue gas temperatures. This technology allows reheat furnaces to economically operate at higher production rates without increasing NOx emissions.



How to get involved

Through Industries of the Future partnerships, as well as research in combustion and other enabling technologies, U.S. manufacturers reap the competitive advantages of more efficient and productive operations. In turn, these manufacturers contribute to our nation's energy efficiency and environmental quality.

To participate:

- *Monitor the OIT Web site for news and announcements of R&D solicitations, meetings and conferences, and research projects.*
- *Team with other organizations and respond to solicitations for cost-shared research.*
- *Begin saving energy, reducing costs, and cutting pollution today by participating in the BestPractices program, which addresses immediate improvement opportunities in key systems.*
- *Take advantage of OIT's extensive information resources, training, software decision tools, and technical advice.*
- *Attend the biennial Industrial Energy Efficiency Symposium and Expo.*

For more information on these and other resources, please contact the OIT Clearinghouse at (800) 862-2086,

www.oit.doe.gov/combustion

For more information on the OIT Combustion program,
contact the OIT Clearinghouse at (800) 862-2086
or visit www.oit.doe.gov/combustion

Please send any comments, questions, or suggestions to webmaster.oit@ee.doe.gov

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