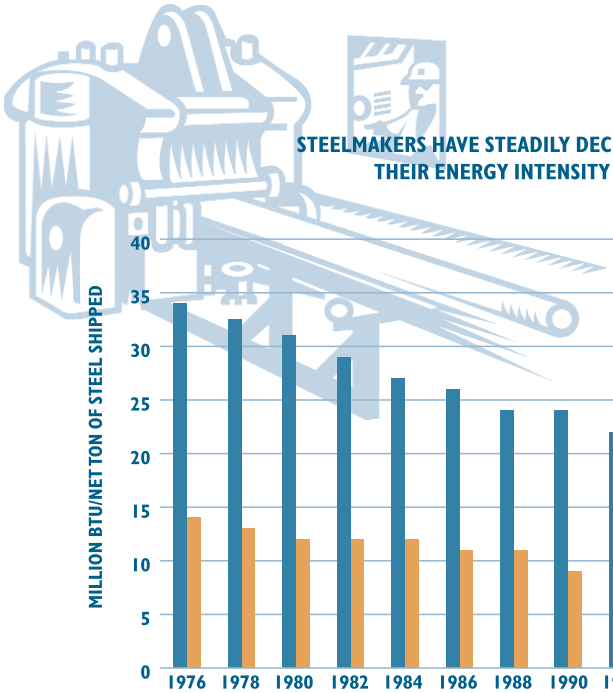
Over the past 20 years, the U.S. steel industry has undergone massive restructuring and modernization to significantly improve its productivity, energy efficiency, environmental performance, and competitiveness.

Steel Industry

PROFILE

Value of Shipments	$75.9 billion
Employment	211,900
Capital Expenditures	$3.34 billion
Net Trade Balance	-$10.6 billion
Net Energy Consumption	1.71 quads



Source: American Iron and Steel Institute

MARKETS

Traditionally, the two biggest customers for steel have been the automotive and construction sectors. Other significant markets include machinery or equipment and containers. These markets may expand and new ones emerge as steelmakers continue to aggressively improve and modify their products. More than 80% of the steels used in auto manufacturing today did not exist just 10 years ago.

EMPLOYMENT

As the industry has downsized and streamlined its operations over the past two decades, employment has dropped by more than 60%. Today, approximately 212,000 workers are employed in a smaller but far more productive and competitive U.S. steel industry.

PRODUCTION

Steel is manufactured in two different types of facilities: integrated (ore-based) mills and electric arc furnace (EAF) facilities (mainly scrap-based).

Integrated mills use blast furnaces to produce molten iron using coke, then refine that iron in energy-intensive basic oxygen furnaces (BOFs) to produce steel. Integrated mills typically produce about three million tons of steel each year per mill, but over the past 20 years, production in integrated mills
has been declining.

EAF facilities produce steel from steel scrap and other iron-bearing materials. The typical EAF facility or mini-mill produces only about one million tons per year, but EAF production overall has been increasing steadily. As of 1998, 45% of U.S. raw steel was produced in electric arc furnaces (AISI 1999).

Whereas the United States once led the world in steel production, China now claims that distinction with 114.3 million metric tons of crude steel output in 1998. The United States, with 97.7 million metric tons, was the second largest producer that year, just ahead of Japan (93.5 million metric tons).

Despite declines in production over the past 25 to 30 years, the U.S. steel industry has dramatically increased its productivity. New technologies have increased process yields from around 70% in the early 1970s to more than 90% today.

ENERGY

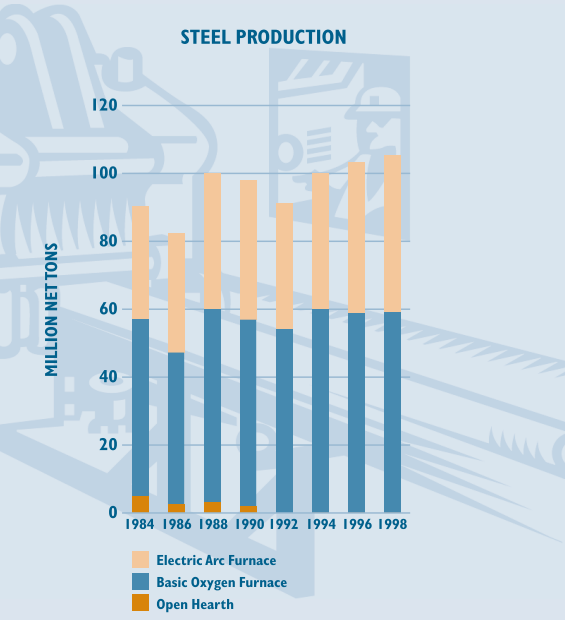
The energy-intensive steel industry accounts for about 2% of all energy consumed in the United States. This is easily understood when one considers that blast furnaces must reach temperatures of over 3,300°F to melt iron. For every ton of steel shipped, integrated mills require an average of 19 million Btu.

Since energy represents about 15% of the total manufacturing cost for steel, the industry is highly motivated to reduce its energy intensity and has done so significantly over the past decade. Industry adoption of more efficient technologies and the gradual shift from integrated mills toward EAF facilities are largely responsible for this improvement.

ENVIRONMENT

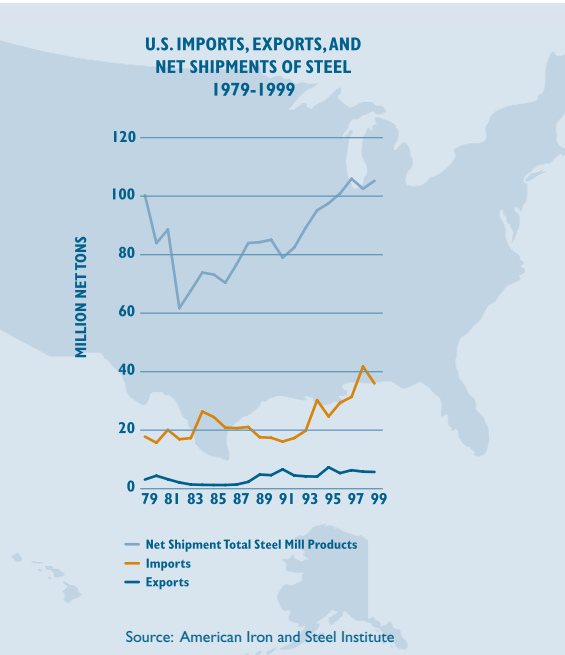
Steelmakers have achieved major environmental improvements by investing in overall cleaner production, better maintenance, and improved practices. New technologies, operating practices, employee education, and management attention have all been important.

- In a typical year, 15% of the industry's capital investments go to environmental projects.
- Over 95% of the water used in steel production is now recycled.
- In 1997, steel recycling saved enough energy to provide power for about 18 million homes for one year.
- Steel is 100% recyclable; it can be used over and over again without deteriorating to a lower-quality product.



Source: American Iron and Steel Institute

Source: Based on data from the American Iron and Steel Institute



Source: American Iron and Steel Institute

Industry Vision and Roadmap

As the global economy becomes steadily more competitive, the U.S. steel industry continually seeks new ways to stay at the forefront of manufacturing technology. To stimulate steel-related technology research, the industry entered a cooperative partnership with DOE in 1995 as part of OIT's Industries of the Future strategy.

STEEL INDUSTRY VISION

In May of 1995, the steel industry published *Steel: A National Resource for the Future.* Known as the steel industry's vision document, it set forth the industry's broad economic, energy, and environmental goals for 2020. Specifically, the vision document identified four critical areas in need of research: process efficiency, recycling, environmental engineering, and product development.

STEEL INDUSTRY ROADMAP

Led by the American Iron and Steel Institute (AISI) and the Steel Manufacturers Association (SMA), the steel industry has identified its top R&D needs and is helping to form cost-shared research partnerships to develop the needed technologies. More than 40 steel experts representing the entire range of U.S. iron and steel companies participated in the development of *The Steel Industry Technology Roadmap*, which was published in March 1998.

The roadmap clearly identifies the specific research and development (R&D) areas that must be pursued if the steel industry is to achieve its economic, energy, and environmental goals. For each critical area defined in the vision document, the *Technology Roadmap* identifies the key technology barriers, discusses the trends driving technology development, summarizes the new and emerging technologies, and lists the most critical R&D needs. Detailed background information is provided on each process or technology, and related issues are discussed at length.

STEEL INDUSTRY TECHNOLOGY NEEDS BY ROADMAP AREAS

TECHNOLOGY AREAS	PROCESS DEVELOPMENT	ENVIRONMENT	RECYCLING	PRODUCT DEVELOPMENT
Models	■	■		■
Separations		■	■	
Sensors & Controls	■	■	■	■
Product Applications				■
Materials Characterization	■	■	■	■
Improved Understanding of Phenomena-Materials	■	■	■	■
Improved Understanding of Phenomena-Processes	■	■		
Techniques to Improve Steel Properties	■			■
New/Improved Materials	■	■	■	■
Heating/Melting	■	■		
New/Improved Equipment/ Processes	■	■	■	■
Materials Composition Control	■		■	■
Coatings	■			■
Reduce/Eliminate By-products	■	■	■	
Use of Alternative Materials	■	■	■	
Emissions Characterization		■		
Maintenance Techniques	■			
Joining/Welding				■
Injection/Pouring				■

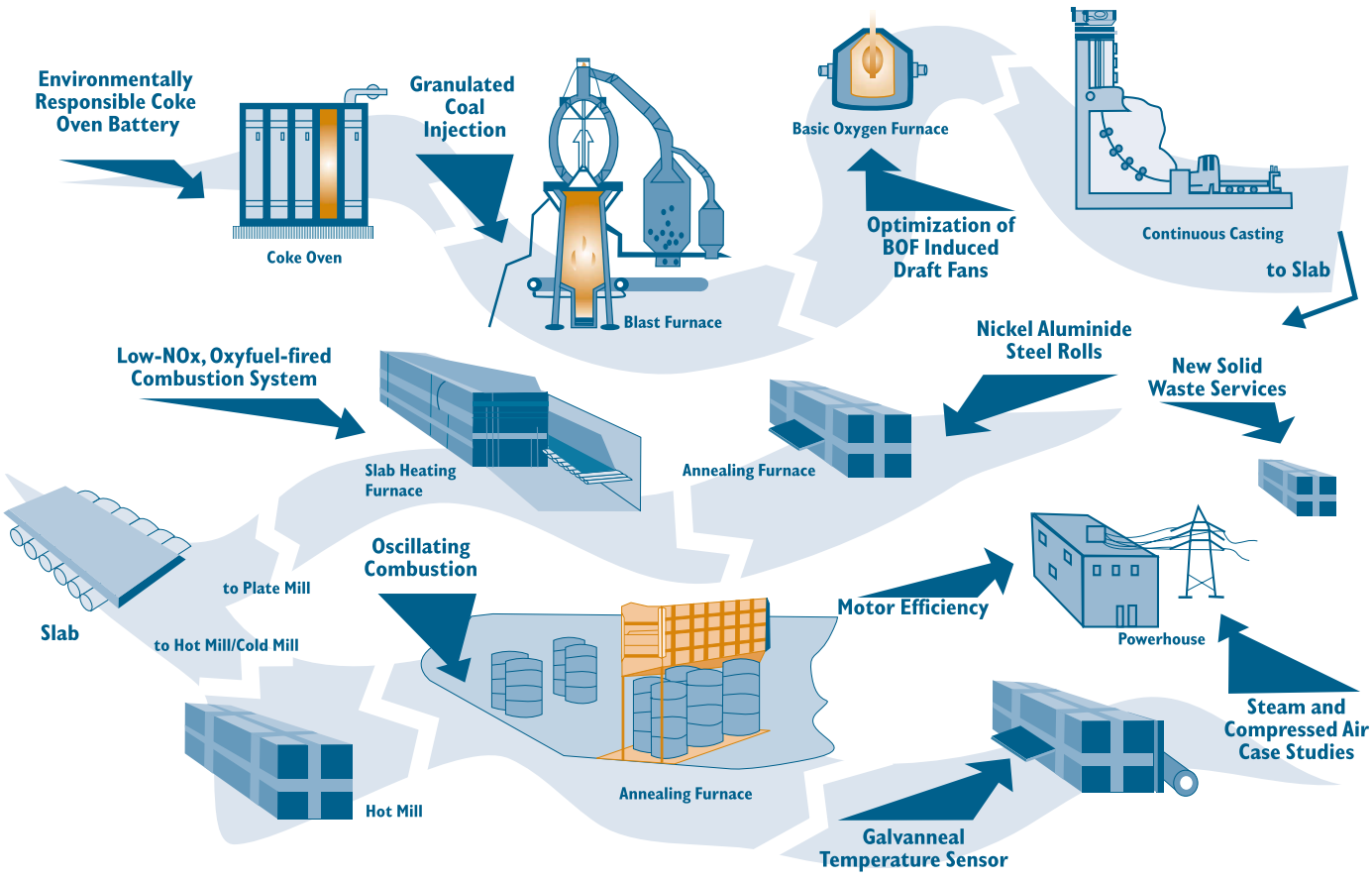
Team & Partnership Activities

Led by the American Iron and Steel Institute and the Steel Manufacturers Association, the steel industry has formed research partnerships to pursue the priority research needs identified in the *Steel Industry Technology Roadmap*. Private steel companies, government, national laboratories, universities, and equipment suppliers are participating in and sharing the cost of the needed research.

TECHNOLOGY SHOWCASES

U.S. steel companies and equipment suppliers have taken advantage of the opportunity to observe and evaluate emerging steel technologies at two showcases held in cooperation with the DOE Office of Industrial Technologies. The first was held in 1998 at Bethlehem Steel Corporation's Burns Harbor Division. The Burns Harbor Showcase offered a full day of presentations, tours, and demonstrations featuring many of the technologies that have emerged from the highly successful partnership between the DOE and the U.S. steel industry. The Bethlehem Steel Corporation's plant in Burns Harbor, Indiana, is one of the most modern integrated mills in the United States. It incorporates state-of-the-art technologies and is the field test site for a number of energy-efficient OIT-supported technologies. These include nickel aluminide steel rolls for use in reheating furnaces, granulated coal injection for blast furnaces, optimized use of induced-

BURNS HARBOR TECHNOLOGY SHOWCASE – BETHLEHEM STEEL CORPORATION



draft fans for basic oxygen furnaces, and an oxyfuel-fired combustion system for a continuous slab reheat furnace. All of the technologies are designed to help the industry save energy, reduce emissions, and increase productivity.

The Pittsburgh Regional Showcase: A Celebration of the New Steel was held in May 2000 in partnership with the American Iron and Steel Institute, the State of Pennsylvania, and the Steel Manufacturers Association. The two-day event highlighted the importance of steel both to the region and to the nation. Showcase hosts U.S. Steel and Weirton Steel arranged for participants to see advanced steel technologies and practices in use at their nearby facilities: U.S. Steel's Edgar Thomson Plant of the Mon Valley Works and Weirton Steel's Weirton Works. Participants found the plant tours, instructional sessions, exhibit hall, and congressional field hearing associated with this landmark event highly informative.

PORTFOLIO

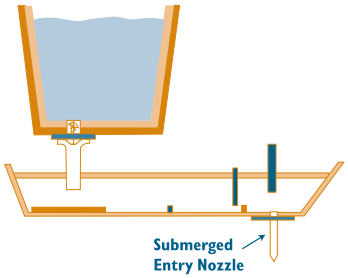
Collaborative partnerships continue to research and develop technologies that address priority needs in various aspects of the steel industry. Some of the steel-related projects in OIT's current portfolio are listed below, with selected projects highlighted on the following pages.

REPRESENTATIVE STEEL-RELATED PROJECTS IN OIT'S PORTFOLIO

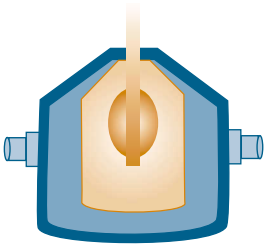
	IRONMAKING	STEELMAKING	CASTING	FORMING/ FINISHING	RECYCLING
Steel Industry					
•Advanced Control of Blast Furnace Operations	●				
•Enhanced Inclusion Removal in the Tundish			●		
•Hot Oxygen Injection into the Blast Furnace	●				
•Hot Strip Mill Model				●	
•Improving Refractory Service Life in EAFs		●			●
•Intelligent Inductive Processing				●	
•Optical Sensors & Controls for BOF		●			
•Recycling of Waste Oxides in Steelmaking		●			●
•Removal of Residuals in Carbon Steels		●			●
•Strip Casting: New Routes to Steel Sheet			●		
•Submerged Entry Nozzles That Resist Clogging			●		
•Temperature Measurement of Galvanneal Steel				●	
Industrial Materials					
•Transfer Rolls for Steel				●	
Combustion					
•Dilute Oxygen Combustion System				●	
Motor Systems					
•Fan System Improvement		●			
•Motor Upgrades Reduce Scrubber Energy Costs		●			
NICE³					
•Hydrochloric Acid Recovery System				●	●
•Oxyfuel Burners for Steel Reheating				●	
•Process EAF Dust into Chemical Product					●

See "Selected Steel Portfolio Highlights" on the next two pages for additional information

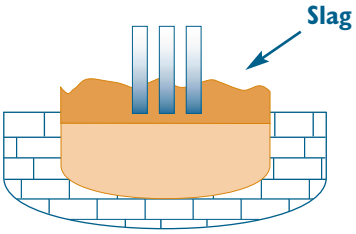
Selected Steel Portfolio Highlights



Reduction or elimination of nozzle clogging will increase productivity and quality.

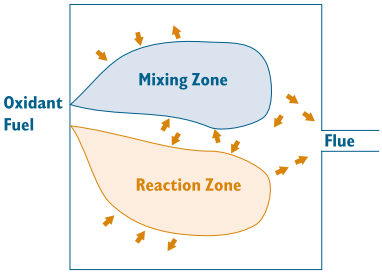


Operating practice to avoid slopping will facilitate recycling of waste oxide agglomerates directly into the steelmaking process.

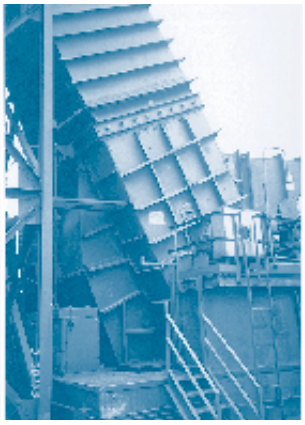


Disposal of spent refractories are raising growing concerns over future environmental regulation, liability, and cost.

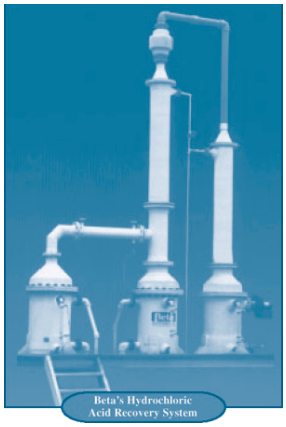
AREA	CASTING	RECYCLING	STEELMAKING
PROJECT	**Clog-Resistant Submerged Entry Nozzles**	**Recycling of Waste Oxides in Steelmaking**	**Improving Refractory Service Life and Recyclability**
DESCRIPTION	Partners are conducting a comprehensive research program that will provide the data needed to define the mechanisms controlling nozzle accretion, providing the basis for new technologies that will reduce or eliminate nozzle clogging. • Reduces refractory costs • Increases steel quality • Increases productivity and energy efficiency	Slopping is caused by the violent evolution of gas when waste oxide agglomerates are added to the steelmaking vessel. Researchers are examining the mechanism of zinc oxide formation and slag foaming to devise practices to allow the recycling of waste oxides. • Avoids landfilling about 3 million tons of waste oxides annually • Saves up to $180 million and 15 trillion Btu annually	A team of refractory producers, steel producers, university researchers, and processors of steelmaking wastes are working to make refractories last longer and be fit for reuse or recycling. R&D is focusing on control of the slag foaming process and calibration of models with data from electric arc furnaces and experiments on wear. • Fewer spent refractories in landfills • Reduces furnace downtime • Economic savings on decreased rate of refractory replacement
PARTNERS	Acme Steel Company AK Steel Corporation American Iron and Steel Institute Bethlehem Steel Corporation ISPAT Inland, Inc. LTV Steel Company National Steel Corporation Rouge Steel Company Stelco, Inc. The Timken Company USX-US Steel Group Weirton Steel	Carnegie Mellon University Cleveland Cliffs, Inc. American Iron and Steel Institute Bethlehem Steel Corporation The Timkin Company Weirton Steel	Albany Research Center Argonne National Laboratory Baker Refractories Chaparral Steel Clemson University Martin Marietta Magnesia Specialties Steel Manufacturers Association University of Alabama



Replacing combustion air with oxygen improves reheat furnace performance and generates low NOx emissions.



Variable frequency drive and other modifications boost efficiency of BOF fan system by 50%.



On-site hydrochloric acid recovery system helps steel manufacturers handle wastes.

FORMING & FINISHING

Dilute Oxygen Combustion System

The system separately injects fuel gas and oxygen into the furnace. The high-velocity streams then mix with the hot furnace gases prior to reacting with each other. This dilution prevents the high peak flame temperatures that are responsible for generating NOx.

- Potential to increase productivity by 10-30%
- NOx emissions equivalent to only 10 ppm from air-fuel combustion
- Fuel savings up to 50% over air-fuel combustion

Praxair, Inc.
North American Manufacturing Company
Auburn Steel Company, Inc.
Pittsburgh Industrial Furnace Company
University of Michigan

MOTOR SYSTEMS

Fan System Improvement

Bethlehem Steel's Burns Harbor facility and General Conservation Corp. found that an induced draft fan on one of Burns Harbor's basic oxygen furnaces was in continuous operation. Since maximum flow was really needed during only ⅓ of the cycle, the fan could be shut down during the rest of the time.

- Saves over $542,000 per year
- Increases fan system efficiency by nearly 50%
- Annual energy savings of 15,500 MWh

Bethlehem Steel Corporation
General Conservation Corp.
Meade Industrial Services

RECYCLING

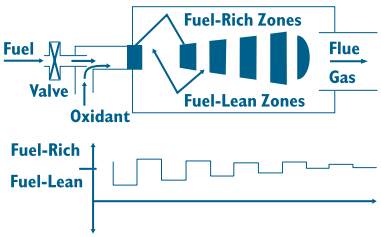
Hydrochloric Acid Recovery System

The cost to transport and dispose of the spent hydrochloric acid pickling solutions used by steel manufacturers to clean and remove rust is rising while disposal sites are diminishing. With a NICE^3 cost-shared grant, Beta Control Systems has developed a system that small- and medium-sized plants can use to recover all parts of the potential waste.

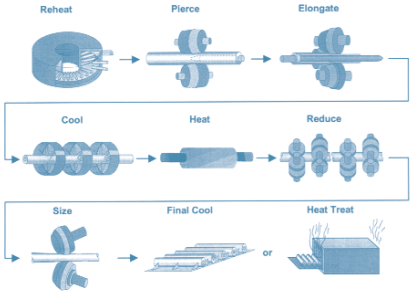
- Eliminates disposal costs and long-term liabilities of waste disposal
- Generates a saleable by-product (iron chloride) used in fertilizer, animal feed, and waste treatment

Beta Control Systems, Inc.

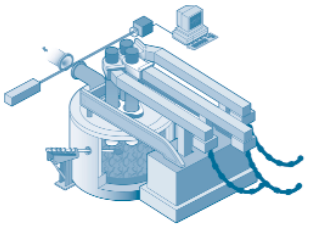
Selected Steel Portfolio Highlights



Oscillating combustion reduces NOx and improves efficiency simultaneously.



Models that link microstructure with product performance will increase yield and quality.



Careful control of post-combustion in the EAF can boost furnace energy efficiency.

AREA	STEELMAKING	FORMING AND FINISHING	STEELMAKING
PROJECT	**NOx Emission Reduction by Oscillating Combustion**	**Controlled Thermo-Mechanical Processing (CTMP) of Tubes and Pipes**	**Optical Sensor for Post-Combustion Control in Electric Arc Furnaces**
DESCRIPTION	Steelmakers and others must comply with increasingly stringent regulations on NOx emissions. To reduce NOx formation, researchers are exploring use of a retrofit technology for oscillating combustion on a wide range of burners used in box annealing, steel reheating, and ladle drying/preheating. The oscillating valve installed on the gas line to each burner creates successive fuel-rich and fuel-lean zones that simultaneously retard the formation of NOx and enhance heat transfer. • Increases heat transfer by up to 13% • Increases efficiency by 5% or more • Reduces NOx emissions by up to 75%	A coalition of steel companies and national laboratories is working with process and equipment experts to develop a system that will prescribe process parameters for producing tubes and pipes uniquely suited to target applications based on microstructure. The effort involves fundamental metallurgical studies and the development and integration of models that simulate thermal and deformation processes and predict relationships between product microstructure and performance. • Reduce scrap and rework • Reduce alloy content • Reduce post-processing heat treatment • Reduce greenhouse gas emissions	Electric arc furnaces can operate at higher efficiency if control systems have access to accurate, real-time data on the composition of post-combustion off-gases. A laser-based optical sensor is being developed to measure carbon monoxide, carbon dioxide, and water vapor concentrations in real time using absorption spectroscopy. The sensor will be integrated with a neural-net process control system to reduce electricity and fuel use while increasing furnace throughput. • Save $0.32 per ton of steel • Reduce electricity use by 9 kWh per ton of steel • Increase furnace throughput by 10% • Reduce carbon monoxide emissions
PARTNERS	Air Liquide Bethlehem Steel Corporation CeramPhysics, Inc. Gas Research Institute Institute of Gas Technology Others	The Timken Company Daimler Chrysler Corporation Idaho National Engineering Laboratory USX-US Steel Group Ford Motor Company Others	American Iron and Steel Institute The Timken Company North Star Steel Sandia National Laboratory IPSCO Steel Georgetown Steel Corporation Stantec Global Technologies

For more information on OIT's Steel Portfolio, visit www.oit.doe.gov/steel