

partnerships

Profiles and Partnerships



A strategy for enhancing the competitiveness, efficiency, and environmental performance of American industry through Industry of the Future partnerships



Office of Industrial Technologies



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

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PROFILES AND PARTNERSHIPS

The Office of Industrial Technologies

**A strategy for enhancing the competitiveness,
efficiency, and environmental performance
of American industry through Industry of
the Future partnerships**



U.S. Department of Energy

Office of Energy Efficiency and
Renewable Energy

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To Our Readers:

While e-commerce and other innovations have opened new markets, foreign cost competition is also greater than ever before. To succeed in the new global marketplace, many U.S. companies must lower production costs. They need advanced technologies and processes that will increase efficiency and productivity while cutting waste and emissions. Many of our most energy-intensive industries, however, lack the resources to conduct the needed technology R&D on their own. Increasingly, they are turning to collaborative partnerships such as the **Industries of the Future**.

This document describes the Industries of the Future strategy and how the **Office of Industrial Technologies** (OIT) works in partnership with nine of our most energy-intensive industries to develop and deliver advanced technologies and best practices. It describes the energy, economic, and environmental trends facing these industries collectively and provides a profile of each industry and its accomplishments through collaborative partnerships.

Located within DOE's Office of Energy Efficiency and Renewable Energy, OIT is the principal DOE organization responsible for the development and transfer of advanced technology to basic U.S. industries. The energy-efficient technologies we support promote industrial competitiveness and enhanced environmental performance, yielding new jobs, higher wages, increased exports, and improved profits.

The Industries of the Future strategy has been hailed as a model for government-industry partnership. It focuses public and private resources on R&D that addresses industry-defined priorities and helps achieve national goals for energy and the environment. Since its inception in 1994, the strategy has evolved steadily--streamlining, tailoring, and integrating OIT services to better serve our industry customers. In the process, the partnership has gained widespread support and is now producing impressive results, many of which are already in commercial use.

I hope you'll enjoy reading about the achievements of our partners. As always, we welcome your comments or questions on any aspect of this report or the OIT program.

Sincerely yours,

A handwritten signature in blue ink that reads "Denise Swink".

Denise Swink
Deputy Assistant Secretary
for Industrial Technologies
Office of Energy Efficiency and Renewable Energy



Industries of the Future Strategy



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A Powerful Partnership

Industry consumes about 38% of all energy used in the United States. By adopting more energy-efficient technologies, U.S. industry can boost its productivity and competitiveness while simultaneously strengthening national energy security, improving the environment, and reducing emissions implicated in global climate change.

The Office of Industrial Technologies (OIT) works in partnership with U.S. industrial firms to increase the efficiency with which industry uses energy and materials both now and in the future. Through an innovative, industry-driven strategy known as Industries of the Future (IOF), OIT helps industry develop and apply advanced, energy-efficient technologies. The strategy optimizes the energy and environmental benefits of OIT's technology investments by focusing on nine energy-intensive industries and by fostering the formation of collaborative public-private partnerships.

AN INDUSTRY-DRIVEN APPROACH

OIT's Industries of the Future strategy is designed to help U.S. industry increase its energy efficiency and boost productivity, thereby reducing waste and emissions and paving the way for market growth. Most significantly, the strategy enables industry to take the lead in defining its own technology needs. Industry identifies and establishes its technology priorities, providing authoritative guidance for focusing public and private resources on industry's toughest technical challenges. Using this approach, OIT is effectively leveraging scarce federal research and development (R&D) dollars to achieve its twin missions of improving industrial energy efficiency and reducing environmental impacts of industrial processes.

FOCUS ON ENERGY-INTENSIVE INDUSTRIES

Many of the most energy-intensive industries in the U.S. economy are involved in the initial processing of raw materials. These industries necessarily use tremendous amounts of heat and energy to physically or chemically alter the materials and prepare them for further processing or use in manufacturing. OIT maintains cooperative partnerships with nine industries, which, as a group, account for 67% of all energy used by U.S. industry and roughly 25% of all U.S. energy use:

- agriculture (renewable, bio-based products)
- aluminum
- chemicals
- forest products
- glass
- metalcasting
- mining
- petroleum
- steel

Since most of the products of these industries do not go directly to the consumer market, the average consumer tends to overlook the importance of these industries. In essence, however, these nine industries are the foundation of the U.S. economy. They produce more than 90% of the materials used in our finished products, manufacturing equipment, buildings, transportation vehicles, and infrastructure. They also produce \$1 trillion in annual shipments and account for 5% of the GDP. They directly provide more than 3 million well-paying jobs and generate four times as many additional jobs in related industries. Not surprisingly, these same industries are among the largest producers of waste, representing a significant opportunity for energy savings and improved environmental performance.



CHALLENGES

OIT's partner industries face tough economic, technological, and environmental challenges in an increasingly global marketplace. Survival in this market depends upon distinguishing one's product from those of competitors or offering the lowest price. U.S. manufacturers frequently find themselves in direct price competition with foreign firms that employ cheap labor, receive special support from their governments, or are subject to less stringent environmental regulation.

U.S. manufacturers must comply with strict environmental guidelines, offer good wages, and provide safe working conditions. To succeed in open markets while adhering to and improving on these standards, U.S. industrial firms require advanced technologies, processes, and practices that can further increase productivity, reduce unit costs, and enhance product quality while minimizing waste and emissions. Such advances support U.S. economic growth and address the risk of global climate change.

Today's industries are in a bind: at the same time they must cut costs to stay competitive (particularly the basic materials industries), they must also invest in basic and applied R&D to develop the technologies that will boost productivity, improve product quality, and address environmental challenges.

Recent technological developments present both hurdles and opportunities for major advances in industrial technologies and processes. As manufacturing processes have grown more sophisticated and products more complex, R&D increasingly requires a broad range of specialized facilities and disciplines, dramatically increasing costs. At the same time, the explosive growth in information technology has raised the feasibility of truly integrated manufacturing and real-time process control, which could significantly increase productivity.

DRIVING THE NEED FOR BASIC & APPLIED R&D

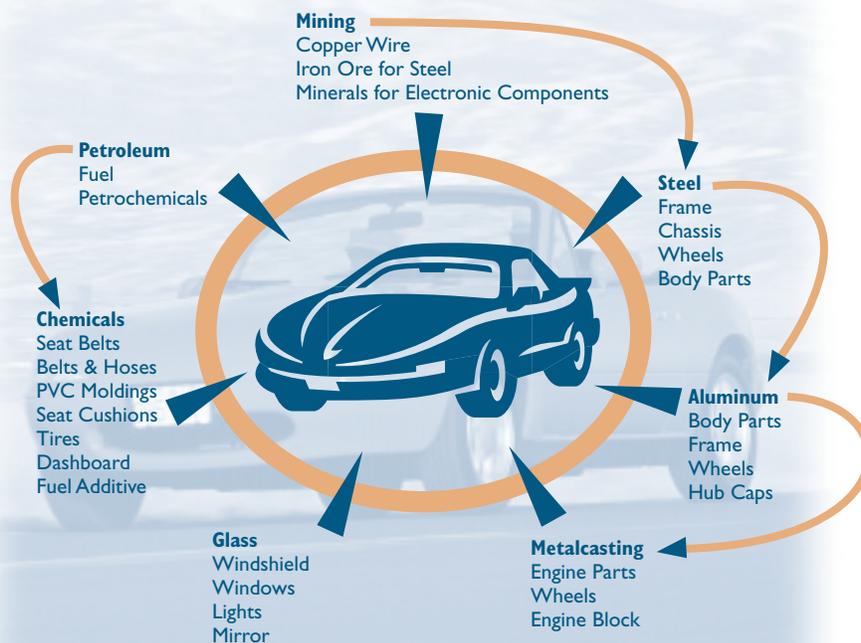
Market Globalization

As national trade barriers continue to fall, the purchase of undistinguished commodities (such as steel or aluminum sheet) on the open market will be based increasingly on price alone. Basic processing industries need to distinguish their products in terms of quality or beat the price of all competitors.

Climate Change

As the nation's largest energy-consuming sector, industry will be called upon to help reduce emissions of greenhouse gases. Progressive companies are investing in technologies to reduce emissions as the responsible course of action. Others are restricting emissions as a wise business strategy, anticipating that such restrictions will soon be required.

HIDDEN INDUSTRIES



BARRIERS TO BASIC & APPLIED R&D

Pressure for Near-Term Profits

Manufacturers are under pressure to show near-term profits. Basic materials industries already operate on extremely narrow margins, and many firms have essentially no R&D budget. Any investment in product development necessarily detracts from basic research activities—the type of research that could lead to major technology breakthroughs and open new markets.

R&D Trends

While R&D investment is robust, more than 93% of industry's R&D spending goes to applied research and product development.

Escalating R&D Costs

The increased technological complexity of materials, processes, and products requires expertise in an expanding range of disciplines. The scientific, technological, and business resources for needed research have grown beyond the reach of many individual manufacturers.

The Evolving "Industries of the Future" Process

OIT's innovative Industries of the Future strategy helps entire industries to define their long-term goals, identify their most critical needs for the future, and enter into public-private partnerships to share the costs and risks of R&D and technology advancement. The approach takes full advantage of the unique insight and resources that industry itself can bring to the R&D planning and implementation process. By giving industry "ownership" of the process, the strategy obtains strong industry commitment to the R&D and essentially ensures widespread adoption of the resulting energy-efficient technologies.

Since 1994, OIT has been using this highly successful strategy to identify the energy-related technologies most needed by some of our nation's most energy-intensive industries. The Industries of the Future model is simple and flexible. OIT facilitates the process, but the industries themselves take the lead to

- set their own industrywide goals for 2020 and beyond
- develop detailed R&D agendas for achieving those goals
- form collaborative partnerships to share the costs and risks of the needed R&D.

VISIONS

OIT brings together the diverse sectors of an industry and assists them in creating a common strategic vision for the

future. Leading representatives from each industry are asked to anticipate the likely economic, regulatory, and market pressures on their industry 20 years from now. On the basis of those projections, they jointly develop a unified vision of their desired future and the types of capabilities they will need to survive and prosper. The resulting vision outlines the industry's explicit market, business, and technology goals for the next 20 years.

ROADMAPS

Based on its strategic vision, each industry then develops a technology roadmap, which sets priorities, articulates specific technology strategies, and provides a comprehensive R&D agenda. Roadmaps lay out a logical, prioritized sequence of R&D for the long term. They identify discrete areas of research and provide quantified performance targets and milestones for the work. In some cases, roadmaps may also suggest appropriate roles for government and other research partners.

Knowledgeable and experienced individuals representing a broad cross-section of each industry participate in roadmap development. In addition, representatives of major suppliers, customers, and research organizations contribute valuable input to these "living" documents. The roadmaps are regularly updated by the industries to reflect new trends and developments.

OIT assists industry during the roadmapping process and acts as a neutral party to help competitors, suppliers, customers, and other key stakeholders reach a consensus. The published roadmaps effectively align public and private technology investments to solve the most critical common challenges facing industry and the nation.

Industries of the Future Process



The government is no longer a rulemaker or an adversary, but rather a facilitator and partner.

Denise Swink

DOE's Deputy Assistant Secretary
for Industrial Technologies

PARTNERSHIPS

The roadmaps are used to guide the formation of collaborative technology partnerships composed of private companies, suppliers, industry associations, national laboratories, private research institutions, government agencies, and other interested organizations. These partnerships can investigate promising, complex technology options that would be too costly for individual firms to undertake. OIT facilitates the planning process, serves as a clearinghouse for potential partners, and cost-shares projects that help achieve its energy and environmental goals.

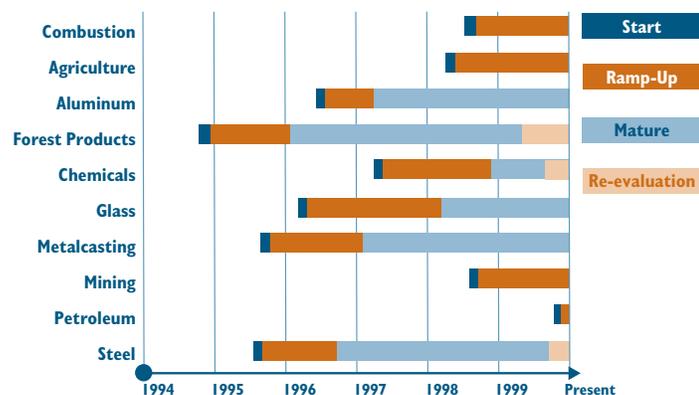
By spreading the R&D costs and risks among partners, the strategy counteracts pressures that currently tend to discourage private firms from pursuing the long-term, high-risk R&D necessary to support progress toward more efficient technologies.

Through competitive solicitations, OIT supports a broad portfolio of collaborative, cost-shared R&D projects that will yield results over the near, mid, and long term. By concentrating on high-risk, high-payoff R&D projects in pre-competitive areas, U.S. firms in these industries are finding that they can work effectively in cooperation with traditional competitors and other partners to accelerate the pace of technology development and boost the competitiveness of their entire industry. Spreading the

costs and risks of R&D appeals to private firms and public agencies alike, but the benefits don't end there. The quantity, quality, efficiency, and speed of R&D are markedly increased.

OIT's Industries of the Future strategy enjoys a high level of industry support and has received numerous accolades from industry and government leaders. Additional industries, including forging, heat treating, welding, advanced ceramics, powdered metals, and industrial process heating, have recognized the far-reaching benefits of the approach and have requested OIT assistance in vision and roadmapping efforts.

INDUSTRIES OF THE FUTURE PROGRESS



Streamlined Solicitations

OIT's new R&D project awards are determined through a competitive solicitation process in which industry takes an active role. Task groups composed of industry experts help define the pre-competitive technology areas to be targeted in the solicitations and later conduct technical assessments of the proposals received from prospective R&D partners. OIT makes the final selections based on each proposal's potential contributions toward energy-efficiency, productivity, and environmental goals.

For each award, OIT requires its partners to contribute between 30% and 50% of total project costs, with the partners' share normally increasing as the technology or process nears the commercialization stage. In this way, OIT stimulates the commitment of additional funds to needed R&D.

In response to feedback from customers, OIT has been streamlining its solicitation process. At its Idaho Operations Office, for example, rather than demanding a full-scale, highly detailed proposal up front, initial submissions now sometimes require only a 15-page "overview" and a one-page cost summary sheet. Similarly, pre-award audits are now conducted only on an "as-needed" basis, and the solicitation package has been simplified and shortened, with clearer language and fewer mandatory forms and certifications. These changes represent only the beginning of OIT's solicitation simplification and streamlining efforts.

PARTNERSHIP MECHANISMS

Industry can use a variety of mechanisms to participate in OIT programs. These include the following:

- Cost-Shared Financial Assistance Awards and Cooperative Agreements**—A financial assistance award is a legal instrument reflecting a negotiated agreement between a private firm or firms and the government. It is usually cost-shared. To protect proprietary interests of private parties, the government generally agrees not to disseminate commercially valuable data that is generated under a cost-shared financial assistance award for a specified period of time.

Cooperative agreements may also reflect a relationship between the federal government and state or local government or universities in order to support or stimulate R&D. In cooperative agreements, substantial involvement is anticipated between DOE and the recipient during the performance of the contemplated activity.
- Cooperative Research and Development Agreements (CRADAs)**—CRADAs are agreements between government laboratories and nonfederal parties in which both participants provide personnel, services, facilities, or equipment to conduct specified R&D. The nonfederal parties may also provide funds, as no direct funding is provided by the laboratory. Rights to inventions and other intellectual property are negotiated between the laboratory and participants.
- R&D Consortia**—Consortia are arrangements involving multiple federal and nonfederal parties working together toward a common R&D objective. Funding for R&D consortia may be shared, but usually no funds are exchanged between participants.
- Exchange Programs**—These programs allow government or laboratory employees to work in industry facilities, and industry personnel to work in government labs and facilities. Exchange programs enhance technical capabilities and are used to support R&D in specific areas. Costs are borne by the organization sending the personnel. Intellectual property rights are set forth in the exchange agreement.
- User Facility Agreements**—These agreements permit private parties to conduct R&D at a DOE laboratory. For proprietary R&D, the laboratory is paid for the full cost of the activity. If the work will be published, the cost can be adjusted. Intellectual property rights generally belong to the private-party user of the facility.
- Work-for-Others (WFO) Agreements**—WFO agreements accommodate proprietary work for a nonfederal party done by technically qualified government laboratory staff using laboratory facilities, with full costs charged to the nonfederal party. Title to intellectual property generally belongs to the party sponsoring the work. The government retains a nonexclusive royalty-free license to such intellectual property.

Protection of Property Rights

Rights to intellectual property developed as a result of DOE's financial assistance and R&D partnership mechanisms vary widely. They depend on factors such as the nature of the technology, the contracting instruments, the recipient cost-share, the type of performing organization, and the source of funding. The financial assistance award is the principal mechanism used by OIT to support R&D, which almost always involves recipient cost sharing of 30% to 50%. Generally, DOE will honor requests for intellectual property rights to awardees who substantially cost-share the development of new concepts in non-nuclear or non-defense applications.

Financial assistance awards are based on the premise that it is in the public's interest for the work to be supported by DOE. Successful OIT-supported technologies help create jobs, stimulate economic growth, and improve the nation's energy efficiency. Benefits are conferred on both the producers and consumers of these technologies, as well as the government.

DOE financial assistance awards do not entitle the government to ownership of any pre-proposal know-how, nor is the knowledge contained in proposals available to the public under the Freedom of Information Act. Financial assistance awards can protect proprietary information from public disclosure for up to five years. However, data on the performance characteristics of devices or systems under development must be provided to the government. DOE has the right—indeed, the responsibility—to verify performance data of any technology supported through financial assistance awards. This measure affirms any efficiency, environmental, or other performance characteristic claimed for the technology.



Industrywide Technology Support

In addition to supporting priority R&D for specific partner industries, OIT's Industries of the Future strategy embraces efficiency improvements in technologies and processes that can be widely used by many of the IOF industries and, indeed, by a large cross-section of all U.S. industry. Technologies emerging from OIT-supported R&D in these crosscutting areas often undergo further development for application in specific industries. For the near term, OIT's BestPractices program also provides a wide range of technical assistance designed to help U.S. industry adopt and apply the cleanest and most energy-efficient technologies and practices currently available.

ENABLING TECHNOLOGIES

Cost-shared R&D in crosscutting technologies enriches the knowledge base and enables the development of revolutionary new technologies. Given the scale of use these technologies receive throughout industry, even small improvements can mean substantial energy and cost savings at the national level. OIT conducts programs to advance technology in each of the following crosscutting areas (see page 108 for further detail):

- **Combustion Systems.** Approximately two-thirds of the energy used by U.S. manufacturing is supplied by combustion systems. Cleaner, more efficient combustion equipment will improve energy efficiency and flexibility, reduce emissions, and boost productivity in a wide range of industries. Priority needs include burner development and efficiency improvements in industrial boilers and process heating systems.

- **Sensors and Controls.** Advanced sensor and control technologies will improve monitoring of process parameters, even in harsh environments, and accelerate correction measures to save time, energy, and materials. Advances in sensors and the integration of data from diverse types of sensors are needed to harness the potential of real-time control.

- **Industrial Materials of the Future.** New capabilities for designing inter-metallic alloys, ceramic composites, microstructures, and specialized coatings hold solutions to many industrial processing challenges. Materials that resist high-temperature fatigue, corrosion, and wear will enhance productivity, product quality, and energy efficiency.

Benefits of these R&D efforts go well beyond OIT's energy-intensive target industries to enable improvements in productivity and energy efficiency throughout U.S. industry.

BESTPRACTICES: BOOSTING PRODUCTIVITY TODAY

The Office of Industrial Technologies offers a broad array of tools, information, and assistance that makes it easy for companies to identify and adopt more efficient practices and technologies on a plant-wide basis. Manufacturing plants can take advantage of BestPractices' plant-wide assessments and other resources to make sure all operations and practices are as efficient as they can be with today's technology. As the near-term component of OIT's Industries of the Future strategy, BestPractices helps plants start saving money right away by applying the most energy-efficient technologies and practices currently available or just emerging from R&D.

Energy efficiency is a powerful, relatively untapped business strategy for improving a company's bottom line. In addition to lowering costs, energy-efficient technologies often boost productivity, reduce or eliminate waste, create saleable by-products, aid compliance with emissions regulations, and improve product quality. OIT actively encourages the adoption of clean, efficient technologies that are available to help manufacturers begin saving energy and money right away. OIT's BestPractices program provides technical assistance emphasizing decision tools, demonstration of emerging technologies, identification of opportunities for energy savings, and heightened awareness of the benefits and correct applications of energy-efficient technologies. In all these efforts, OIT advocates a systems approach and steady, incremental improvements in efficiency.

INHERENT BENEFITS OF ENERGY EFFICIENCY



MOTOR SYSTEMS: BOTTOM LINE IMPACTS

Industry Sector	Annual Savings per Establishment	Savings (% Operating Margin)
Paper Mills	\$659,000	5
Petroleum Refining	\$946,000	1
Inorganic Chemicals	\$283,000	6
Paperboard Mills	\$492,000	5
Steel Mills and Blast Furnaces	\$358,000	2
Organic Chemicals	\$91,000	1
Industrial Gases	\$116,000	13
Plastics and Resins	\$121,000	1
Cement, Hydraulic	\$219,000	4
Pulp Mills	\$483,000	5

Technical Assistance

OIT's technical assistance programs provide a variety of tools, training, and information that can help plant managers make informed decisions affecting plant efficiency. Technical experts in a variety of industrial plant systems are available to answer questions on optimal matching and integration of components within and among plant systems, including electric motors, steam, compressed air, and process heating.

Through BestPractices, manufacturing plants have access to training and tools that can help to quickly identify opportunities for efficiency improvements. Tools are available for such diverse tasks as selecting, purchasing, and deciding to repair or replace electric motors; evaluating the use of adjustable speed drives; finding potential savings in pump systems; and optimizing savings in steam pipes and equipment. Software tools, workbooks, and databases are delivered to industry through a variety of channels, including the OIT Clearinghouse, OIT Resource Center, Internet, or professional technical societies. While program participation is strictly voluntary, the potential energy and cost savings associated with the use of these tools have attracted widespread interest and involvement.

Plant-Wide Assessments

Manufacturing plants may also be eligible for a free or cost-shared energy efficiency assessment to assist in identifying the most promising savings opportunities. Small and medium-sized plants may be eligible for a free, one- or two-day assessment by one of OIT's 26 university-based Industrial Assessment Centers. Larger plants may respond to periodic OIT solicitations for more comprehensive in-plant assessments (see page 114 for further information).

FINANCIAL ASSISTANCE FOR INVENTIONS AND DEMONSTRATIONS

OIT helps U.S. industry implement energy-efficient technologies through two specialized financial assistance programs: Inventions and Innovation (I&I) and National Industrial Competitiveness Through Energy, Environment, and Economics (NICE³). These programs target the Industries of the Future, but also address the needs of other industries (see page 118 for more detail).

The Inventions and Innovation Program evaluates the technical merits of energy-related inventions submitted by individual inventors and small businesses and provides financial and technical assistance to the most promising ideas. The program issues annual solicitations for technologies and concepts that will help achieve selected performance targets identified by OIT's partner industries.

NICE³, a cost-sharing grant program, helps fund state-industry partnerships seeking to *demonstrate* technologies that promote energy efficiency, clean production, and economic competitiveness.

Leveraging Opportunities

Recognizing the limits of available federal funding for energy efficiency, OIT capitalizes on various opportunities to leverage its funds by networking and partnering with a range of other organizations and funding sources.

STATE-LEVEL IOF

States can play an important role in encouraging industrial innovation and adoption of energy-efficient technologies. Since energy-intensive industries are key to the economies of most states, there is a natural basis for partnership between state governments and the industries within their borders. This relationship has been widely recognized and has given rise to an extensive network of partnerships among state agencies, industry associations, and regional agencies. The IOF strategy capitalizes on these networks and seeks to expand them to leverage funding and other resources for implementing the IOF roadmaps.

OIT continues to maintain and expand the State Industries of the Future initiative by working in partnership with state energy and economic development offices, universities and land-grant colleges, laboratories and research institutions, and industry representatives and associations. OIT supports state industrial development by investing in state projects competitively awarded through the State Energy Program's Special Project State Grants.

States that participate in the IOF program gain a variety of benefits. In addition to helping state industrial programs improve their focus on industry needs, state-level participation in IOF facilitates access to OIT/DOE resources such as the Laboratory Coordinating Council (LCC), Regional Centers for Innovation,

Regional Offices, and technical and financial assistance programs. Speakers from the national-level program are also made available to address state industry groups.

DOE NATIONAL LABORATORIES

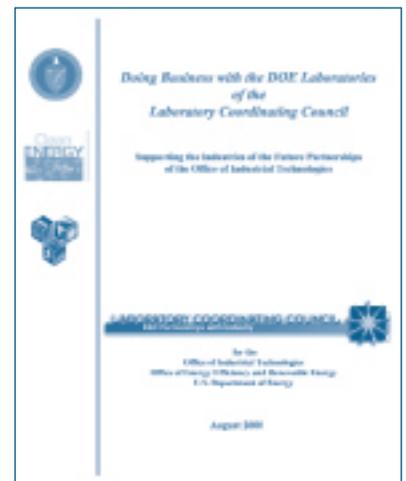
DOE's National Laboratory System is a priceless resource for the development of cleaner, more energy-efficient industrial technologies. The 17 laboratories and facilities in the system represent a wealth of technical knowledge and expertise plus highly specialized equipment necessary to advanced R&D.

To support OIT and the Industries of the Future, the Laboratory Coordinating Council (LCC) gives U.S. industry access to a "virtual" laboratory that can be tailored to meet the specific requirements of almost any R&D project. Industry researchers no longer need to approach each lab separately to gauge suitability and work out agreements. The laboratories now function in a distributed manner through common intellectual property agreements and other mechanisms.

To facilitate industry access, the LCC has developed a matrix of competencies identifying the laboratories and facilities with specific areas of excellence. The matrix links each of the priority technology areas identified by the industries with laboratory areas of directly related and crosscutting R&D expertise.

EXPO

OIT sponsors the *Biennial Industrial Energy Efficiency Symposium and Expo* in partnership with some of the leading companies participating in the Industries of the Future strategy. The event attracts manufacturers, suppliers, university



A new document from the LCC explains how industry can work with the national laboratories. Download your copy from www.oit.doe.gov/LCC.



researchers, National Laboratory scientists, Congressional staffers, government officials, and others from across the country. The Expo offers a unique forum for networking, meeting potential partners, and sharing successes and new challenges. Sessions and speakers are organized to address issues, trends, and technologies that will help IOF industries and individual companies improve their efficiency and competitiveness. The popular Exhibit Hall features scores of booths highlighting revolutionary technologies now under development, cutting-edge processes emerging from research, and other exciting benefits of collaborative partnerships.

TECHNOLOGY SHOWCASES

OIT periodically sponsors industry showcases to highlight the advanced technologies, processes, and practices of interest to a particular industry. These events allow members of an industry to get a firsthand look at a variety of energy-efficient technologies emerging from OIT-sponsored R&D and the savings possible through the adoption of a systems approach to energy analysis. Participants attend briefings, plant tours, and demonstrations to learn about new processes, technologies, and practices, and see them in use at an operating plant.

Showcase formats are flexible, and OIT works closely with the host company to address any safety or security concerns. In addition to the energy and cost savings that accrue from the adoption of energy-efficient technologies and practices, past showcase hosts have noticed that other companies demonstrate an increased willingness to cooperate with them on solutions to technical concerns. Past hosts have included the following facilities:

- Bethlehem Steel's Burns Harbor Division
- Lester Precision Die Casting
- U.S. Steel's Edgar Thomson Plant
- Weirton Steel

OIT salutes these companies and future showcase hosts for their pioneering spirit and exemplary operations.

INFORMATION RESOURCES

OIT provides a wealth of technical publications, fact sheets, and other materials of interest to industry CEOs, plant managers, engineers, researchers, and others. To help our customers find exactly what they're looking for, we offer several initial points of access:

OIT Clearinghouse: Our on-call team of 17 professional engineers, scientists, research librarians, energy specialists, and communications information staff is prepared to help you find the right OIT tools, resources, or information. They can offer answers to immediate questions, suggest relevant OIT resources, send you OIT publications and products, provide technical assistance, or refer you to industry experts or DOE staff. Since 1994, the Clearinghouse has handled over 26,000 cases of programmatic and technical assistance to U.S. industry. Call 800-862-2086.

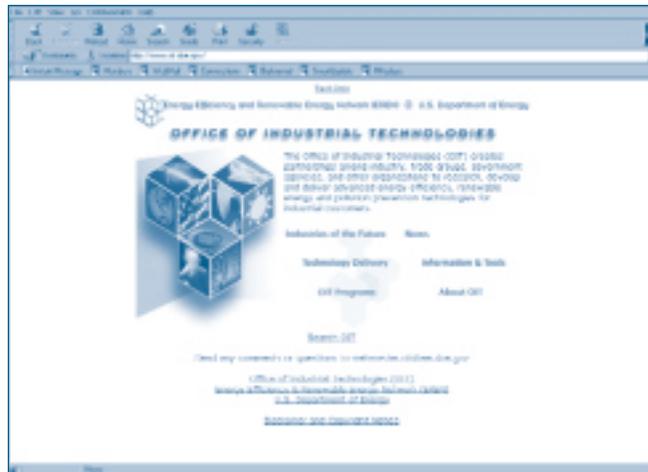
Newsletters: OIT keeps its industry partners and other customers up to date on program and partnership activities through the *OIT Times*. This quarterly newsletter has all the latest information on technology successes, new solicitations and awards, showcases, conferences, and other events of interest. The bimonthly *Energy Matters* newsletter focuses on best practices for improving industrial energy efficiency using existing technologies. Each issue highlights successes, offers tips for boosting efficiency, and provides information on tools, training, and other assistance available through OIT. To get your name on the mailing list for either or both publications, please call 800-862-2086.

OIT's Information Resources

Catalog: OIT's catalog provides a comprehensive listing of available OIT videos, software, publications, and other informative resources, conveniently cross-referenced by industry and technology area. Also available online at www.oit.doe.gov/catalog.

Industry Profiles: Detailed reports describe the energy use and environmental characteristics of each of the key manufacturing processes within an industry. These profiles provide useful benchmarks for measuring the benefits of new and more efficient technologies. Energy and environmental profiles are currently available for the Chemicals, Steel, Aluminum, Petroleum, Metalcasting, and Mining industries, and additional profiles are in progress.

Web Site: Visit us at www.oit.doe.gov.



BENEFITS OF PARTNERSHIP

Participation in the Industries of the Future strategy offers significant benefits to all partners. Manufacturers, suppliers, vendors, universities, industry associations, and others can

- reduce the cost and risk of non-proprietary R&D
- acquire a bigger voice in directing R&D
- stay at the forefront of technology and expand their knowledge base
- leverage available funds and information resources
- protect proprietary technologies and capabilities
- gain access to complementary technical expertise and facilities that can help today, as well as in the future
- gain new patents or licensing agreements
- potentially launch new products or spin-off companies.

Benefits

Partnering generally enables a company to get more technology out of its available resources. Partners can bring to the table whatever they have to offer, whether it's funding, expertise, materials, facilities, specialized equipment, or another commodity. By combining resources, partners are able to tackle projects that would otherwise be too large, complex, costly, or time-consuming to undertake on their own. At the same time, the coordination of R&D that accompanies the partnering process dramatically decreases the redundancy of pre-competitive research efforts throughout industry.

The process pulls together the best available resources from a wide range of manufacturers, suppliers, customers, universities, research laboratories, industry associations, government agencies, and other organizations. As a result, the leading minds, latest technologies, and best analytical practices can be brought to bear on some of the most difficult technological hurdles to greater energy efficiency. Combining these talents and sharing experiences accelerates the attainment of R&D objectives and compresses product development cycles.

Moreover, by bringing suppliers, manufacturers, and customers together in the R&D, resulting products have a built-in market. Individual firms not only save money and boost their efficiency, but secure a place on the leading edge of their industry.

Each of the IOF industries has built up a diverse portfolio of research and development projects. The OIT Aluminum Team, for example, is providing cost-shared support to projects within each of the priority areas defined by the *Aluminum Industry Technology Roadmap*. The projects currently included in the Aluminum Industry of the Future portfolio are expected to reduce the amount of electricity required for producing primary aluminum by 25% to 30% and lower emissions of CO₂ and perfluorocarbons by 7.7 million tons (measured in carbon equivalent). In addition, the projects should lead to lighter, more fuel-efficient vehicles that will reduce carbon emissions by a further 1.6 million tons (in carbon equivalents) and will help to avoid sending 800,000 tons of aluminum salt cake to landfills.

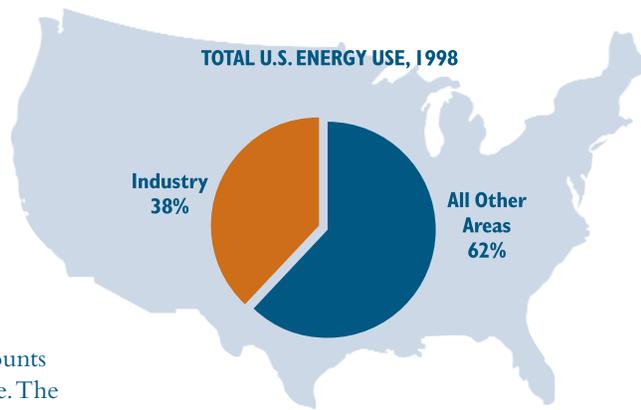
Energy, Economic, and Environmental

Trends and Analysis

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Trends in Industrial Energy Use

The industrial sector currently accounts for about 38% of all U.S. energy use. The amount of energy used by the sector increased by an average of 1.7% annually between 1987 and 1997. In 1998, however, preliminary figures indicate that industry used 1.1% less energy than in 1997—35.5 quadrillion Btu (quads)



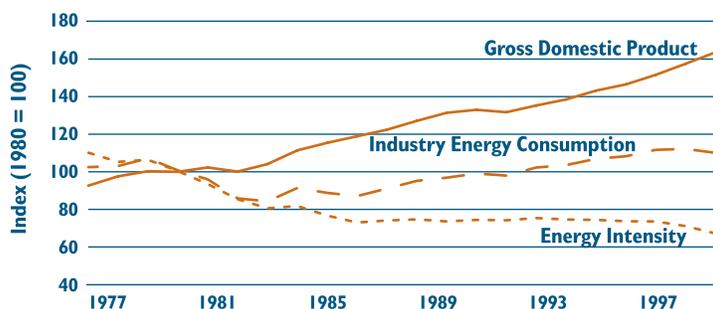
compared to the record 1997 level of 35.9 quads. As shown in Figure 2-1, this slight decrease occurred despite a concurrent rise in the gross domestic product (GDP). While far too early to signal a trend, it is encouraging to note that industrial energy intensity (a measure of the energy used to produce a unit of output) decreased in both 1997 and 1998.

ENERGY USE DOMINATED BY FOSSIL FUELS

U.S. industry is heavily dependent on fossil fuels, primarily natural gas and petroleum (Figure 2-2). Of course, about half the petroleum products and 10% of the natural gas consumed by industry are used as feedstock instead of for heat and power. Electricity use is steadily increasing as the fast-growing fabrication and assembly industries, such as electrical equipment and instruments, tend to use more electricity than the basic material processing industries.

Industry now favors natural gas over any other sources of energy because it burns cleanly and has been available at an affordable price. Use of biomass and other forms of renewable energy is also growing, and recently outstripped industrial use of coal.

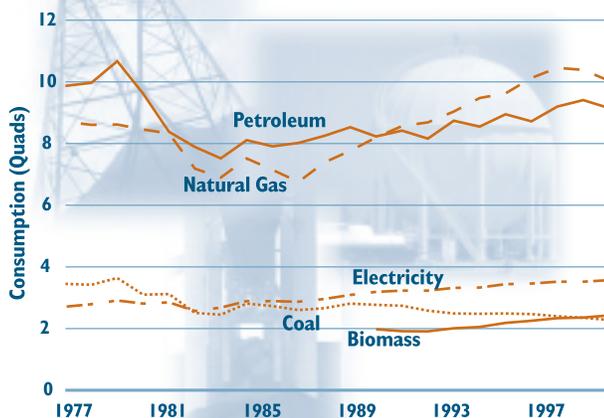
FIGURE 2-1
INDUSTRIAL ENERGY INTENSITY, CONSUMPTION, AND GDP, 1977-1998



Energy Intensity = Industrial energy use per dollar GDP

Source: Annual Energy Review 1998, Energy Information Administration.

FIGURE 2-2
INDUSTRIAL ENERGY CONSUMPTION BY FUEL, 1977-1998



Source: Annual Energy Review 1998, EIA.

Energy-Intensive Industries

OIT PARTNER INDUSTRIES ACCOUNT FOR THREE-FOURTHS OF INDUSTRIAL ENERGY USE

Within industry, manufacturing accounts for about 80% of industrial energy use. The non-manufacturing industries—mining, agriculture, oil and gas extraction, and construction—account for the remaining 20%. OIT’s partner industries within the manufacturing sector—aluminum, chemicals, forest products, glass, metalcasting, petroleum, and steel—account for about 80% of manufacturing energy use. Including mining, OIT’s Industries of the Future account for about 67% of all industrial energy use (Figure 2-3).

These industries are largely involved in the physical or chemical transformation of materials through the application of heat or energy. Massive amounts of energy are required for this transformation process.

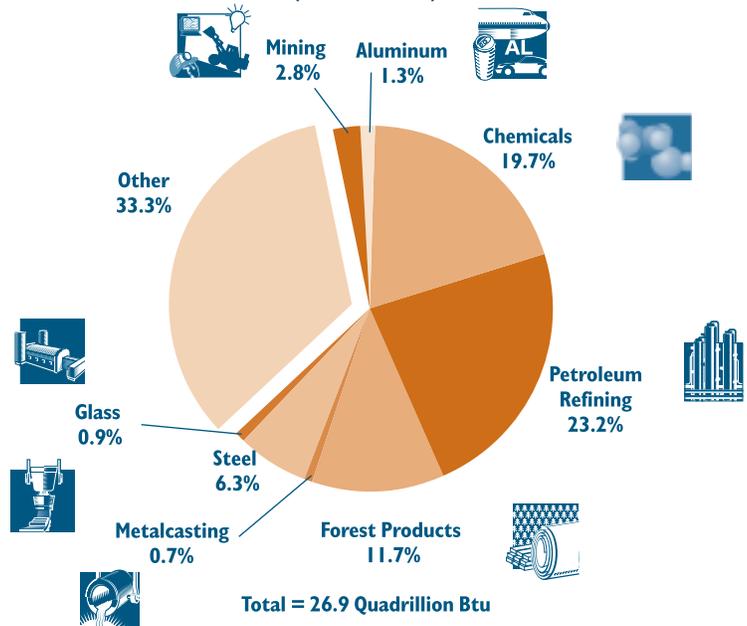
THE USE OF ENERGY

Industry uses energy in a variety of ways. It is used as a feedstock in the chemical, steel, and petroleum refining industries. Steam, which is produced in boilers, represents the largest use of energy. Direct process heat, which is generated in furnaces, ovens, kilns, and similar equipment, is used for melting and smelting, curing and drying, and other processes. Electricity is used for driving machines such as pumps, fans, compressors, conveyors, ventilators, and materials-handling equipment. Other important uses of energy include electrolytic processing, space heating, and lighting.

In 1994, OIT’s nine partner industries used in excess of

- 3,400 trillion Btu as feedstocks or raw materials
- 2,500 trillion Btu for boiler fuel
- 2,000 trillion Btu for process heating
- 850 trillion Btu for operating machines
- 310 trillion Btu to generate electricity
- 240 trillion Btu in electrochemical processes

**FIGURE 2-3
ESTIMATED INDUSTRIAL ENERGY USE
BY INDUSTRY, 1994
(END-USE BASIS)**



Source: EIA; OIT Estimates.

Energy Costs

INDUSTRY SPENDS NEARLY \$120 BILLION ANNUALLY

The U.S. industrial sector spent nearly \$120 billion on energy in 1997. Although this seems a large sum, it represents only about 3% of total production costs. Purchased electricity, natural gas, and petroleum accounted for the largest energy expenditures (Figure 2-4).

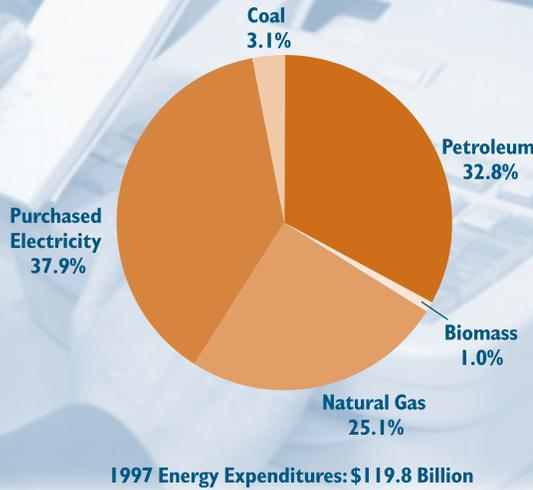
- Because electricity costs are relatively high, purchased electricity accounted for 38% of total energy costs, yet represented only 13% of industrial sector energy use on an end-use Btu basis
- Petroleum was more expensive than natural gas on a Btu basis in 1997

OIT PARTNER INDUSTRIES HAVE BIG ENERGY BILLS

OIT's partner industries tend to have above-average energy costs (Figure 2-5). In some industries, such as primary aluminum and portions of the chemical industry, energy costs can be 5 to 10 times above the average of industry overall. Fabrication industries, on the other hand, generally have below-average energy costs.

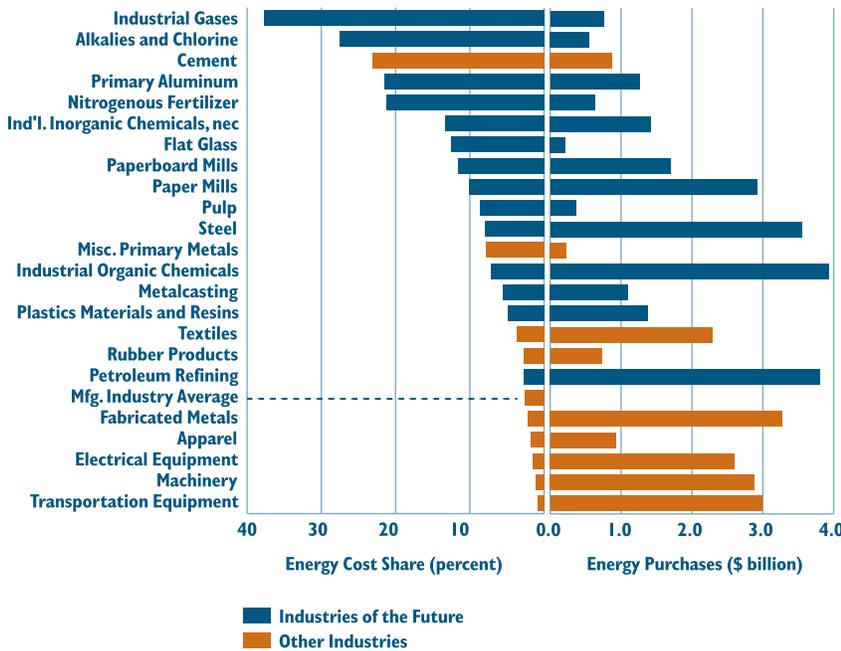
When energy prices are high, firms in energy-intensive industries aggressively seek energy conservation measures and switch fuels (when feasible) to lower their energy costs. In an era of relatively low energy prices, investment in energy-efficient technologies can still yield substantial productivity or environmental benefits for the industrial user.

FIGURE 2-4
INDUSTRIAL ENERGY COSTS



Source: State Energy Price and Expenditure Report 1997, EIA.

FIGURE 2-5
ENERGY PURCHASES AND THEIR SHARE OF PRODUCTION COSTS BY INDUSTRY, 1996



Source: 1996 Annual Survey of Manufactures: DOC.

Projected Industrial Energy Use

USAGE TO INCREASE

DOE's Energy Information Administration (EIA) projects that industrial energy use will grow steadily through the year 2020. Depending on the growth of the economy, industrial energy use may increase to only 38.5 quads or up to 47.0 quads by 2020 (Figure 2-6). The annual growth rate for energy consumption is expected to range from 0.5% to 1.4%.

ENERGY INTENSITY WILL DECREASE

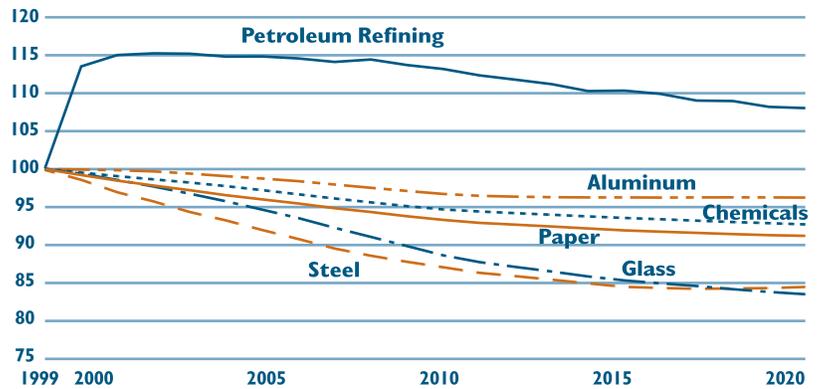
EIA also projects that energy intensity will improve over the next 20 years. Factors contributing to improvement in energy intensity include the following:

- The gradual restructuring of U.S. industry to emphasize knowledge-intensive vs. materials-intensive industries
- Higher capacity facility use because of improved controls and just-in-time manufacturing and inventory methods

- Process efficiency gains due to higher energy prices, efficiency standards, and improved technology
- Concern regarding global climate change and the use of fossil energy sources

EIA expects that OIT's Industries of the Future will achieve varying levels of improvement in energy intensity (Figure 2-7). Steel and glass are projected to show the greatest improvement, while petroleum is expected to improve slowly after a near-term increase in energy intensity related to implementation of the Clean Air Act.

FIGURE 2-7
PROJECTED ENERGY INTENSITY OF SELECTED OIT PARTNER INDUSTRIES, 1999-2020 (1999 = 100)



Source: EIA.

FIGURE 2-6
INDUSTRIAL SECTOR ENERGY USE
(In Quads)

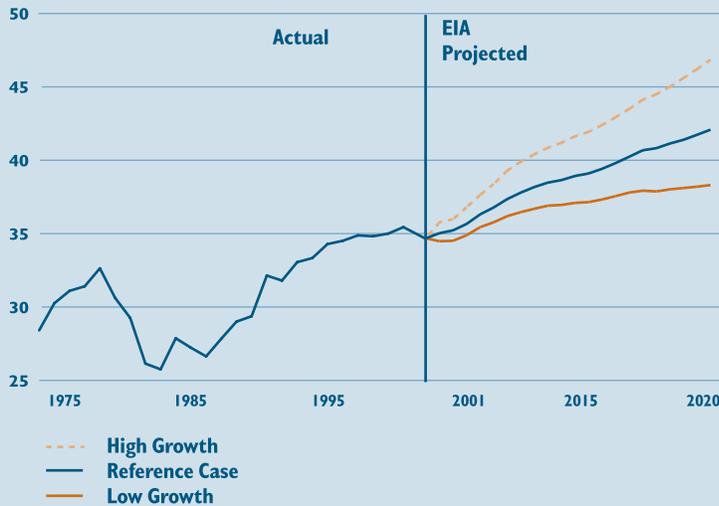
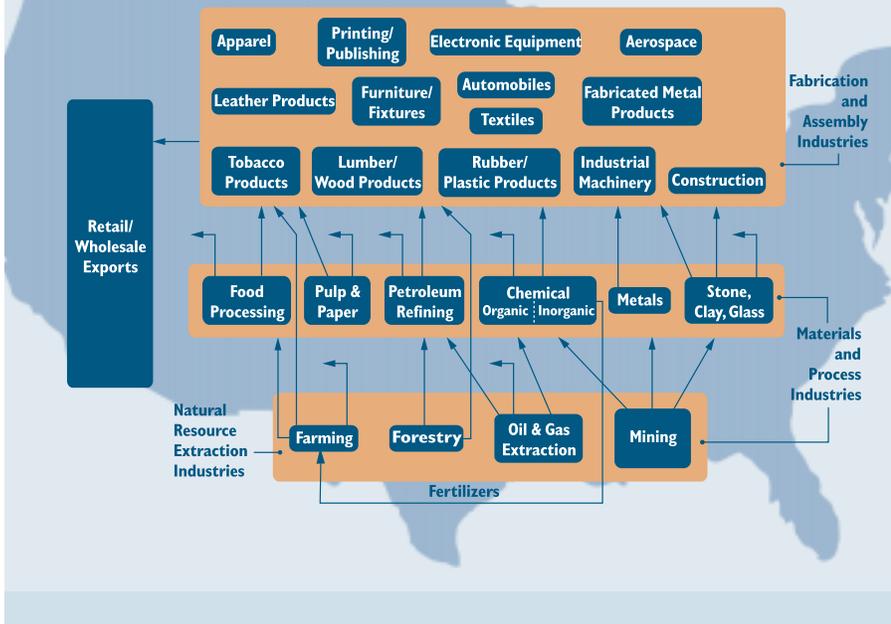


FIGURE 2-8
ROLE OF INDUSTRIES IN THE ECONOMY



Role of the Industries of the Future in the Economy

CRITICAL LINKS IN THE INDUSTRIAL SECTOR

The finished products of OIT's partner industries constitute the beginning of the long and intricate "materials chain" of the manufacturing sector of the economy.

While some products—such as gasoline and some paper products—are sold more or less directly to consumers, the preponderance of products produced by the Industries of the Future become inputs to other manufacturing industries. Indeed, many such industrial products typically require further processing before they are transformed into consumable goods.

As shown in Figure 2-8, the products of the Industries of the Future are converted by other value-adding fabrication and assembly industries into a complex array of consumer, industrial, and defense-related goods ranging from textiles and clothing, books and newspapers, and computers and telephones, to beverage cans and grocery bags, automobiles and aircraft, tractors and machine tools, tanks and submarines, and drugs and medical equipment.

ECONOMIC DATA IN THIS REPORT ARE FROM OFFICIAL GOVERNMENT SOURCES

Unless otherwise indicated, this report draws on official government sources for economic statistics pertaining to value of industry shipments, employment, wages, trade, capital investment and so on. In some instances, OIT's partner industries collect their own industry statistics through trade associations, trade journals, or other means. For a number of reasons, this data frequently differs from official government statistics. Use of government statistics helps ensure consistent industry definitions and uniform time intervals, facilitating more reliable aggregation across industries and more dependable inter-industry comparisons.

One notable exception is the treatment of Agriculture. OIT focuses its program on Renewable Bioproducts, which represents a small portion of agriculture and crosses into other industries (such as forest products and chemicals); official government statistics for agriculture are therefore not included as part of totals for OIT's partner industries.

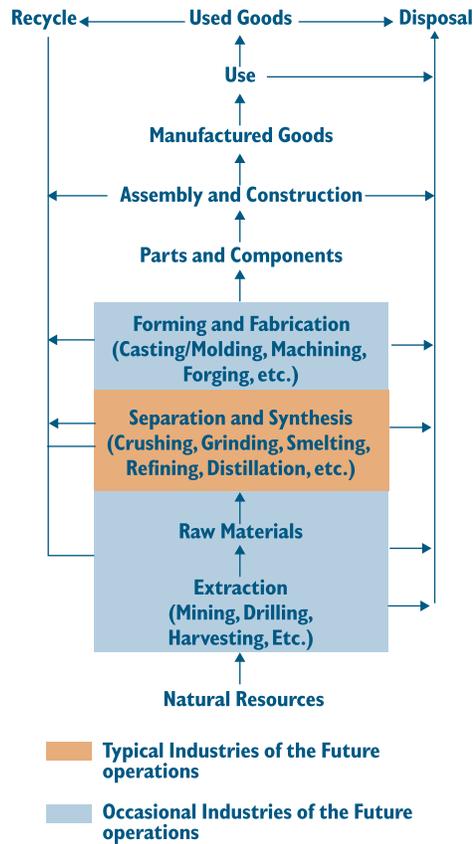
Figure 2-9 is adapted from an article by Robert Ayers entitled “Industrial Metabolism.” It identifies the principal stages of transforming raw materials into manufactured goods. The goods-producing process typically begins with the extraction of raw materials that are subsequently refined by energy-intensive processes. These pure intermediate materials are then recombined (or synthesized) into finished materials. This process typically entails the chemical or physical blending of materials (or ingredients) to yield the specific properties desired by the industrial consumer. Finished parts are then cast, machined, or otherwise fabricated into parts or components that can be assembled into manufactured goods. Ultimately, manufactured goods are either recycled or disposed of as waste.

FOUNDATION OF THE ECONOMY

Unfortunately, the critical role of these industries in the economy is often overlooked by the national media and misunderstood by the public. Because their products largely lose their identity in the process of being converted into usable consumer products, mass media advertising is not widely practiced by many firms in these industries (exceptions include the oil industry and some paper and chemical companies that sell some of their products directly to consumers).

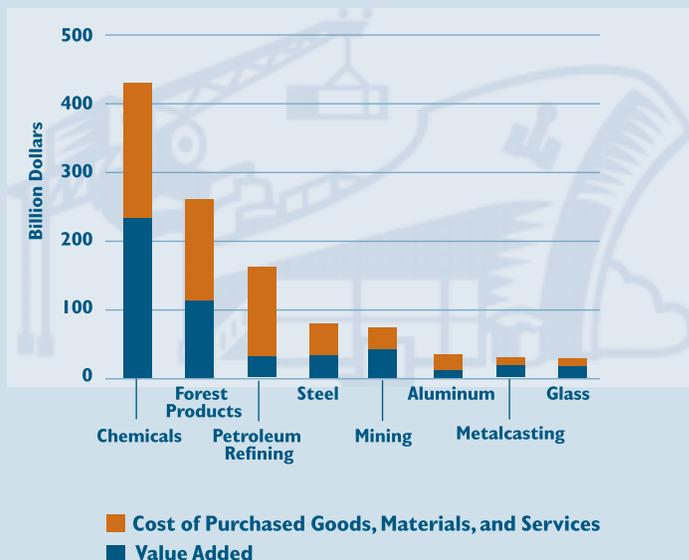
As a consequence, firms in these industries often are not widely recognized, which contributes to a lack of public appreciation for their roles in the economy. From an economic and physical standpoint, however, these essential industries quite literally underpin the entire industrial economy.

**FIGURE 2-9
PRINCIPAL STAGES IN THE PROCESSING
OF RAW MATERIALS INTO MANUFACTURED GOODS**



Source: Industrial Metabolism, Robert Ayers

**FIGURE 2-10
VALUE OF SHIPMENTS IN
INDUSTRIES OF THE FUTURE, 1997**



Sources: 1997 Census of Manufacturers and 1997 Census of Mining; Bureau of the Census

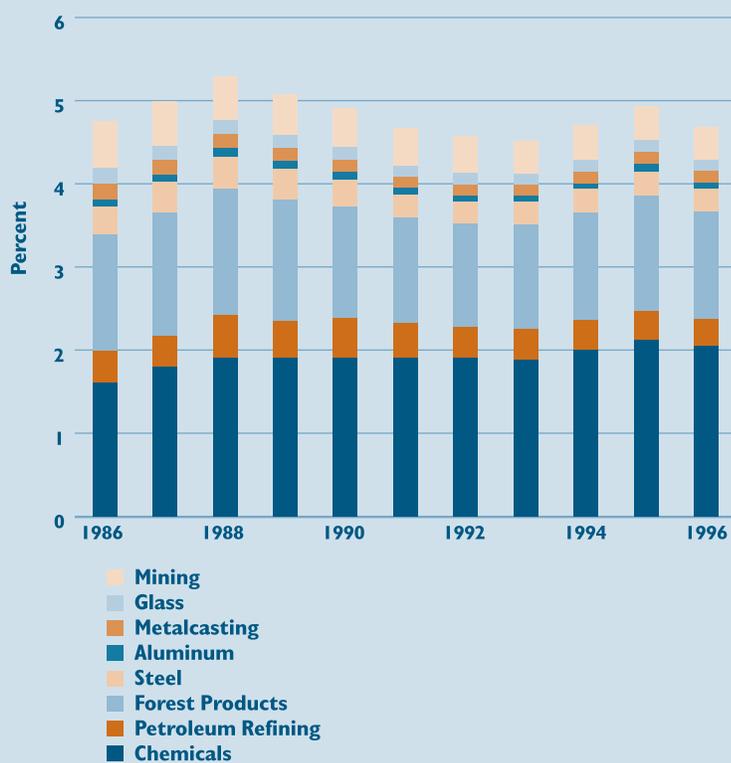
Economic Output

In 1997, OIT's nine partner industries shipped a total of over \$1 trillion worth of products. This included about \$418 billion in shipments by the chemical industry, \$253 billion by the forest products industry, and \$158 billion by the petroleum refining industry (Figure 2-10). In 1996, the total value added by the Industries of the Future amounted to over \$480 billion, directly accounting for about 5% of all U.S. economic output (Figure 2-11).

On the whole, however, these industries are cyclical industries and their long-term growth at best equals, or more commonly is slightly less than, that of the overall economy. Indeed, from 1992 to 1996, shipments by the nine Industries of the Future increased by about 20%, while overall manufacturing shipments rose by almost 24%, and the overall economy grew by almost 25%.

Moderate growth trends often translate into low price/earnings (P/E) ratios for the stocks of companies in these industries. Despite the lack of glamour that accompanies high-growth, high-P/E industries, the nine Industries of the Future underpin and support the entire manufacturing economy. The health, performance, and competitiveness of these industries are tightly intertwined with the rest of U.S. manufacturing.

**FIGURE 2-11
INDUSTRIES OF THE FUTURE: SHARE OF GDP**



Sources: Department of Commerce; OIT estimates for Department of Commerce data.

Employment and Wages

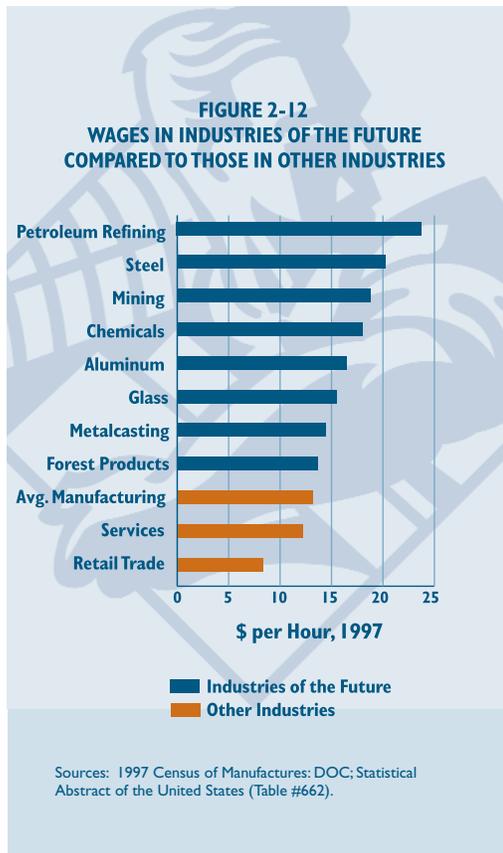
OVER 3 MILLION WELL-PAYING JOBS

In 1997, the nine Industries of the Future employed around 3.1 million people. These jobs represent 11% of U.S. industrial sector employment and about 3% of the nation's total non-farm, private-sector employment.

OIT's partner industries also indirectly support many other workers. Many of the largest employers in the manufacturing sector are fabrication-related industries that rely heavily on inputs from OIT's partner industries. Indeed, the Economic Policy Institute estimates that each job in OIT's partner industries supports four workers in the supplier, equipment, repair, finance, engineering, sales, and even government sectors.

Wages in the Industries of the Future are well above average (Figure 2-12). The payroll for all of these industries (excluding mining) totaled over \$100 billion in 1997. OIT's partner industries also allow production workers to supplement their income with overtime pay during strong economic periods, and health benefits are generally provided for many of the employees in these industries.

- Wages in the Industries of the Future are about 15% above the manufacturing average and 26% above the national non-farm, private-sector average
- While the petroleum refining and steel industries have undergone significant restructuring, these two industries have some of the highest wages in the industrial sector



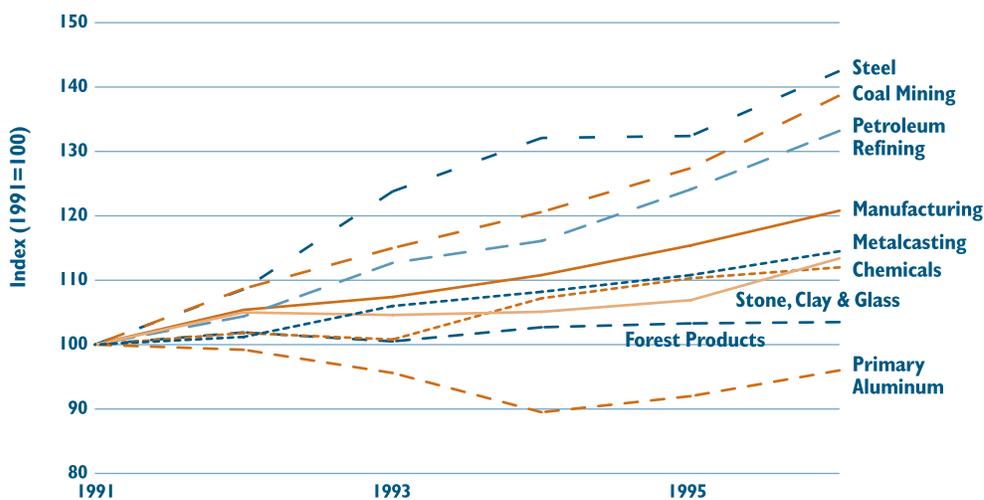
Capital Intensity and Productivity

HIGH CAPITAL INTENSITY

Due to the huge size, high throughput, and scale economies of OIT's partner industries, they are among the most capital intensive of all manufacturing industries. In 1997, these nine industries spent over \$50 billion on capital improvements—about a third of all manufacturing capital expenditures. Most of the Industries of the Future have above-average capital expenditures as a percent of sales (Figure 2-13), although capital expenditures will vary for a given industry from year to year. Investments can be made to

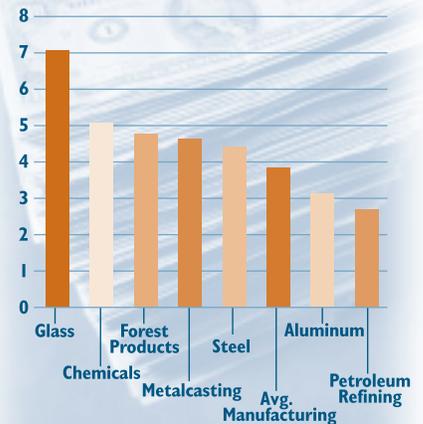
- expand production through new plants,
- upgrade or automate existing facilities, or
- implement new technology or pollution control equipment.

FIGURE 2-14
PRODUCTIVITY TRENDS IN OIT PARTNER INDUSTRIES



Source: Bureau of Labor Statistics.

FIGURE 2-13
CAPITAL EXPENDITURES IN SELECTED
OIT PARTNER INDUSTRIES
Percent of Sales, 1997



Source: 1997 Census of Manufactures, Bureau of the Census.

On a relative basis, capital investment in manufacturing is currently quite high, as the economy is strong, the cost of capital is relatively low, and companies are investing heavily in computer and other electronic technology.

PRODUCTIVITY INCREASES

In most instances, expenditures on capital equipment bring about increases in productivity. Some of the Industries of the Future have greatly improved their productivity in the past several years (Figure 2-14). In the short run, supply and demand factors can negatively influence productivity in a given industry. On a longer-term basis, adjustments will be made to better balance labor and capital needs.

Production and Capacity Utilization

PRODUCTION INCREASES LAG THOSE OF OVERALL MANUFACTURING

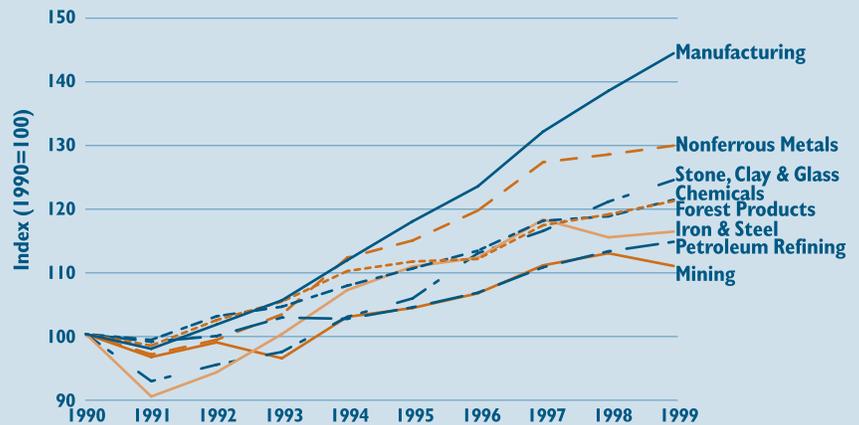
As one might expect from mature, commodity-based industries with substantial foreign competition, the Industries of the Future lag behind the overall gains in production made by the manufacturing sector since 1990 (Figure 2-15). In part, this lag can be attributed to the high growth of several other manufacturing industries, most notably those in the high technology area (including computers, communications equipment, and semiconductors), which increased output by nearly 900% between 1990 and 1999. Other highlights of manufacturing production over the past decade include the following:

- Production in the iron and steel and in the stone, clay, and glass industries dropped sharply in 1991, reflecting dependence on cyclical industries that were weak at the time.
- The chemical industry has achieved steady growth, stemming in part from its innovative products and pharmaceuticals.
- Growth in petroleum refining and mining production substantially lags other industries, even though petroleum products are in high demand.

In 1997, according to industry sources, the Industries of the Future produced:

- Over 350 million tons of chemicals
- Over 90 million tons of steel
- Over 85 million tons of paper
- Over 20 million tons of glass
- Over 12 million tons of castings
- Over 11 million tons of aluminum

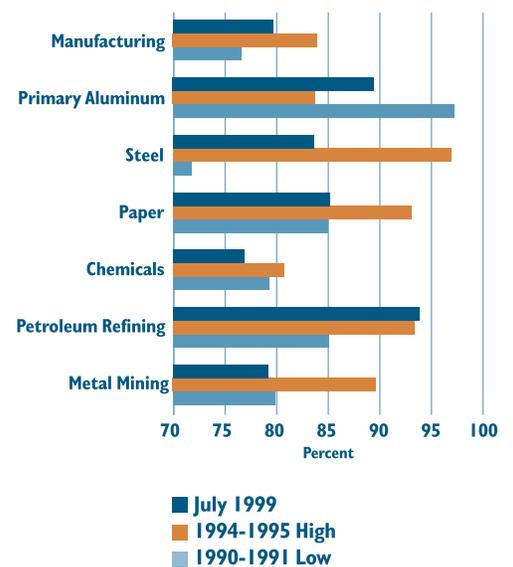
FIGURE 2-15
PRODUCTION TRENDS IN OIT'S PARTNER INDUSTRIES



CAPACITY UTILIZATION VARIES AMONG INDUSTRIES

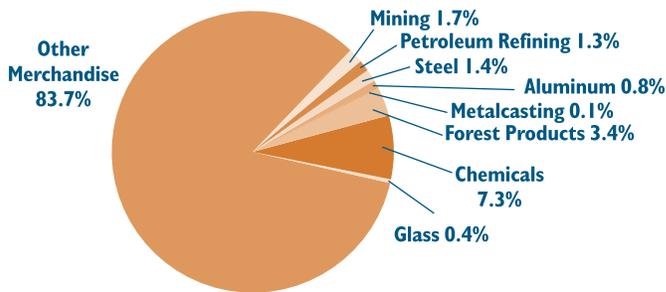
Capacity utilization rates depend on the overall health of the economy and, as one can see from Figure 2-16, vary significantly among the Industries of the Future. On the whole, OIT's partner industries are operating at capacities greater than the manufacturing average. Normally, too much unused production capacity can generate extra production costs. Above 85% utilization, however, can indicate the potential for bottlenecks and delays, which can lead to higher customer prices and increased waiting times for products. Recently, petroleum refineries have been experiencing very high utilization rates. The chemical industry, on the other hand, has exhibited higher production growth, yet has ample capacity to meet customer needs.

FIGURE 2-16
CAPACITY UTILIZATION IN OIT'S PARTNER INDUSTRIES



Source: Federal Reserve Board.

FIGURE 2-17
U.S. MERCHANDISE TRADE IN 1997:
ROLE OF THE INDUSTRIES OF THE FUTURE



Source: International Trade Administration, Commerce Department.

FIGURE 2-18
FOREIGN TRADE BALANCES FOR THE INDUSTRIES OF THE FUTURE, 1997



Sources: International Trade Administration, Commerce Department.

Trade

OVER A SIXTH OF U.S. EXPORTS

OIT's partner industries play a significant role in our nation's trade with foreign countries. In 1997, they accounted for exports of \$124 billion, or over a sixth of all U.S. merchandise exports. On the whole, however, they had a negative trade balance, since imports in these industries were worth \$130 billion. Together, the nine Industries of the Future represent about 15% of U.S. merchandise trade (Figure 2-17). Compared to a total U.S. merchandise trade deficit of \$185 billion, the \$6 billion deficit posted by OIT's partner industries suggests they performed better as a whole than other industries.

Even though the Industries of the Future are considered among the most technologically advanced and competitive in the world, they all face intense foreign competition. As shown in Figure 2-18, the chemical industry had a large trade surplus in 1997. In contrast, substantial trade deficits characterized petroleum refining, which is subject to capacity constraints and dependence on foreign crude oil, and steel, which has strong political support in other countries. In addition, resource-rich developing countries are increasingly seeking to add value to raw commodities such as oil, minerals, and lumber.

The trade deficit is a cause for concern. It affects every citizen through its relationship to prices, inflation, and the strength of the dollar against other currencies. The deficit underscores the need for a strong domestic manufacturing base.

Geographic Profiles of the Industries of the Future

In many instances, OIT's partner industries are located near their material suppliers. For example, petroleum refineries are often located on shipping routes used by oil producers. Wood, pulp, and paper mills are typically situated near large timber resources in the Northwest and Southeast. In other instances, OIT's partner industries are located close to their customers. For example, metal casters tend to select sites near auto and farm or construction equipment assembly plants in the Midwest. Still other industries locate where it is the most economical for them to produce their products, such as aluminum smelters near inexpensive hydroelectric power in the Tennessee Valley and the Northwest.

The locational tendencies of firms in OIT's partner industries mean that they are often especially important sources of income and employment outside major metropolitan areas (Figure 2-19). They are important employers not only for the jobs they provide directly, but for the additional jobs they indirectly support. In states such as West Virginia, Kentucky, Maine, Arizona, and Louisiana, these industries account for close to 10% or more of the total state economic output (Figure 2-20). Conversely, the Industries of the Future in many of the more populous states contribute a relatively smaller share to state output.

FIGURE 2-19
INDUSTRIES OF THE FUTURE: EMPLOYMENT BY STATE

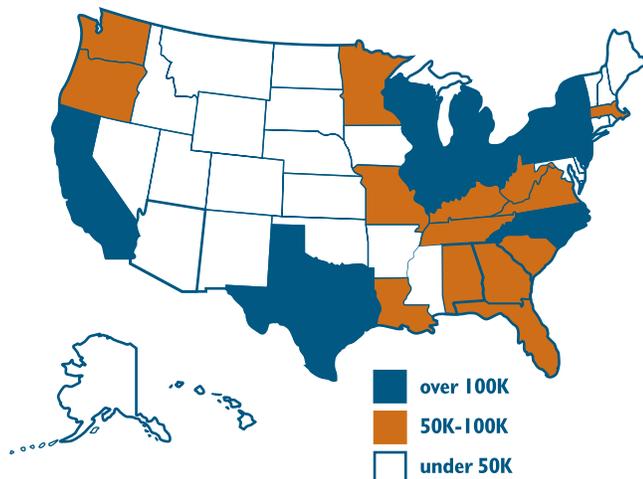
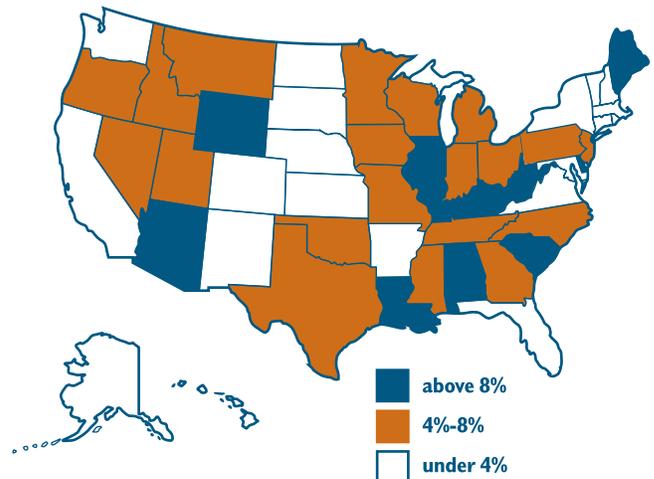


FIGURE 2-20
INDUSTRIES OF THE FUTURE: DIRECT CONTRIBUTION TO STATE ECONOMIC OUTPUT



R&D FUNDING BY INDUSTRY, 1988-1997
(millions of constant 1992 \$)

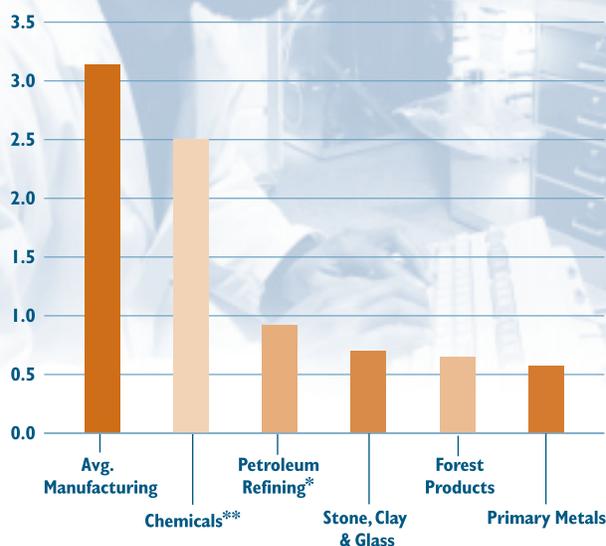
Area	Basic			Applied			Development		
	1988	1997	Change	1988	1997	Change	1988	1997	Change
Forest Products	\$98	\$250	155%	\$374	\$307	-18%	\$593	\$1065	80%
Chemicals**	\$386	\$732	90%	\$2583	\$1907	-26%	\$3916	\$3671	-6%
Petroleum	\$91	\$67	-26%	\$1177	\$597	-49%	\$1027	\$780	-24%
Stone, Clay, Glass	\$160	\$54	-66%	\$425	\$188	-56%	\$224	\$301	34%
Ferrous Metals	\$3.5	\$13*	271%	\$144	\$79*	-45%	\$145	\$454	213%
Nonferrous Metals	\$84	\$31*	-63%	\$113	\$93*	-18%	\$231	\$187	-19%
Manufacturing	\$3433	\$5596	63%	\$16988	\$20315	20%	\$48585	\$80190	65%
Industry	\$4073	\$9336	129%	\$19200	\$29249	52%	\$54163	\$102579	89%

* 1995 data

** excludes pharmaceuticals

Source: Research and Development in Industry: 1997, National Science Foundation.

FIGURE 2-21
R&D EXPENDITURES BY INDUSTRIES OF THE FUTURE
PERCENT OF SALES, 1997



** Excludes pharmaceuticals (1996 data)

* Estimated

Source: Research and Development in Industry, 1997, National Science Foundation; 1997 Economic Census, Bureau of the Census.

Research and Development

R&D LEVELS BELOW AVERAGE

While the Industries of the Future are above the manufacturing average in many respects, spending on R&D is one area in which they fall well below the average (Figure 2-21). Even though they represent essential elements of the economy, the lower-than-average R&D spending in these industries is indicative of their mature markets and technologies. The large-scale economies and high capital expenditures needed to compete in these industries also contribute to below-average R&D spending.

Although individual companies in certain industries invest more than the average in R&D, much of this tends to be product-related research for new applications and products, rather than process-related R&D. While the chemical industry was responsible for over 13% of all patents in the United States in 1996, its R&D investment was still below the average for all manufacturing if one excludes the pharmaceutical research. Nevertheless, the chemical industry spends more on R&D than other OIT partner industries. R&D is essential to feed the continuous innovation and improvement that are required to succeed in the competitive global marketplace.

ALSO SUPPORT NATIONAL DEFENSE R&D

Through R&D, the Industries of the Future play a key role in supporting our national defense. Advanced materials for vehicles, armaments, and communication systems are essential for the military, and OIT's partner industries are involved in providing these materials. In addition, the petroleum refining industry provides the fuels needed by military vehicles, ships, and aircraft.

Industrial Waste and Pollution

INDUSTRIAL WASTE MEANS WASTED ENERGY

When industry transforms raw materials into useful products, numerous by-products are created. If these by-products have economic value, they are sold as secondary materials or further transformed into other useful materials. Unfortunately, an enormous amount of industrial by-products currently have little or no economic value and are discarded as waste. When this waste is controlled through regulation, it is often considered pollution.

When industry generates waste, valuable energy is often wasted as well. Energy is wasted in the embodied energy of unused or poorly used raw materials, in the energy content of waste streams, and in the energy required to manage and dispose of wastes. By preventing pollution, industry can reduce fuel consumption as well as the energy used to treat and dispose of wastes.

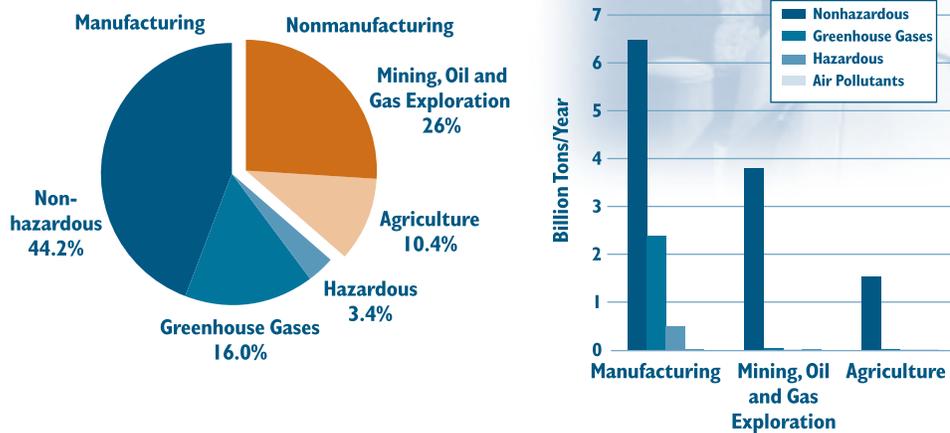
INDUSTRIAL WASTE AND POLLUTION: HOW MUCH AND WHAT TYPE?

Information on the quantity of waste and pollution generated by industry is limited and must be pieced together from a variety of sources that use differing definitions.

The best available estimates indicate that U.S. industry generates more than 14 billion tons of waste each year (Figure 2-22). These wastes include gaseous emissions, solid wastes, sludges, and huge amounts of wastewater. Most of these wastes originate in the manufacturing sector, which generates roughly 9 billion tons per year. The remaining 5 billion tons per year come from agriculture, mining, and oil and gas extraction.

These estimates are at best a rough approximation of the true extent of waste generation. The next two pages describe the principal types of industrial waste and pollution, as defined by various environmental statutes.

FIGURE 2-22
INDUSTRIAL WASTE ≈ 14 BILLION TONS PER YEAR



Sources: Manufacturing Consumption of Energy, 1991; EIA. National Biennial RCRA Hazardous Waste Report 1989, EPA Report to Congress: Solid Waste Disposal in the United States; EPA 1988.

Hazardous and Toxic Wastes

HAZARDOUS WASTES

Hazardous wastes present risk to the environment and human health and are therefore closely regulated. Hazardous waste is characterized as all wastes having toxic, corrosive, reactive, or ignitable properties. In addition, mixtures containing specific (listed) substances are also considered hazardous.

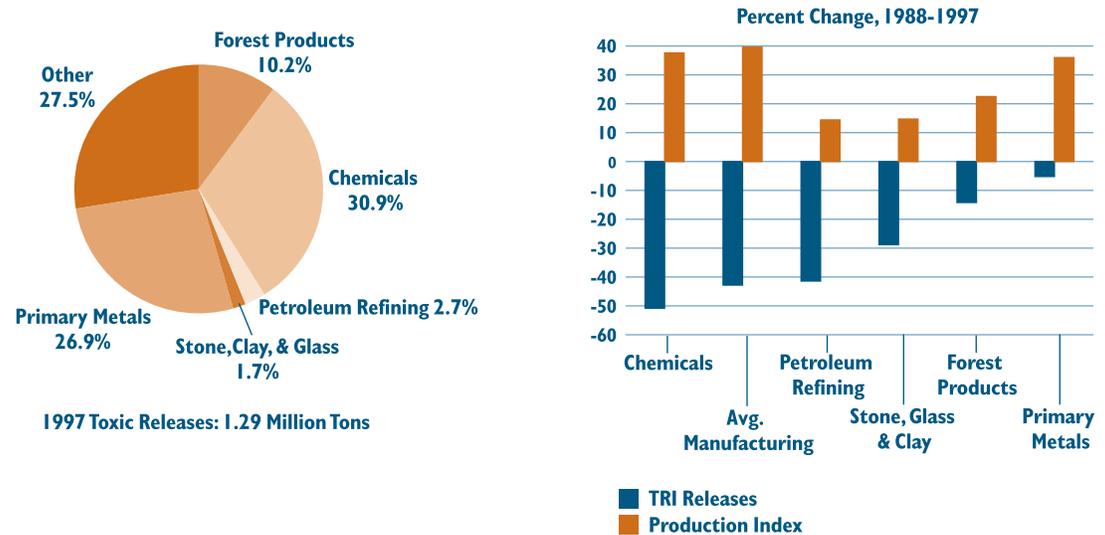
Due to a change in reporting that now excludes most wastewater, EPA reports that large generators of hazardous waste produced only 41 million tons of hazardous waste in 1997. Of course, the total amount of hazardous waste generated could be significantly larger if the many small-quantity generators were counted. Of the 20,316 large-quantity generators, the largest 50 generators account for 80% of the total, and most of those 50 are in the petrochemical industry.

TOXIC WASTES

Toxic waste emissions from manufacturing are of special interest because of their potentially severe impact on the health of workers, local communities, and the environment. In 1997, of the 12.4 million tons of toxic waste produced by the manufacturing sector, only 1.29 million tons of toxic wastes were released (Figure 2-23). Toxic chemicals in the chemical and primary metals industries were responsible for nearly 60% of all releases. However, the majority of toxic waste is either recycled, treated on-site, or used for its energy value.

Primarily because of environmental concerns, manufacturers have greatly reduced their toxic releases, even as production has increased. Overall, manufacturing reduced releases by over 40% between 1988 and 1997, with the chemical industry cutting its releases in half despite a 40% increase in chemical production.

FIGURE 2-23
INDUSTRIAL TOXIC WASTES BY INDUSTRY



Source: Toxic Release Inventory, Environmental Protection Agency; Federal Reserve Board.

Greenhouse Gases and Airborne Pollutants

GREENHOUSE GAS EMISSIONS

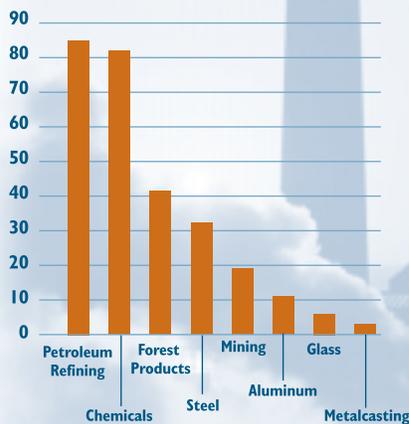
Greenhouse gases comprise a group of gaseous wastes that are associated with global climate change. Major contributors include carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons (CFCs). Carbon dioxide, the largest component of greenhouse gas, is produced by fossil fuel combustion and certain industrial processes (including cement manufacture, lime manufacture, limestone in steelmaking, carbon dioxide manufacture, soda ash manufacture and use, and aluminum production).

In 1994, U.S. industry emitted an estimated 481 million metric tons of carbon dioxide (Figure 2-24). Industrial methane emissions, which result from agricultural activities and energy production and use, were estimated at about 20 million tons in 1996. Although significant uncertainty still remains about the magnitude of future climate change from the accumulation of greenhouse gases, the potential effects of sustained temperature rises (e.g., rising sea levels, availability of water, etc.) continue to be a cause for concern and study.

AIRBORNE POLLUTANTS

Airborne pollutants are gaseous by-products of fossil fuel combustion and other industrial activities. Several of these pollutants such as particulates, SO_x, NO_x, volatile organic compounds (VOCs), and CO, contribute to poor urban air quality and regional air problems like acid rain. EPA has estimated that industrial sources account for more than 40% of all reactive VOC emissions, about 25% of SO_x emissions, and about 15% of NO_x emissions in the United States.

FIGURE 2-24
ESTIMATED CARBON DIOXIDE EMISSIONS FROM INDUSTRIES OF THE FUTURE, 1994
(Million Metric Tons of Carbon Equivalent)

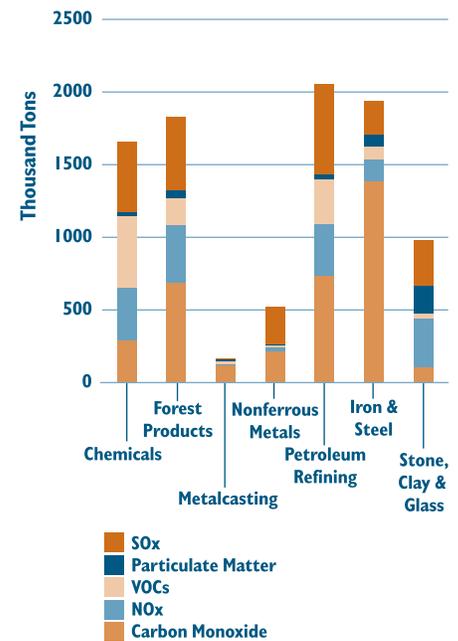


Sources: OIT estimates based on MECs.

Elevated levels of these pollutants can lead to a variety of adverse health effects and have also been blamed for reduced crop yields and stunted forest growth. Ozone, for example, which is produced through chemical reactions that involve both NO_x and VOCs, is a major component of smog. Acidic deposition, or acid rain, occurs when pollutants form acidic compounds in the atmosphere and are later deposited on the earth by rain, snow, or fog. The detrimental effects of these acidic compounds on aquatic systems, forests, and human health are of major concern to the public.

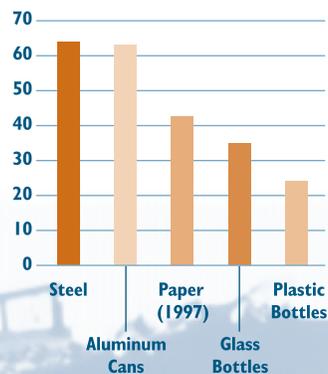
In 1997, air emissions from manufacturing reached more than 10 million tons (Figure 2-25). The highest producers of airborne pollutants are the chemical, petroleum refining, iron and steel, and forest products industries.

FIGURE 2-25
AIR EMISSIONS FROM THE INDUSTRIES OF THE FUTURE



Source: Environmental Protection Agency.

FIGURE 2-26
RECYCLING RATES, 1998
 (Recycling as a percent of production)



Recycling

SMART BUSINESS STRATEGY

In recent years, U.S. manufacturers have come to appreciate more fully the link between our economy and our environment. To maintain a robust economy, both renewable and non-renewable resources must be managed in a responsible and sustainable manner.

The Industries of the Future that engage in materials processing are keenly aware of this linkage and tend to be strong proponents of recycling (see Figure 2-26). Since recycled materials have already gone through energy-intensive processing, when they reenter the manufacturing sector they require less energy, produce fewer air and water pollutants, and generate less solid waste than virgin materials. Additional benefits of recycling include job creation and reduced demand on landfills.

REMAINING HURDLES

Although recycling and its supporting infrastructure have grown considerably over the past 20 years, some major challenges remain. A variety of technologies are needed to cost-effectively sort and separate comingled materials. While steel can be easily extracted using magnets, other sorting tasks (e.g., glass sorting by color) are substantially more difficult to automate.

A growing number of products incorporate alloys, coatings, and other combinations of materials that pose additional challenges for recycling. Some forward-thinking manufacturers are now reexamining the design of their products to ensure that these materials can be easily removed to increase post-consumer value.

Strategies are also needed to stimulate long-term demand for products made from recycled materials. A number of state and local governments are taking an important step in this direction by instituting “buy recycled” policies. Some localities have also launched campaigns that actively encourage consumers to purchase products and packaging with recycled content.

To help meet the growing world demand for chemicals and consumer products, new methods are being developed to use biobased products as additional sources of industrial feedstocks.



Agriculture Industry

PROFILE

AGRICULTURE

3

www.oit.doe.gov/agriculture

UTILIZATION OF WORLD BIOMASS RESOURCES



Total World Biomass Production
 6.9×10^{17} kcal/yr

Source: Plant/Crop-Based Renewable Resources 2020

BIOBASED PRODUCTS

The focus of OIT's Agriculture program is the biobased products industry. The objective of this emerging industry is to create new products from the abundant renewable resources found in agriculture, forests, and pasture lands. Chemicals that can be used to make plastics, for example, could be made from corn, soybeans, or wood. Biobased products are created through the combined efforts of many industrial communities, including agriculture, forestry, chemicals, and biotechnology.

Many of the products that could be made from biobased products are now made from petroleum (e.g., petrochemicals). Plant derived materials will be one way to supplement petroleum and meet increasing worldwide demand for consumer goods.

Renewable agricultural resources have historically been used primarily for food, animal feed, and fibers. Excluding forest products, bio-based resources currently constitute less than 5% of all raw materials used as industrial feedstocks.

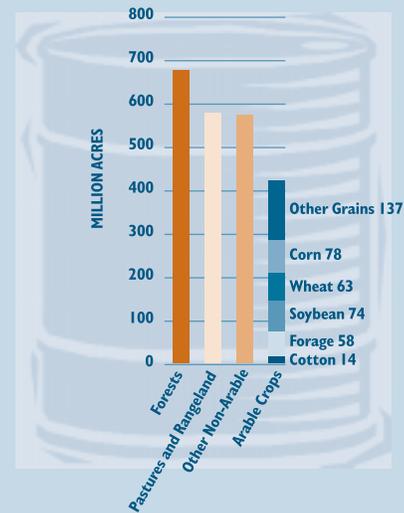
The lack of economical chemical conversion methods and difficulties in manipulating the “structure” of plant materials has often made biobased feedstocks a high-cost option for manufacturers. However, in cases where economical processes do exist, plant-derived production costs are nearly equal to those for conventional production. For example, surfactants, which are used in household soaps and detergents, can be produced from plant-derived material at the same cost per pound (\$0.45/lb) as petrochemical feedstocks. About 35% of surfactants are currently produced from plant resources. In order to increase the use of biobased products, methods must be developed to better separate and synthesize plant components into materials that can be easily and economically used in industrial processes.

MATERIALS AND PRODUCTS

The potential for using plants and crops as raw materials is large. Some plants and crops already serve as feedstocks to a limited extent in a variety of industries. Soybeans are used to make inks, paints, oils, lubricants, and cleaning products. Furniture, particleboard, and other building materials are fabricated from crops such as wheat straw and kenaf. Many industrial processes also use a number of chemical compounds that are extracted from plants and crops, including starches, proteins, fatty acids, and isoprene compounds. Other exciting possibilities, such as using corn to make polylacticacids for polymers, are also on the near horizon.

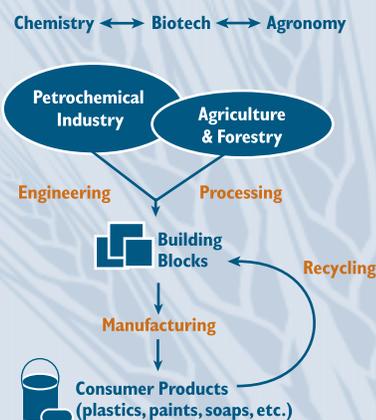
Great potential also exists in harvest wastes. For example, cotton wastes are being used to produce activated carbon and products for absorbing oil spills. Similar possibilities exist for crops that are already grown for food, such as corn, soybeans, wheat, and sorghum; harvest waste currently left in the fields could be used as industrial feedstocks.

PLANT/CROP-BASED RESOURCES IN THE UNITED STATES



Source: Plant/Crop-Based Renewable Resources 2020

THE BIOBASED PRODUCTS INDUSTRY



INDUSTRIAL USE OF RENEWABLE RESOURCES

Inputs	Million tons used per year	Uses
Wood	80.9	Paper, paperboard, lignocellulose composites
Industrial starch	3.0	Adhesives, polymers, resins
Vegetable oils	1.0	Surfactants, inks, paints, resins
Natural rubber	1.0	Tires, household goods
Wood extractives	0.9	Oils, gums
Cellulose	0.5	Textile fibers, polymers
Lignin	0.2	Adhesives, tanning, vanillin

Source: The Carbohydrate Economy, D. Morris and D. Ahmed, 1992



Industry Vision and Roadmap

PLANT/CROP-BASED RENEWABLE RESOURCES INDUSTRY VISION

In 1996, the National Corn Growers Association initiated a workshop to begin work on a strategic vision for the agriculture industry of the future. The vision would focus on the use of renewable bioproducts to supplement use of petroleum-based resources in manufacturing everyday consumer goods, such as plastics, paint, and adhesives. The visioning process brought together over 100 experts from industry, nonprofit organizations, trade asso-

ciations, and academia to provide input to the document. The resulting vision, *Plant/Crop-Based Renewable Resources 2020 – A Vision to Enhance U.S. Economic Security through Renewable Plant/Crop-Based Resource Use*, was published in January 1998.

The vision established a set of long-term, ambitious goals for increasing the use of renewable resources:

- To use plant-derived materials to meet at least 10% of demand for basic chemical building blocks by 2020, with development concepts in place by then to meet 50% of demand by 2050
- To establish a plant/crop-based (crop, forestry, processing) manufacturing infrastructure

THE AGRICULTURE INDUSTRY VISION AND ROADMAP ESTABLISH INDUSTRY-WIDE GOALS AND PERFORMANCE TARGETS...

R&D Opportunity Area	
<p>Replace at least 10% of basic chemical building blocks with plant-derived renewables by 2020, with development concepts in place to achieve a further increase to 50% by 2050</p> <p style="writing-mode: vertical-rl; transform: rotate(180deg);">SELECTED VISION GOAL</p>	<p>Plant Science</p> <ul style="list-style-type: none"> • Develop an understanding of gene regulation and control of plant metabolic pathways as well as functional genomics to improve gene manipulation.
	<p>Production</p> <ul style="list-style-type: none"> • Improve production methods (e.g., higher plant productivity, more desirable plant components) to ensure that an adequate and cost-effective supply of plants is available for industrial use.
	<p>Processing</p> <ul style="list-style-type: none"> • Develop new or modified processes to create chemicals and other products from plants rather than hydrocarbons. Production, separation, and new, more effective catalysts are priority topics.
	<p>Utilization</p> <ul style="list-style-type: none"> • Enhance understanding of the relationships between the structure and functionality of different plant constituents (e.g., proteins, starch). Develop a sound infrastructure and distribution systems to ensure an adequate distribution of raw materials.

- To establish collaborative partnerships among industry, government, and academia for the R&D needed to achieve market opportunities and ensure that processes and systems are commercially viable

PLANT/CROP-BASED RENEWABLE RESOURCES INDUSTRY ROADMAP

In 1998, the manufacturing and growing partners that contributed to the vision formed an Executive Steering Group, made up of industry leaders from several key companies and associations, to oversee and guide the road-mapping process. The steering group developed the *Technology Roadmap for Plant/Crop-Based Renewable Resources 2020*, which identifies the critical R&D pathways necessary to achieve the goals of the vision. With input from over 120

industry experts and professionals, the steering group developed a strategy for optimizing the combined R&D efforts of the agriculture, forest products, life science, and chemical industries.

The roadmap defines both short- and long-term R&D priorities that will lead to the development of a reliable renewable resource base for the future. The R&D priorities target four barrier areas:

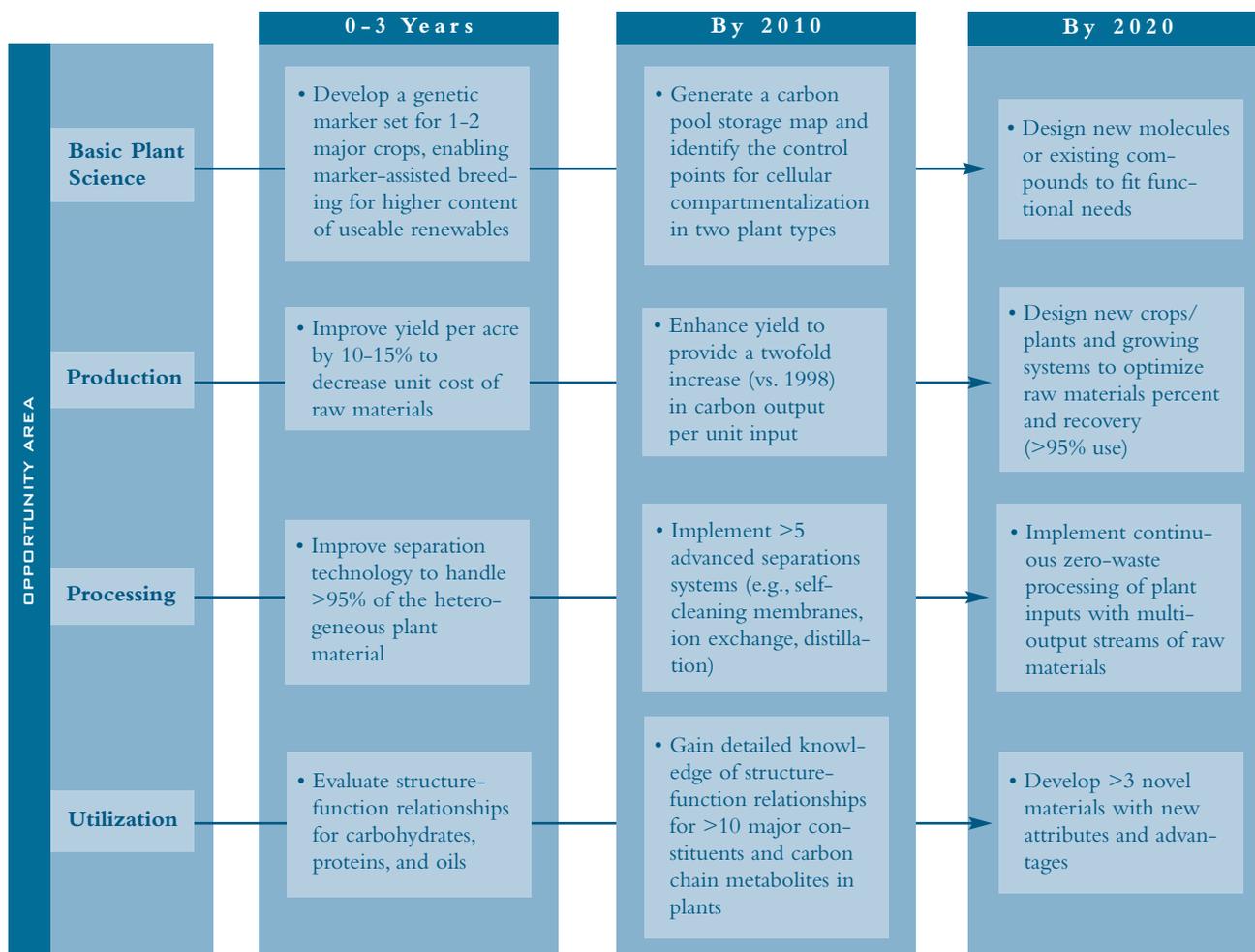
- Plant Science
- Production
- Processing
- Utilization

Within these areas, the agriculture, forest products, life science, and chemical industries will work together in a coordinated manner to advance renewable resource utilization.

PLANT/CROP-BASED RENEWABLE RESOURCES VISION

Provide continued economic growth, healthy standards of living, and strong national security by developing plant/crop-based renewable resources as a viable alternative to non-renewable fossil fuels.

...AND IDENTIFY RESEARCH TO ACHIEVE THOSE TARGETS.



**PARTNERSHIP YIELDS
AWARD-WINNING
COMMERCIAL SUCCESS**

In June 1998, an OIT R&D project received both the 1998 Presidential Green Chemistry Challenge Award and the Discover Magazine Award for Technical Innovation for a process used to produce chemical solvents from corn.

This new, fermentation-based process was developed by scientists from Argonne National Lab and co-funded by and licensed to NTEC, Inc., through a CRADA. The process uses advanced membranes, catalysts, and electrical energy to cost-effectively convert corn starch directly into ethyl lactate using only one-tenth the energy of traditional production and without producing great amounts of waste.

Jim Frank, project director at Argonne National Lab, notes, "Without OIT's continued support for this high-risk project over a period of several years, success would not have been possible. Government is playing a critical role in supporting development of promising, high-risk, pre-competitive technologies."

The Department of Energy invested \$500,000 annually over five years to develop this new process—a process that could result in \$12 billion per year in gross sales of corn-based solvents.

Team & Partnership Activities

OIT's Agriculture Team facilitates the public-private partnerships of the Industries of the Future initiative. Industry and government collaboratively pursue precompetitive R&D that will enhance energy security, minimize environmental impacts, and promote economic well-being.

NEW PORTFOLIO PROJECTS

In August 1999, the Agriculture Team awarded six R&D projects from its first competitive solicitation to help achieve the targets of the strategic vision, *Plant/Crop-Based Renewable Resources 2020*. The solicitation sought projects that would reduce energy use in agricultural and related industries, as well as enhance U.S. economic competitiveness. Specifically, the R&D projects were required to address high-priority research needs identified in the Processing and Utilization categories of the technology roadmap.

OIT's Agriculture Team also leverages the related work of other OIT Industries of the Future teams, such as Chemicals and Forest Products, since the inputs and products of those industries play an integral role in the development of biobased products.

BIOENERGY INITIATIVE

Integrating efforts and leveraging resources will help the Agriculture Team to achieve the far-reaching goals of the vision, reduce reliance on imported oil, and rejuvenate the nation's rural communities. One such effort is supporting the President's 1999 Executive Order 13134 on developing and promoting biobased products and bioenergy. This Presidential Initiative is stimulating public-private partnerships and accelerating the use of biomass as a feedstock for industrial chemicals and other products, power generation, and transportation fuels.

In his Executive Order, the President directed the Executive Branch to achieve greater cohesion and focus in this area. In a memorandum accompanying the Order, the President set a goal of tripling U.S. use of biobased products and bioenergy by 2010. Reaching this goal would generate billions of dollars in new income for farmers, create employment opportunities in rural communities, and reduce greenhouse gas emissions by as much as 100 million tons a year—the equivalent of taking more than 70 million cars off the road.

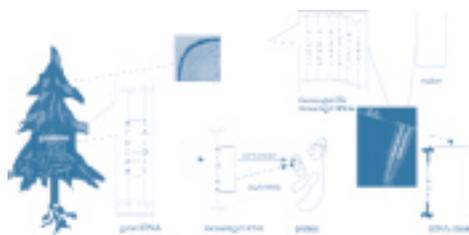
On June 20, 2000, the President also signed the Agricultural Risk Protection Act of 2000 (P.L. 106-224). Title III, the Biomass Research and Development Act of 2000, has several provisions that complement the Executive Order. The major thrusts of the title are to improve inter-agency coordination and focus Federal R&D efforts on the conversion of biomass into fuels, power, chemicals, and other products.

REPRESENTATIVE AGRICULTURE-RELATED PROJECTS IN OIT'S PORTFOLIO

	PLANT SCIENCE & PRODUCTION	PROCESSING	UTILIZATION	ENERGY	ENVIRONMENT	RECYCLING
Agriculture Team						
•Biocatalysis under Extreme Conditions		●		●		
•Biodesulfurization of Gasoline		●			●	
•Catalytic Upgrading of Glucose to Chemicals		●	●			
•Chemicals from Lignocellulose		●				
•Clean Fractionization – Inexpensive Cellulose for Plastics Production		●	●			
•Utilization of Corn-Based Polymers			●			
•Development of Selective Surface Flow Membranes		●				
•Efficient Compressed Air Systems				●		
•Efficient Motor Systems				●		
•Electrodeionization for Product Purification		●				●
•Energy and Waste Audits				●	●	●
•Esters from Bio-based Feedstocks		●				
•Fractionation of Corn Fiber for the Production of Polyols		●	●			
•High-Performance Steam Systems				●		
•Improved Catalytic Enzymes		●				
•Low Temperature Catalytic Gasification of Aqueous Process Streams		●			●	●
•Low-NOx Turbine Retrofits				●	●	
•Pine Gene Discovery Project	●					
•Plastics, Fibers, and Solvents from Bio-derived Acids		●	●			
•Precision Farming	●			●	●	
•Production of Succinic Acid from Biomass		●				
•Products from Wheat Milling		●	●			
•Reactor/Separator for Ethanol from Cellulose		●				
•Recovery and Water Recycling Using Hydrogels		●				●
•Soy-Based Two-Cycle Engine Oils			●			
•Trees Containing Built-in Pulping Catalysts	●					

See “Selected Agriculture Portfolio Highlights” on the next two pages for additional information

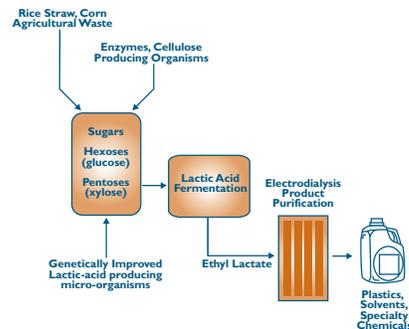
Selected Agriculture Portfolio Highlights



Sets of genes can be expressed to produce proteins with specific cellular functions (e.g., disease resistance).

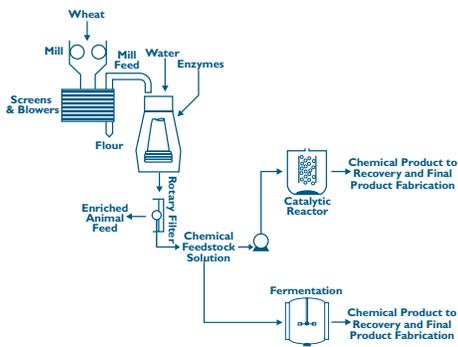


Precise farming tools will reduce energy use, conserve water, and minimize use of pesticides and fertilizers.



Creating chemicals from rice and corn will expand agricultural markets and conserve oil resources.

AREA	PLANT SCIENCE & PRODUCTION	PRODUCTION	PROCESSING
PROJECT	Pine Gene Discovery Project	Precision Farming	Chemicals from Lignocellulose
DESCRIPTION	<p>Although gene sequencing research for major agricultural plants is already underway, there is a lack of fundamental information on genes in woody plants. Access to a catalog of loblolly pine genes will be an important asset for forestry researchers, allowing studies on the genetic engineering of improved tree lines and other ways of improving plant stocks. By identifying a large number of partial gene sequences in woody plants, the project partners will open up new scientific and commercial opportunities for the forestry industry.</p> <ul style="list-style-type: none"> • Catalogs pine genes useful in industrial research • Expands knowledge base for identifying problems in pine physiology • Advances biological information on the similarity of genes among major taxonomic groups of plants and animals 	<p>This process will allow agriculture producers to have commercial access to an integrated system of precision farming tools that will enable farmers and consultants to assess field conditions, create management zone maps, and control applications in small sections with irrigation pivots. Also, the Accu-Pulse system software-based data collection methods that produce GIS layers of information about variations in water, nutrients, vegetative material, and pests will be integrated into the system. If used on 10–15% of irrigated farmlands in the U.S.:</p> <ul style="list-style-type: none"> • Saves significant amounts of energy in crop production • Significantly reduces chemical and energy use 	<p>Researchers are integrating two approaches to utilizing waste agricultural feedstocks by converting wood waste and rice straw to mixed sugars, fermenting the sugars to produce lactic acid, and chemically converting the acid to lactic esters. Lactic esters can serve as solvents or raw material for chemicals and polymers, replacing some of the petroleum-derived end-products.</p> <ul style="list-style-type: none"> • Expands the use of agricultural feedstocks • Enhances national energy security • Serves a \$5 billion U.S. market
PARTNERS	<p>California State University – Hayward North Carolina State University University of Minnesota Georgia-Pacific Corp. Rayonier Corp. Union Camp Corp. Westvaco Corp.</p>	<p>Colorado Corn Administration of Lakewood, CO Colorado Office of Energy Management</p>	<p>Argonne National Laboratory BC International Corporation California Institute of Food and Agricultural Research Collins Pine Company NTEC-Versol</p>



A new process will reduce wheat milling by-products by 50% while creating new feedstocks for chemicals.



Enhancing the properties of corn-based polymers will increase use of bioproducts.



Marine oil from soybeans is environmentally friendly.

PROCESSING

Products from Wheat Milling

Mill feed (the product of wheat flour milling) is currently used as a low-value animal feed, but researchers are developing processes to recover the starch component for use as a feedstock in valuable chemicals. Converting starch will reduce by-product waste by 50% and provide an energy-efficient feedstock for chemicals such as sugar alcohols (sorbitol, mannitol) and polyols (propylene glycol), and for the food, cosmetic, and plastic industries.

- Decreases emissions of CO₂, SO₂, NO_x, particulates, and VOCs
- Replaces petroleum as a feedstock for chemicals
- Significantly reduces the amount of electricity and petroleum in processing

Mennel Milling Company
Pacific Northwest National Laboratory
Pendleton Flour Mills, Inc.

UTILIZATION

Enhanced Utilization of Corn

Project partners are examining the structure—physical/chemical property relationship—of poly (lactic acid) (PLA), a biodegradable plastic, in order to improve the processing ability of PLA. Ultimately, this will allow for new materials with improved properties, expanding the application of PLA to areas such as hybrid paper-plastic packaging.

- Utilizes renewable source as feedstock
- Reduces landfill volumes
- Removes greenhouse gases from atmosphere

Cargill Dow Polymers, LCC
Colorado School of Mines
National Renewable Energy Laboratory

UTILIZATION

Soy-Based 2-Cycle Engine Oils

About 15 million gallons of oil are consumed by the recreational boating sector in North America. Researchers want to develop, test, and screen a series of 2-cycle engine oils based on vegetable oils for use in water-cooled engines that will offer the same performance as petroleum-based products without harming the environment.

- Saves 7.5 million gallons of petroleum annually
- Offers a 90-100% biodegradable product
- Produces fewer emissions
- Increases fire safety
- Extends engine life

Omni Tech International, Ltd.
Smith, Bucklin & Associates
Terresolve Technologies, Ltd.
United Soybean Board

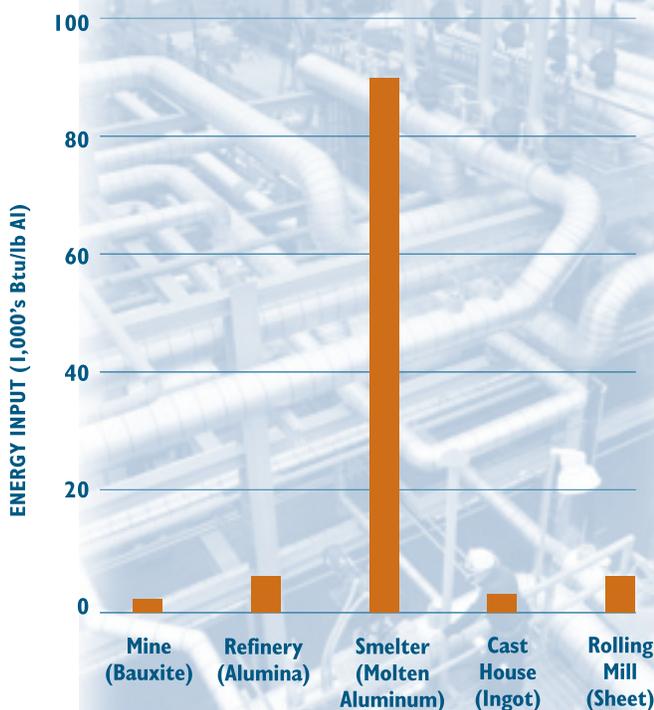
The U.S. aluminum industry is the largest in the world, annually producing more than 22 billion pounds of metal worth over \$30 billion. Aluminum's light weight, resistance to corrosion, high strength, and recyclability have made it an essential material for modern economies.



PROFILE

Aluminum Industry

ENERGY REQUIREMENTS IN THE ALUMINUM INDUSTRY



Source: The Aluminum Association

Value of Shipments	\$32.7 billion
Total Employment	85,300
Capital Expenditures	\$1,028 million
Net Trade Balance.....	-\$1.859 billion
Net Energy Consumption	360 trillion Btu

MARKETS

The largest aluminum markets are in the transportation, packaging, and construction industries, and applications are expanding in infrastructure, aerospace, and defense. Over the past ten years, aluminum shipments have increased by an average of about 3% per year.

EMPLOYMENT

The industry directly employs about 85,300 people with a payroll of \$2.7 billion. In addition, the industry supports thousands of workers in recycling facilities and other related operations. Aluminum producers are broadly dispersed across the country, contributing to national, regional, and local economies.

PRIMARY PRODUCTION

Primary aluminum production involves the refining of alumina from bauxite ore and subsequent electrolysis of the alumina. Major upheavals in world aluminum markets following the breakup of the former Soviet Union in 1989 forced plant closings that reduced U.S. smelting capacity by nearly 25%.

Although the United States no longer produces 41% of the world's primary aluminum as it did in 1960, it continues to lead world production with a share of roughly 17%.

The electrolysis (smelting) of alumina to form aluminum is accomplished using the energy-intensive Hall-Heroult process. During this process, carbon anodes are gradually consumed, accounting for significant quantities of CO₂ emissions. CO₂ is also generated during the manufacture of the carbon anodes themselves and in the production of electricity to run the smelters.

SECONDARY PRODUCTION

Secondary producers recover aluminum from both new (industrial) and old (post-consumer) aluminum scrap. Recycling or secondary production saves 95% of the energy needed to produce aluminum from bauxite ore. Recycled beverage cans continue to be a major source of scrap supply. The reclamation of aluminum scrap continues to grow in importance to the industry, driven by energy and environmental considerations. In 1998, 33% of total supply was recycled aluminum.

ENERGY

The energy-intensive smelting process accounts for the major share of energy consumption in primary aluminum production.

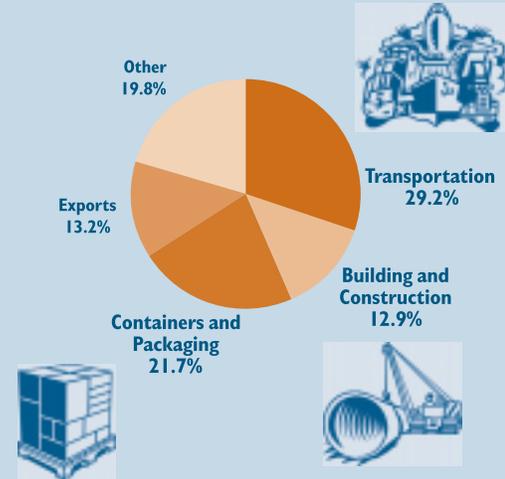
- Aluminum represents approximately 1.8% of all energy consumed by U.S. industry.
- In 1997, the industry spent about \$2.0 billion on energy.
- Energy accounts for as much as 30% of the cost of primary aluminum production.

ENVIRONMENT

The biggest environmental concern associated with primary aluminum production is the generation of greenhouse gases: carbon dioxide and perfluorocarbons (mainly CF₄).

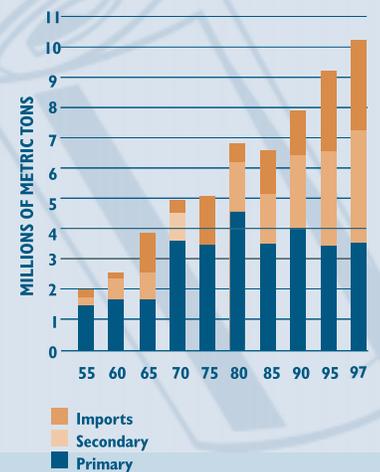
- Between 1970 and 1996, total industry emissions decreased by an estimated 27%, even though total production increased by about 59%. This decrease is attributed, in part, to an increase in secondary and a decrease in primary production.
- Combustion-related CO₂ emissions for alumina refining and smelting are estimated at 6.2 million metric tons (MMT) of carbon equivalent (ce) in 1995.
- Consumption of carbon anodes during smelting resulted in CO₂ emissions of 1.3 MMTce in 1995.
- Process emissions also included about 4.1 MMTce of perfluorocarbons in 1995.

THREE MARKETS ACCOUNT FOR ALMOST TWO-THIRDS OF ALUMINUM SHIPMENTS, 1997



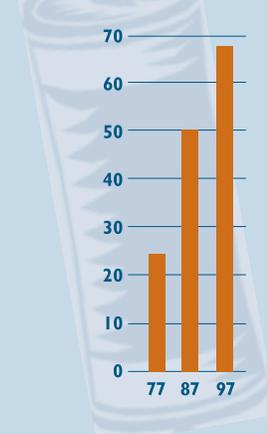
Source: The Aluminum Association

TOTAL US ALUMINUM SUPPLY, 1955-1997



Source: The Aluminum Association

PERCENT OF ALUMINUM CANS COLLECTED



Source: The Aluminum Association



Industry Vision and Roadmaps

ALUMINUM INDUSTRY VISION

In 1996, The Aluminum Association published *Partnerships for the Future*, the industry's vision for the year 2020. That vision established broad technical, environmental, and market goals for the industry, focusing on three sectors: raw materials, semi-fabricated products, and finished products.

ALUMINUM INDUSTRY ROADMAP

With support from DOE and the Aluminum Association, the aluminum industry developed the *Aluminum Industry Technology Roadmap*, which describes the industry's R&D strategy

for accomplishing the goals outlined in the vision. The roadmap assigns highest priority to the development of improved anode and cathode technology for smelting, particularly the development of a viable inert (or non-consumable) anode. The international aluminum community has pursued the development of non-consumable anode technology for many years. The combination of this technology and wettable cathode technology could achieve the following:

- A 25% increase in the energy efficiency of electrolysis
- Up to a 10% reduction in operating costs
- A reduction in greenhouse gas emissions of up to 8 MMTce, assuming 100% market penetration

THE ALUMINUM INDUSTRY ROADMAP ESTABLISHES INDUSTRY-WIDE PRIORITIES AND PERFORMANCE TARGETS...

SAMPLE PERFORMANCE TARGETS	Primary Products	<ul style="list-style-type: none"> • Develop 13 kWh/kg retrofit cell (mid-term) • Develop 11 kWh/kg advanced cell (long-term) • Eliminate CO₂ emissions • Improve Bayer productivity by 20% • Develop new uses for wastes and by-products
	Casting	<ul style="list-style-type: none"> • Increase reliability of manufacturing operations to 95% • Improve process control • Advance strip-casting technology
	Rolling & Extrusion	<ul style="list-style-type: none"> • Use new forming technologies to reduce weight by 20% • Reduce cost of joining technologies • Increase reliability to 95% • Reduce extrusion energy use • Improve process control; improve productivity and quality
	Finished Products	<ul style="list-style-type: none"> • Reduce metal production costs by 25% • Reduce aluminum:steel cost ratio to < 3:1 in autos • Increase aluminum use in auto markets by 40% in 5 years • Increase aluminum use in non-auto transportation markets • Increase aluminum use in infrastructure markets by 50% • Increase aluminum use in construction markets

Other key targets set by the roadmap are to improve the energy efficiency of the smelting process by 13% within 10 years (developing a cell that uses only 13 kWh/kg) and 27% by 2020 (with a cell using only 11 kWh/kg).

ADDITIONAL ROADMAPS

To better address two of the priority areas identified in the roadmap, the industry has developed two more detailed documents. These technology roadmaps focus on specific research needed for the development of inert anodes and automotive markets.

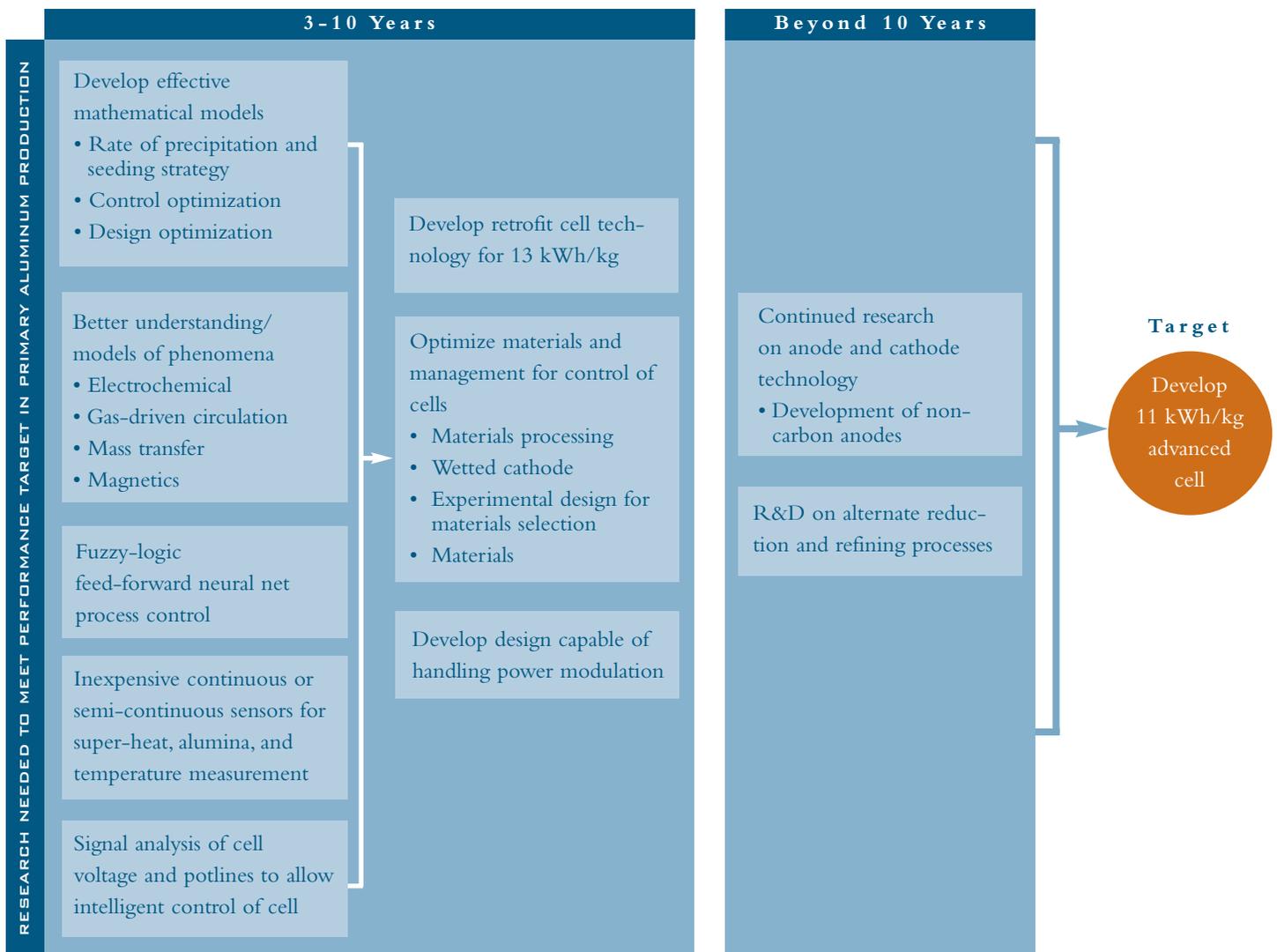
In February 1998, the U.S. aluminum industry (working with The Aluminum Association) published the *Inert Anode Roadmap*, which defines required per-

formance characteristics to guide development of any new inert anode technology. This framework is expected to accelerate research in advanced cell technology by aligning efforts of the diverse research community toward a clearly defined goal.

The *Aluminum Industry Technology Roadmap for the Automotive Market* was developed by the industry with support from the DOE Office of Transportation Technologies (June 1999). This roadmap defines actions needed to enhance the cost-effectiveness of using aluminum in automobiles. The focus is on increasing processing efficiency and reducing the cost of converting ingot, sheet, or extrusion products into vehicle parts or components.



...AND IDENTIFIES RESEARCH TO ACHIEVE THOSE TARGETS.



Team & Partnership Activities

“The smarter we run our plant, the better it is for the company’s bottom line, the local community, and the environment.”

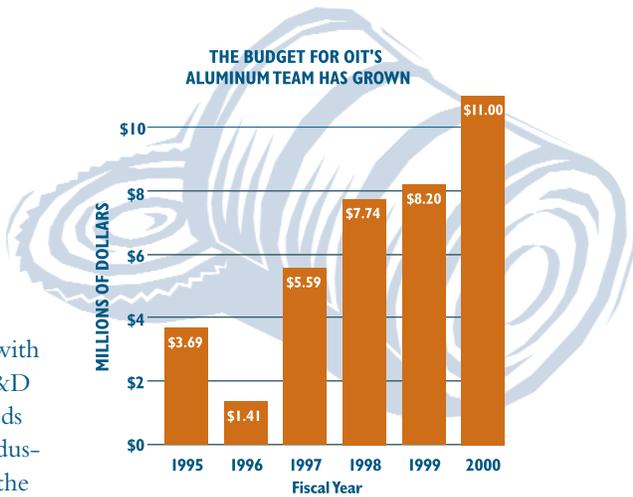
-- Cecil Pulley, Team Leader, Alcoa

ACTIVE INDUSTRY PARTICIPATION

Industry task groups work closely with OIT in crafting solicitations for R&D that will meet the most critical needs specified in the three aluminum industry roadmaps. Task groups identify the specific technology areas for the solicitations and perform technical review of the proposals that are received.

OIT’s Aluminum Team makes the final selection of projects for cost-shared funding on the basis of energy-efficiency and clean production benefits. All of the projects are awarded to collaborative partnerships, many involving national labs, universities, suppliers, and equipment manufacturers, in addition to aluminum manufacturers.

The budget provided to OIT’s Aluminum Team for funding cost-shared research has grown steadily in response

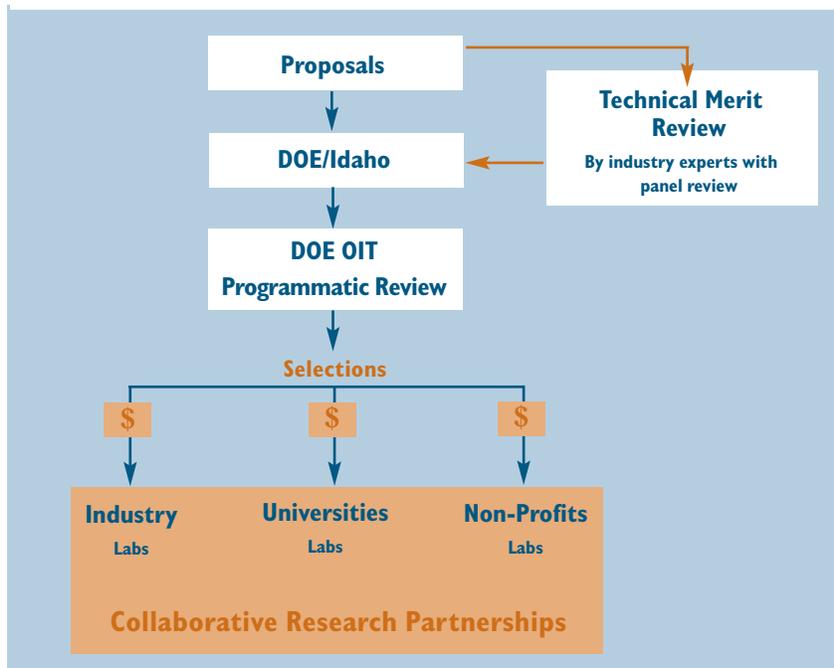


to the establishment of clear, industry-specified priorities for aluminum R&D. The Aluminum Association has played an active role in coordinating industry participation—both in developing the vision and roadmaps and in assisting the OIT Aluminum Team with feedback on planning and activities.

COORDINATION WITHIN OIT

OIT’s Aluminum Team supplements its own R&D budget by coordinating activities with other OIT programs that can help advance aluminum industry goals. As shown in the chart on the facing page, for example, a number of innovative processes for aluminum melting and forming have been developed by small businesses with guidance and assistance from OIT’s Inventions and Innovation program. Similarly, OIT’s program in Continuous Fiber Ceramic Composites (CFCCs) has contributed funding to several technologies that have application in aluminum melting and forming. OIT’s Steel and Metalcasting Teams also fund R&D that may have carryover benefits for aluminum production and recycling. Emerging technologies gain credibility after being demonstrated in plant conditions through OIT’s NICE³ program.

INDUSTRY PARTICIPATES IN SOLICITATIONS



REPRESENTATIVE ALUMINUM-RELATED PROJECTS IN OIT'S PORTFOLIO

	PRIMARY PRODUCTION	SECONDARY PRODUCTION	FORMING	PRODUCTS	RECYCLING
Aluminum Industry					
•Advanced Anodes and Cathodes	●				
•Molten Salt Detection and Removal		●			
•Aluminum Melting Using O ₂ -Enhanced Combustion			●		
•Grain Refinement Process		●			
•Inert Metal Anode For Low-Temperature Reduction	●				
•Vertical Flotation Melter		●			
•Potlining Additives	●				
•Explosion Prevention		●			
•Recycling/Reuse of Aluminum Waste					●
•Recycling of Saltcake					●
•Semi-Solid Aluminum Alloys			●		
•Conversion of Spent Potliner to Useful Products					●
•Wettable Ceramic-Based Cathodes	●				
Inventions & Innovation					
•Reflective Aluminum Chips				●	
•Products From Metal Powders				●	
•Filtering Molten Metal	●				
Industrial Materials					
•CFCC Immersion Tubes		●			
•Heat Treating Furnace Fan			●		
•Radiant Burner Reverberatory Screen		●			
NICE³					
•Aluminum Scrap Decoater		●			
•On-Site Process for Recovering Waste Aluminum					●
BestPractices					
•Efficient Electric Motor Systems at Alcoa (Alumax)	●	●	●		
Other IOF Metal-Related Projects					
•Dilute Oxygen Combustion		●			
•Laser-Based Ultrasonic Systems			●		
•Die Life Extension			●		

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

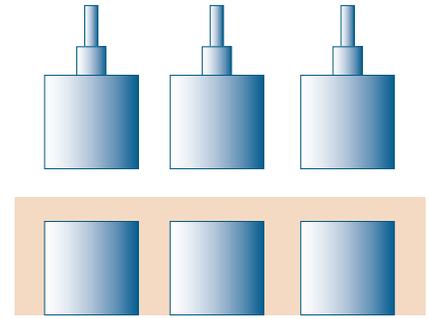
Selected Aluminum Portfolio Highlights



Lightweight aluminum chips form a reflective surface on asphalt roofs, reducing the need for air cooling.



The aluminum recycling industry landfills about 2 billion pounds of black dross and saltcake each year.



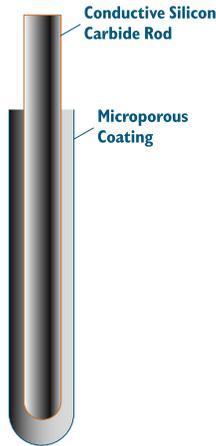
Stable ceramic cathode lining reduces energy consumed during aluminum production.

ALUMINIUM

3

www.oit.doe.gov/aluminum

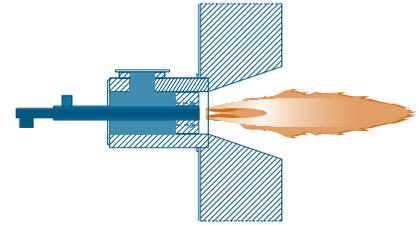
AREA	PRODUCTS	RECYCLING	PRIMARY PRODUCTION
PROJECT	Reflective Aluminum Chips	Recycling of Aluminum Dross/Saltcake	Wettable, Ceramic-Based Drained Cathode
DESCRIPTION	<p>With the help of a grant funded by OIT's Inventions and Innovation Program, Transmet Corporation developed a proprietary process for producing these 1-mm-square chips that have been used on more than 33 million square feet of roofing. The chips are an inexpensive way to reduce the energy demands and pollution associated with air conditioning.</p> <ul style="list-style-type: none"> • For each 10,000-square-foot warehouse roof, the chips save the equivalent of nearly 14 barrels of oil each year • Reduce air conditioning energy use (by 8.6 trillion Btu annually if <i>all</i> dwellings had such roofs) • Increase roof service life, reducing maintenance and reroofing costs • Cut installation costs and effort due to lighter weight 	<p>Conventional dross processors recover only the largest pieces of aluminum. Over 90% of the dross—which contains aluminum, salt, and the non-metallic portion (NMP)—is then landfilled. Under a NICE³ grant, ALUMITECH and the Ohio Department of Development constructed a commercial facility that makes the NMP suitable for processing into end-use products used in steel making. Success prompted ALUMITECH to fund construction of a new facility with four times the capacity.</p> <p>If 80% of current aluminum/black dross is processed:</p> <ul style="list-style-type: none"> • Save (potentially) over 19 trillion Btu annually • Divert 1.6 billion pounds of waste saltcake from landfills • Reduce CO₂ emissions by 50% 	<p>Ceramic-based wettable cathode materials and the necessary engineering packages are being developed to retrofit existing reduction cells as a means to improve the performance of Hall-Heroult cells. Researchers have developed the materials and will commence pilot- and industrial-scale tests of the technology.</p> <ul style="list-style-type: none"> • Potential energy savings of 1,500 megawatts per year (applied to current U.S. annual production of aluminum) • Cell efficiency increase of 13 to 20%
PARTNERS	Transmet Corporation	ALUMITECH, Inc. Ohio Department of Development	Advanced Refractory Technologies Kaiser Aluminum and Chemical Corporation Reynolds Metals Company



A simple electrical probe can sense the presence of salts in molten aluminum.



Efficiency of dust collection system fans increased by 10%.



The Air-Oxygen Fuel Burner provides high-efficiency operation, low natural gas consumption, and great flexibility in operation.

FORMING

Molten Salt Detection and Removal

Chloride salts initiate defects when they agglomerate and migrate to the surface of an ingot or casting. Selee Corporation has invented a simple electrical probe that detects salts in molten aluminum and a filter that selectively removes liquid salts from the liquid metal. The project seeks to calibrate the probe and test the filter under real casting conditions to assess capacity and efficiency.

- Potential to save 0.04 trillion Btu annually
- Improve metal quality and productivity
- Reduce chlorine use and release by about 71,000 cubic ft./year

Alcoa
Selee Corporation

PRODUCTION & FORMING

Efficient Electric Motors

As part of a DOE Showcase Demonstration project, Alcoa and Jacobs-Sirrine Engineers performed an in-depth analysis of fan systems at Alcoa's Mt. Holly Aluminum Production Facility. Turning off one of four fans and changing variable inlet vane set points reduced energy demand by 382 kW annually.

- Reduced annual energy use by 12%
- Saved \$103,736 per year in energy costs
- No capital cost; immediate payback
- Increased fan control accuracy
- Reduced noise and maintenance

Alcoa
Jacobs-Sirrine Engineers

SECONDARY PRODUCTION

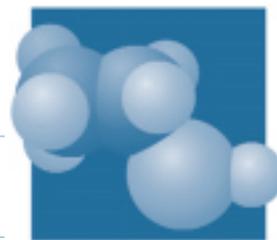
Oxygen-Enhanced Combustion for Efficient, Low-NOx Aluminum Melting

A novel, high-efficiency, high-capacity, low-NOx combustion system is being developed and integrated with a low-cost, on-site VSA (vacuum-swing-absorption) oxygen generation system. The resulting system will improve heat transfer to the melt and help meet environmental regulations in California. The system can be installed as a retrofit to the reverberatory furnaces commonly used in melting recycled aluminum.

- Increase production rate by 30% while reducing cost
- Maintain NOx emissions at level below California standards
- Reduce emissions of CO₂ and volatile organic compounds
- Decrease energy consumption by 40% relative to baseline air-fuel operation

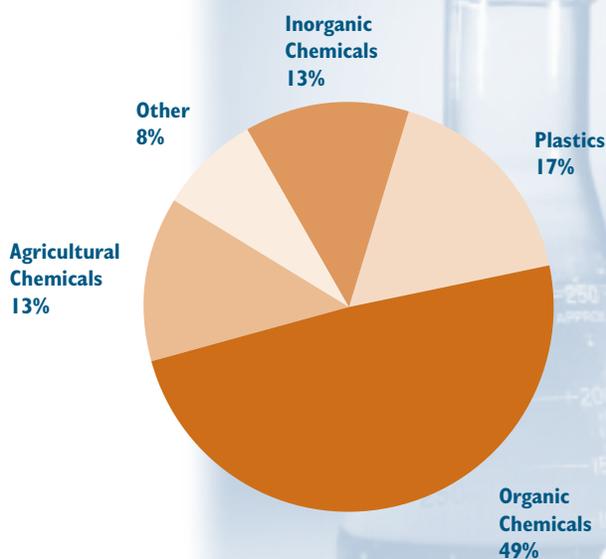
Air Products and Chemicals, Inc.
Brigham Young University
Wabash Alloys, L.L.C.
Argonne National Laboratory

The United States chemical industry is the world's largest, accounting for 25% of world chemical production. Chemicals are the building blocks of many products that meet our most fundamental needs for food, shelter, and health, as well as products vital to such advanced technologies as computing, telecommunications, and biotechnology.



Chemical Industry

PROFILE



Total Chemical Industry Energy Use = 5.3 quads

Value of Shipments	\$418.4 billion
Employment.....	877,100
Capital Expenditures	\$21.3 billion
Net Trade Balance	\$18.9 billion
Net Energy Consumption	5.3 quads

The United States chemical industry has been changing the way it does business as part of its continued efforts to remain globally competitive. For example, many of the industry's large companies have been increasing emphasis on life sciences and biotechnology. In addition, the chemical production process is becoming more comprehensive. Traditionally, some chemical companies manufactured primary or commodity chemicals, which were then sold to other chemical companies to refine into intermediate and

specialty chemicals. Today, more companies are manufacturing the entire spectrum of chemical products and marketing them directly to consumers, bypassing the secondary chemical companies and adding value to their own products.

MANUFACTURING AND OPERATIONS

About 9,000 chemical facilities account for more than 70,000 products that are essential to many industries such as pharmaceuticals, automobiles, textiles, furniture, paint, paper, electronics, agriculture, construction, appliances, and services. Investments in new plants and equipment reached \$21 billion in 1997, up from \$16.4 billion in 1992. Research and development funding reached an estimated \$18.6 billion in 1997, with pharmaceuticals R&D accounting for \$11.6 billion of that amount. The chemical industry continues to enjoy steady growth, contributing 2.1% of the annual U.S. GDP. Production in the overall chemical industry rose 5.1% in 1997 from the previous year, and an estimated \$418 billion worth of chemical products were shipped.

EMPLOYMENT

The chemical industry employs nearly a million people, almost half of whom work in chemical production. Approximately 90,000 chemists, engineers, and technicians are employed in R&D. More than 63% of chemical production is concentrated in ten states: Texas, New Jersey, Louisiana, Illinois, Ohio, California, North Carolina, Pennsylvania, New York, and South Carolina. Roughly 70% of basic chemicals are produced in the Gulf Coast region.

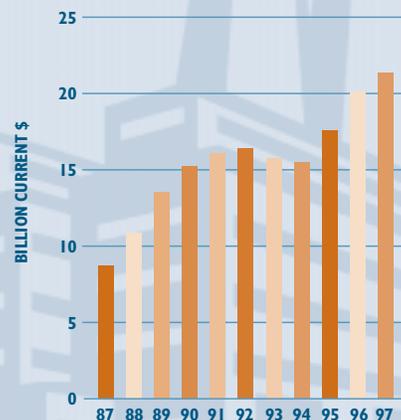
ENERGY

The chemical industry is energy-intensive, using energy as both fuel and feedstock. In 1994, the chemical industry consumed more than 5.3 quads of energy (the equivalent of over 2 million barrels of crude oil per day), which is approximately 25% of total manufacturing energy use. Of that 5.3 quads, over half was used for heat and power; the remaining energy was used as feedstock. The industry has made significant gains in energy efficiency, decreasing the energy consumed for fuel and power per unit of output by about 41% between 1974 and 1997.

ENVIRONMENT

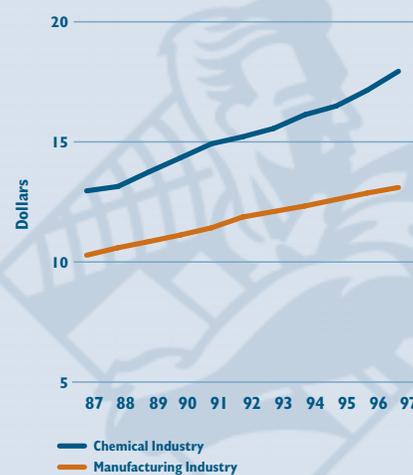
There are 16 major federal statutes as well as numerous state laws that impose significant compliance and reporting requirements on the industry. In addition, the industry's own voluntary program, Responsible Care®, further commits chemical companies to continuously improving their health, safety, and environmental performance in response to public concerns. The industry spent nearly \$7 billion in 1994 to meet government requirements for pollution abatement and control. These expenditures are clearly making a difference. The industry decreased toxic releases 51% between 1988 and 1997, yet production rose 38% during that same time period.

CHEMICAL INDUSTRY INVESTMENT IN PLANTS & EQUIPMENT, 1987-1997



Source: U.S. Census Bureau

HOURLY EARNINGS: CHEMICAL INDUSTRY VS. MANUFACTURING, 1987-1997



Source: U.S. Census Bureau

CHEMICAL INDUSTRY ENERGY USE



Source: EIA, MECS



Industry Vision and Roadmaps

CHEMICAL INDUSTRY VISION

Partnerships between the chemical industry and OIT continue to pursue the goals set forth in the 1996 industry document, *Technology Vision 2020: The U.S. Chemical Industry*. Working with representatives from a wide variety of companies and associations, the chemical industry and OIT are developing a portfolio of manufacturing technologies that will ensure the continued global success of U.S. chemical companies and products. *Technology Vision 2020* identifies the following areas as critical to improving the industry's competitiveness:

- New chemical science and engineering technology

- Supply chain management
- Information systems
- Manufacturing and operations

CHEMICAL INDUSTRY ROADMAPS

Technology roadmaps in several critical areas describe the priorities and performance targets necessary to meet the challenges facing the industry and to achieve the goals outlined in *Technology Vision 2020*. These roadmaps will guide R&D efforts in the five critical areas outlined in the vision.

In the area of **chemical synthesis**, the roadmap for new process chemistry promotes the use of alternative processes and reaction media that are more environmentally benign than traditional methods and make more efficient use of raw materials. Catalysis is also an important factor in chemical synthesis. About 90% of chemical manufacturing processes and more than 20% of all industrial products in the United States

THE CHEMICAL INDUSTRY ROADMAPS ESTABLISH INDUSTRY-WIDE PRIORITIES AND PERFORMANCE TARGETS...

SAMPLE PERFORMANCE TARGETS	Area	Targets
	Computational Fluid Dynamics	<ul style="list-style-type: none"> • Shorten lead times (from research to final plant design) to 3-5 years • Shorten plant down times to 1% • Reduce separation energy use and improve separation efficiency by 20% • Increase reliability of design/reduce or eliminate design errors
	Computational Chemistry	<ul style="list-style-type: none"> • Increase speed of performance by 2¹⁰ • Quantum scale—achieve 0.2kcal/mole accuracy for 20-30 heavy-atom systems and 1-2 kcal/mole accuracy for larger systems • Atomistic scale—routinely address systems of 1 million atoms/1,000 angstroms • Meso scale—predict continuum properties on scales as large as 10,000 nanometers with accuracy similar to atomistic level calculations
	Materials Technology	<ul style="list-style-type: none"> • Reduce the use of nonreusable (nonsustainable) materials by 20% • Reduce CO₂ emissions per kWh by 30% by 2020 • Increase speed of testing of materials by an order of magnitude by 2020
	Materials of Construction	<ul style="list-style-type: none"> • Minimize capital cost and energy consumption by 30% by 2020 • Maximize asset productivity by increasing uptime 25% and improving first-pass, first-quality yield by 20% • Protect the environment by containing the process with zero fugitive emissions, eliminating toxic discharges to the ground, and reducing hazardous wastes by 50% • Provide a safe operating environment with zero on-the-job injuries
	Separations, Biocatalysis, and Reaction Engineering	<ul style="list-style-type: none"> • Achieve 30% reduction in relative indicators for material usage, energy use, water consumption, toxic dispersion, and pollutant dispersion
	New Process Chemistry	<ul style="list-style-type: none"> • Reduce industry-wide energy intensity (energy per unit product) by 30% • Reduce total emissions and effluents from chemical manufacturing by 30% • Reduce cost of production by 25% • Reduce lead-times and time-to-market for new products and technologies by 30%
	Catalysis	<ul style="list-style-type: none"> • Accelerate the catalyst discovery process • Develop catalysts with selectivity approaching 100%

rely on various catalytic steps. Goals outlined in the *Catalysis Report* will help the industry realize significant process improvements. For example, if all catalytic processes associated with the top 50 chemicals were raised to their maximum process yields, total energy savings would exceed an estimated 0.47 quads per year.

Bioprocessing and biocatalysis will become increasingly important in the coming decades as lower energy and more environmentally friendly process methods are developed. The biocatalysis roadmap outlines the R&D needed to increase the use of bioprocessing in the chemical industry.

The development of new **materials**, such as synthetic polymers and composites, has fueled the growth of the chemical industry. These materials are used to create products with lower weight, better energy efficiency, higher performance and durability, and increased flexibility. Two new road-

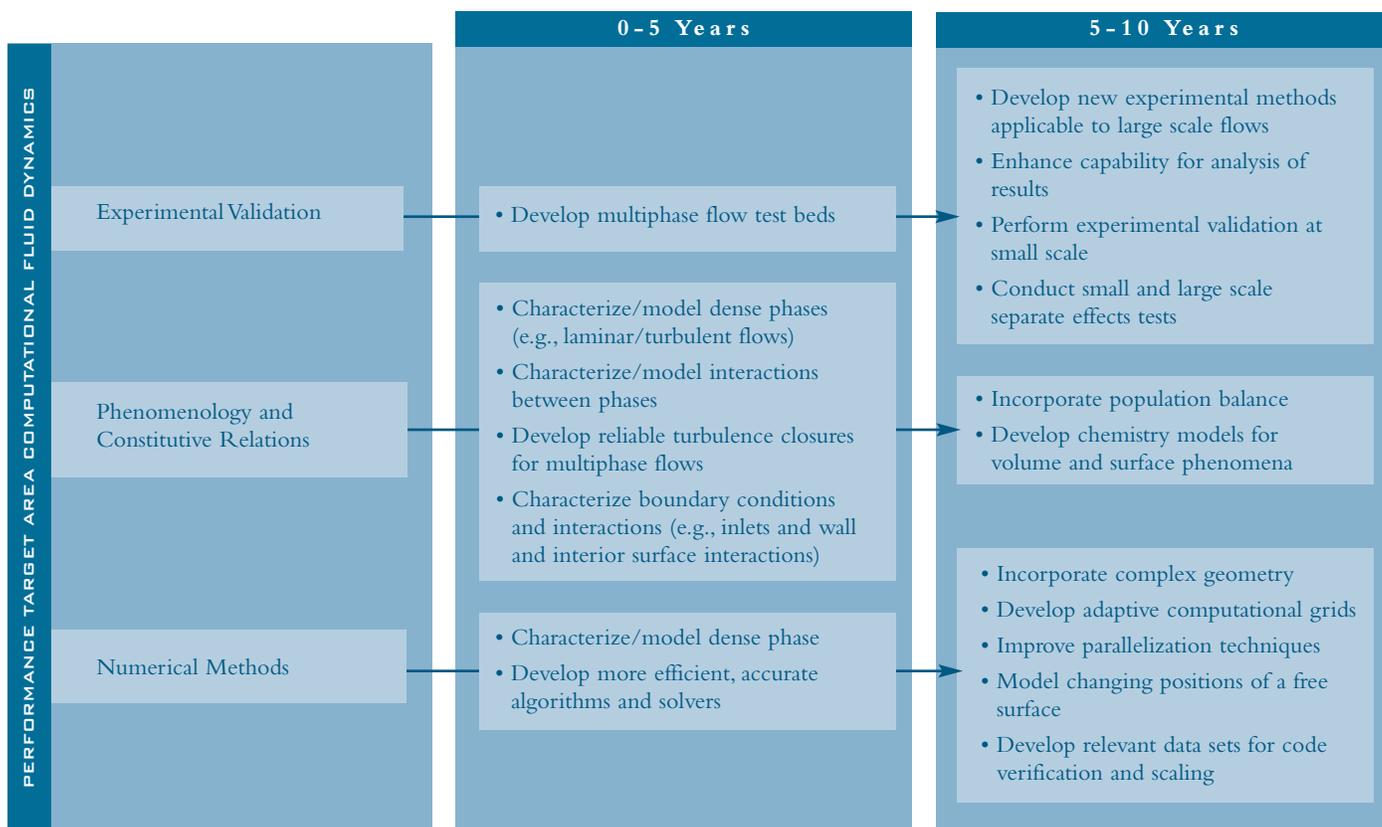
maps, *Materials Technology* and *Materials of Construction*, outline goals for the further enhancement of new materials technology and materials used in the construction of processing equipment.

Separations, reaction engineering, and chemical measurements are critical elements of **process science and engineering**. Separation processes underlie virtually all aspects of the production process. Additionally, separation processes account for nearly two-thirds of the industry's process energy consumption. *Vision 2020: 2000* Separations Roadmap identifies R&D needs in eight separation technologies: adsorbents, crystallization, distillation, extraction, membranes, separative reactors, bioseparations, and dilute solutions. Reaction engineering covers reactor design and scale-up, chemical mechanisms, and new reactor development. Addressing these research needs should result in optimized, integrated reactor systems with higher selectivity, yield, and purity. **Chemical measurements**

are needed to characterize, monitor, and control chemical processes. Although no roadmap has been developed, a workshop has been held to define future R&D needs in this area.

Computational technologies are used in many aspects of chemical R&D, design, and manufacturing and have a broad range of applications—from molecular modeling to process simulation and control. The industry has developed roadmaps in two computational technology areas: computational chemistry and computational fluid dynamics. The impact of advances in these areas could be dramatic: reduced plant downtime, quicker progression from R&D to market, increased efficiency, and more reliable designs.

...AND IDENTIFY RESEARCH TO ACHIEVE THOSE TARGETS.



Team & Partnership Activities

ACTIVE INDUSTRY LEADERSHIP

Guided by the goals defined in *Technology Vision 2020* and the technology priorities described in the roadmaps, OIT's Chemical Industry Team works in partnership with industry, trade groups, other government agencies, and the academic community. By aligning interests and leveraging capabilities and resources, these groups are creating the momentum needed to increase the energy efficiency and competitive position of the U.S. chemical industry.

The industry has established an executive steering group to assist OIT in determining how best to align its research activities with industry goals. The expertise and guidance of the industry leaders on the steering committee are helping the Chemical Industry Team ensure that the chemical R&D portfolio yields the greatest benefits for the industry while contributing to national goals for improved energy efficiency and environmental quality.

AN EXTENSIVE R&D PORTFOLIO

Through the roadmapping process, industry has identified critical chemical R&D areas. OIT is now working with industry to advance research in those areas by soliciting proposals for relevant R&D projects. Industry experts perform technical reviews of proposals received and, based on their recommendations, OIT's Chemical Industry Team makes the final selection of projects for cost-shared funding.

Currently, OIT's Chemical Team portfolio includes 28 projects. These projects represent a wide range of R&D activities that support *Technology Vision 2020* and the industry's roadmaps. Some aim to improve enabling technologies, such as computations, while others explore the possibilities in new chemical sciences, such as new materials and chemical synthesis.

COOPERATIVE ACTIVITIES

Since the chemical industry's outputs form the building blocks for products in a variety of other industries, the Chemical Team encourages joint efforts with OIT's other Industries of the Future teams to meet its vision goals. Similarly, many of OIT's enabling technologies programs—those that can potentially benefit a wide range of industries—offer opportunities for cosponsored activities with the chemical industry. Recently, the Chemical Team joined forces with OIT's Petroleum Team to collaborate on projects and activities of mutual benefit, including:

- a Practical Minimum Energy study to explore opportunities for improving energy efficiency
- joint efforts in multiphase computational fluid dynamics
- communications activities through the American Institute of Chemical Engineers

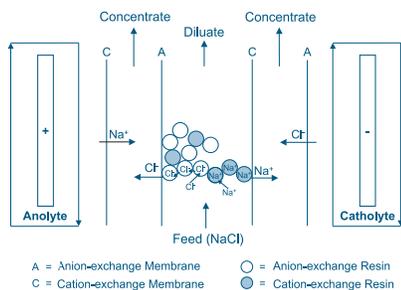
OIT's portfolio mix also includes activities, tools, and information to help the industry solve immediate competitive and environmental challenges. OIT's BestPractices programs provide support directly to companies with an emphasis on improving energy efficiency in the normal course of production.

REPRESENTATIVE CHEMICAL-RELATED PROJECTS IN OIT'S PORTFOLIO

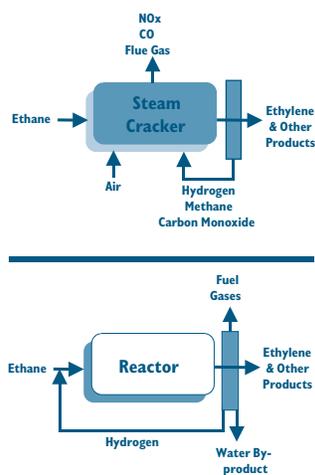
	CHEMICAL SYNTHESIS	BIOTECHNOLOGY	MATERIALS	PROCESS SCIENCE & ENGINEERING	COMPUTATIONAL TECHNOLOGY
Chemical Team					
•Membrane for p-Xylene Separation			●	●	
•Direct Production of Silicones from Sand	●		●		
•Electrodeionization for Product Purification				●	
•Multi-Phase Computational Fluid Dynamics	●		●	●	●
•Sorbents for Gas Separations			●	●	
•Nanoscale Catalysts	●			●	
•Oxidative Cracking of Hydrocarbons to Ethylene	●		●	●	
•Selective Oxidation of Aromatic Compounds	●			●	
•Recovery of Thermoplastics via Froth Flotation			●	●	
•Catalytic Hydrogenation Retrofit Reactor	●			●	
•Separation of Hydrogen/Light Hydrocarbon Gases			●	●	
•Membrane Tube Module			●	●	
•Pressure Swing Absorbtion for Product Recovery				●	
•Alloys for Ethylene Reactors			●	●	
•Development of Non-Aqueous Enzymes	●	●			
•Chloro-Alkali Electrochemical Reactors	●			●	
•Plastics from Cellulose		●	●		
•Integrated Workbench for Gas-Phase Thermodynamics					●
•Instrumentation of Multiphase Flows					●
Combustion					
•NO _x Emissions Reduction by Oscillating Combustion				●	
•Radiation Stabilized Burner				●	
•Dilute Oxygen Combustion				●	
•Forced Internal Recirculation Burner				●	
Best Practices					
•Practical Minimum Energy	●	●	●	●	
•Plant-wide Assessments			●	●	
•Efficient Motor, Steam, Compressed Air, and CHP Systems				●	
Industrial Materials					
•Nickel Aluminides			●	●	
•Oxide Membranes			●	●	
•Metals Processing Laboratory			●	●	
Sensors & Controls					
•Intelligent Extruder			●	●	

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

Selected Chemical Portfolio Highlights

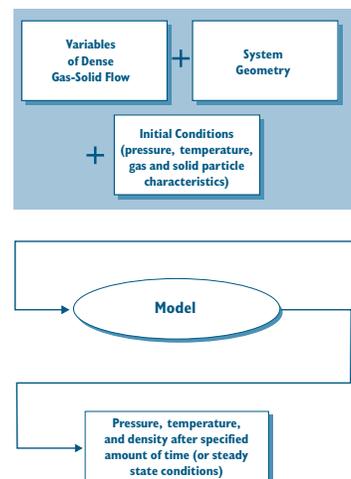


Electrodeionization combines ion exchange and electro-dialysis to offer efficient, continuous operation.



The energy-efficient oxidative cracking process requires a reactor much smaller than a steam cracker.

Characteristics of Gas-Solid Flow



Computational models will predict characteristics of gas-solid flow to improve productivity in the petrochemical industry.

PROCESS SCIENCE & ENGINEERING

Electrodeionization for Product Purification

Electrodeionization, also called electro-chemical ion exchange, has been recently established to make high-purity water for boiler feed, semi conductors, and pharmaceutical applications. To extend the use of this energy-efficient and non-polluting technology to the chemical industry, novel device technology is being developed and scaled up. Successful results will enable the direct deionization of chemical product streams economically, efficiently, and without creating waste salts:

- Potential energy savings of 5.3 x 10¹² Btu in 2020
- Wastewater reduction of 61.5 x 10⁶ tons per year
- Avoids use of chemical regenerates

Argonne National Laboratory
EDSep, Inc.
The Puro-lite Company

CHEMICAL SYNTHESIS

Oxidative Cracking of Hydrocarbons to Ethylene

Production of ethylene by the traditional steam cracking process has been ranked as the single most energy-intensive process in the chemical industry. A new, internally fired process does not require a furnace, produces no flue gas, and eliminates decoking shutdowns. The simplified process produces the required olefin, along with water and small amounts of fuel gas.

- Eliminate NO_x production
- Reduce carbon dioxide generation
- Save 11 to 15 trillion Btu annually by 2020
- Conserves resources

Sandia National Laboratory
Los Alamos National Laboratory
Dow Chemical Company
University of Minnesota
Reaction Engineering International

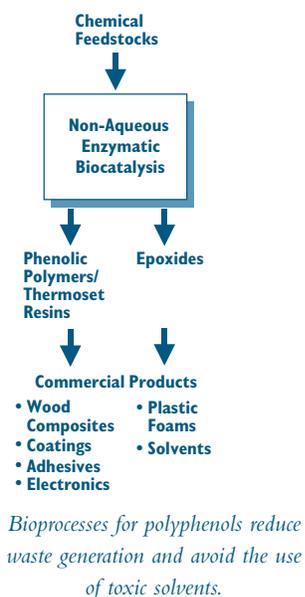
COMPUTATIONAL TECHNOLOGY

Multiphase Computational Fluid Dynamics

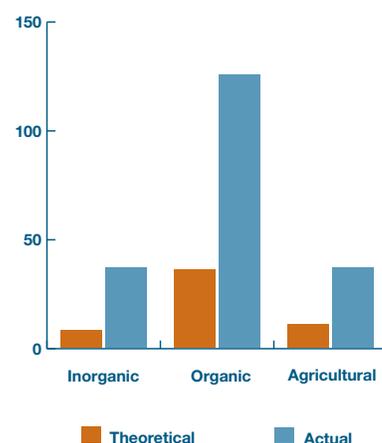
The Multiphase Fluid Dynamics Research Consortium was established to advance Computational Fluid Dynamics (CFD) beyond the state-of-the-art achievable by any single business or laboratory. The consortium's current projects include developing a computer model that can accurately predict dense gas-solid turbulent flow, which is the industry's highest priority for CFD modeling.

- Improves overall gas-solid flow operating capacity by as much as 90%
- Increases the capacity of existing gas-solid processes by 10-20%
- Increases industrial productivity

The consortium is a partnership among five DOE National Laboratories, seven universities, seven petrochemical companies, an energy equipment manufacturer, and a computer manufacturer.



Alloy coatings are expected to reduce carburization and coke formation inside ethylene furnace tubes.



Practical minimum energy use for selected chemical products and processes falls between the theoretical minimum and actual use.

BIOTECHNOLOGY

Development of Non-Aqueous Enzymes

Chemical processes currently employed to produce phenolic polymers use formaldehyde, create undesirable by-products, or generate wastes that require treatment. Producing polyphenols through biocatalysis would enable manufacturers to significantly reduce costs and avoid disposal pre-treatments. Researchers are developing active and stable biocatalysts to carry out phenolic polymerization and to directly epoxidize propylene and other alkenes.

- Could save nearly 70 trillion Btu in 2020
- Higher yields with less waste
- Increased process efficiency

Massachusetts Institute of Technology
Oak Ridge National Laboratory
Rensselaer Polytechnic Institute
University of California–Berkeley
Four chemical company collaborators

MATERIALS

Alloys for Ethylene Reactors

Coating the inside of ethylene furnace tubes with intermetallic alloy materials promises to reduce tube maintenance, a leading cause of inefficiency in ethylene production. Research is focusing on using these coatings to prevent two major problems with conventional tubes: carburization, which limits tube life, and coke formation, which requires costly plant shutdowns to steam decoke the tubes. Fabrication methods and welding techniques are also being developed.

- Longer tube service life
- Reduced furnace downtime
- Improved reaction conditions
- Lower energy use

Exxon Chemical Company
Shell Chemical Company
BP Amoco
Air Products and Chemicals, Inc.
Oak Ridge National Laboratory
Plus 6 other industry partners

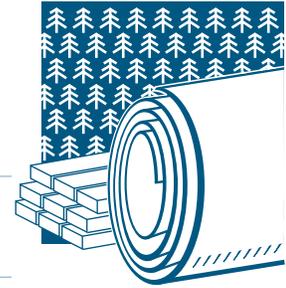
BEST PRACTICES

Practical Minimum Energy Study

The objectives of this work are to develop baseline energy use for the manufacture of major chemicals and to determine the best and least energy-intensive way to manufacture those chemicals under practical operating conditions. The initial focus is on five chemical compounds within a single reaction class. Researchers will determine energy use in four different scenarios: theoretical; current practice; the most efficient combination of existing unit operations (processes); and the best practical combination of emerging unit operations. When completed for all top fifty chemicals, practical energy use minimums will assist decision-makers in developing energy management strategies and provide a useful comparison of energy needs across the chemical industry.

Bridges to Sustainability
University of Texas
University of Houston
North Carolina State University
Rice University

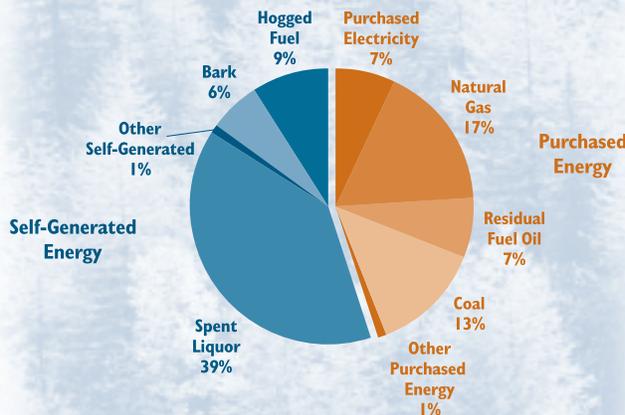
America's vast forest resources have helped make the U.S. forest products industry a world leader. The industry produces over \$267 billion in wood and paper products each year. Materials from these products are used by consumers every day for communication, shelter, sanitation, and protection.



Forest Products Industry

Value of Shipments	\$253.1 billion
Employment	1.23 million
Capital Expenditures	\$12.1 billion
Net Trade Balance	-\$7.63 billion
Net Energy Consumption	3.16 quads

PULP AND PAPER INDUSTRY ENERGY SOURCES, 1993



INDUSTRY SEGMENTS

The U.S. forest products industry is divided into two major segments: lumber and wood products, and pulp and paper products. The lumber and wood products segment processes solid wood products and grows, harvests, and processes wood and wood fiber. In 1997, the lumber and wood products segment shipped about \$103 billion worth of products.

The pulp and paper segment manufactures pulp, paper, and paperboard products from virgin and recycled fiber.

Although only 16% of the world's pulp mills are located in the United States, the United States produces 35% of the world's pulp and close to one third of the world's paper. This equates to 82 million tons of paper and paperboard and 10 million tons of market pulp.

Industry facilities range from large, state-of-the-art mills to small, family-owned sawmills. These mills use resources from approximately seven million individual woodlot owners.

EMPLOYMENT

The U.S. forest products industry employs 1.23 million people directly and ranks as one of the top 10 manufacturing industries in 46 of the 50 states. In 1997, the paper segment employed 575,000 workers at an average hourly wage of \$16.17, which exceeded the average worker's hourly pay by about 32%. Average hourly wages for the entire forest products industry that year were \$13.65.

CAPITAL INVESTMENT

The forest products industry is one of the most capital-intensive industries because of the high cost of papermaking and pollution control equipment. On average, the paper industry has invested more than \$120,000 per worker.

COMPETITION

Following decades as a global leader, the U.S. forest products industry is increasingly challenged by its traditional competitors, such as Canada, Scandinavia, and Japan, as well as emerging nations like Brazil, Chile, and Indonesia.

Long-term competitiveness in today's global economy will require enhanced financial performance through improvements in energy and capital efficiency. In particular, the industry must focus on cost-effective use of recycled materials and reduction of energy costs.

ENERGY USE

The forest products industry is the third most energy-intensive industry in the United States — only petroleum refining and chemicals consume more energy. The industry uses approximately 3.16 quads of energy per year to make its products. Of this total, the lumber and wood products segment uses nearly half a quadrillion Btu (quad), and the pulp and paper segment uses 2.7 quad.

The industry makes significant use of renewable sources, including pulping liquor, bark, and wood. Currently, the industry is 54% energy self-sufficient, up from 36% in 1972. Even so, the industry spends about \$8 billion on purchased energy each year, or nearly 3% of the value of its shipments. On average, these expenditures are nearly twice those of other industries.

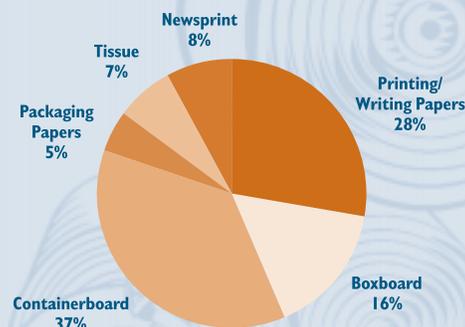
ENVIRONMENT

The industry spends more than \$1 billion per year on environmental improvements and \$2.9 billion on pollution control. These costs could increase dramatically due to stricter environmental regulations expected over the next decade. Currently, the industry is ahead of schedule in meeting emissions reduction goals developed by the Environmental Protection Agency.

RECYCLING

Waste recovery and recycling are critical to meeting environmental goals. These efforts also increase profitability by broadening the industry's raw materials base. About 45 million tons, or 42% of paper in the United States, is recovered for recycling each year. The industry is striving to increase this rate to 50% in the year 2000. In addition, more than 400 of the 547 pulp and paper facilities in the United States use recovered paper as one of the raw materials for papermaking, and more than 200 rely on it entirely.

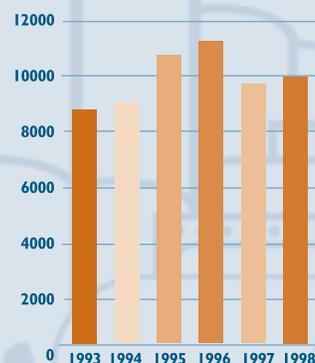
U.S. PAPER AND PAPERBOARD PRODUCTION, 1997



Total Paper: 44,679 million tons
Total Paperboard: 50,346 million tons

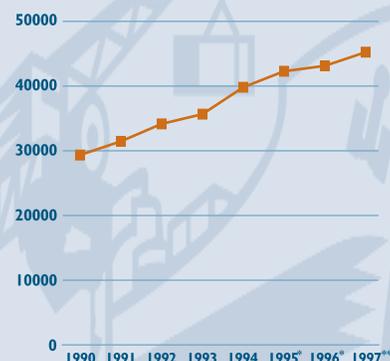
Source: American Forest and Paper Association

CAPITAL SPENDING BY U.S. PAPER AND ALLIED INDUSTRY (million \$)



Source: Pulp and Paper Project Report

U.S. WASTEPAPER RECOVERY (thousands of tons)



* Revised
** Preliminary

Source: American Forest and Paper Association

Industry Vision and Roadmap

FOREST PRODUCTS INDUSTRY VISION

In 1994, the U.S. forest products industry, represented by the American Forest and Paper Association (AF&PA), published its strategic vision. *Agenda 2020: A Technology Vision for the Future* describes the industry's status, its broad goals and vision for the future, and technology requirements to achieve this vision.

Agenda 2020 describes how, despite a record of success, the forest products industry must now address the changing standards of society while remaining economically viable and globally competitive. Pressures on performance and competitiveness include decreased availability of land, increased interest in recycling, increased foreign competition,

more demanding environmental requirements, and the need to reduce capital and energy intensity.

To meet these challenges, the forest products industry vision calls for pre-competitive research, development, and demonstration in six technology areas:

- Sustainable Forestry
- Environmental Performance
- Energy Performance
- Capital Effectiveness
- Recycling
- Sensors and Control

PRESSURES ON PERFORMANCE AND COMPETITIVENESS

Decreased availability of land	In the future, less land will be available for planting and harvesting trees, which will drive up prices. It will also create pressure to use lower quality wood, which requires higher energy use.
Increased interest in recycling	Increased demand for recycling means lower grades of recovered fibers used. Upgrading this fiber is costly and energy-intensive.
Foreign competition	The United States increasingly faces competition from low-cost producers like Chile and South Africa, and from countries that have gained technological leadership, like Canada and Scandinavia.
More demanding environmental requirements	Compliance with new regulatory initiatives means unprecedented increases in capital expenditures, operating costs, and energy use.
High capital and energy intensity	Long-term viability demands improvements in energy and capital efficiency if financial performance is to reach satisfactory levels.

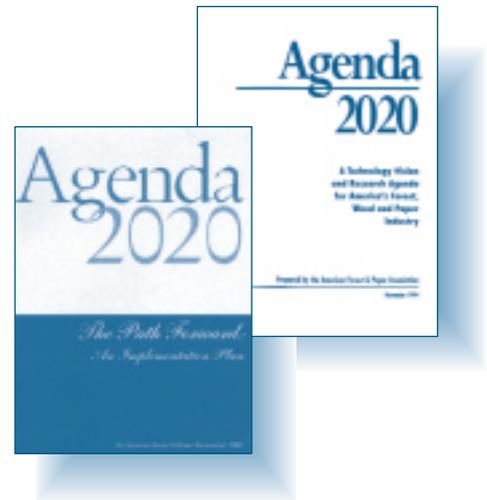
**FOREST PRODUCTS
INDUSTRY ROADMAP**

Industry-led task groups, organized in cooperation with the AF&PA, were established for each of the six technology areas identified in *Agenda 2020*. Comprised of representatives from academia, government, national laboratories, and a broad cross-section of the industry, each group developed a detailed vision of the future for its specific area, identified technology required to achieve the vision, and developed a prioritized program or agenda. This information was used to

develop research pathways, or roadmaps, for each vision area. These research pathways, known collectively as the *Implementation Plan*, describe:

- the link to *Agenda 2020*
- ongoing and future research needs
- desired research products and results

The pathways are updated annually by the task groups and provide the basis for competitive solicitations for research proposals.



FOCUS AREAS IN AGENDA 2020 IMPLEMENTATION



Team & Partnership Activities

To manage the IOF process, OIT and AF&PA rely on the six task groups established for each of the technology focus areas. The groups define specific research needs, issue requests for proposals, and evaluate and recommend proposals for funding to the industry's chief technology officers (CTOs). CTOs make final recommendations to OIT's Forest Products Team, which cost-shares selected projects with industry. As of October 1999, 91 research projects had been funded through the forest products Industries of the Future process.

PROGRESS OF THE FOREST PRODUCTS IOF

The program has made significant strides since it became the first 'Industry of the Future' in 1994. Industry partners consider the program a success, not only for the resulting technologies, but because the program helped industry determine its long-term priorities. According to Ben Thorp, director of Pulp and Paper Engineering at Georgia Pacific Corporation and co-chair of the Capital Effectiveness Task Group, "The program helped the pulp and paper industry come together to establish rules for working together and decide what was important to the industry. These pathways not only helped industry, but suppliers and academic institutions as well. Instead of each forecasting on its own, we now have a very broad and very real picture of industry needs. No one company or organization could have afforded that. Subsequently, the IOF process will have a huge commercial impact."

LEVERAGING RESOURCES

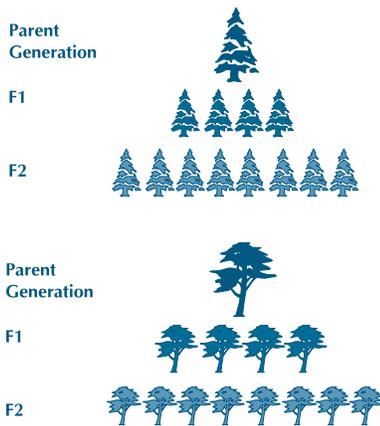
Now that the industry has identified its goals and priorities, the Forest Products Team is developing partnerships with other organizations to leverage available resources. The team is currently developing partnerships with other government agencies, such as the U.S. Department of Agriculture (USDA). Currently, the USDA is cost-sharing nine projects with industry. OIT is also working with other DOE offices, including the Office of Power Technologies, to fund gasification research, one of the industry's most promising new technologies. In addition, the Forest Products Team works with several other IOF teams, including Agriculture and Chemicals, to cost-share R&D projects of mutual benefit.

REPRESENTATIVE FOREST PRODUCT-RELATED PROJECTS IN OIT'S PORTFOLIO

	SUSTAINABLE FORESTRY	ENVIRONMENTAL PERFORMANCE	ENERGY PERFORMANCE	CAPITAL EFFECTIVENESS	RECYCLING	SENSORS & CONTROLS
Forest Products Team						
•Acoustic Separation Technology					●	
•Biomass/Black Liquor Gasification Combined Cycle		●	●	●		
•Bleach Plant Capital Reduction				●		
•Intensively Managed Forests	●					
•Low-VOC Drying of Lumber and Wood		●				
•Marker-Aided Selection Methods	●					
•Methane de-NOx® Reburn Technology			●			
•Multiport Cylinder Dryers			●			
•Near Infra-Red Sensor						●
•Pine Gene Discovery Project	●					
•Productivity of High-Yield Hardwood Species	●					
•Removal of Wax and Stickies					●	
Industrial Materials						
•Materials for Kraft Recovery Boilers				●		
Inventions & Innovation						
•Acoustic Humidity Sensor						●
•Apparatus for Removing Bark from Whole Logs	●					
•Molten Film Paper Dryer			●			
NICE³						
•Chemicals for Increasing Wood Pulp Yield		●				
•Long Wavelength Infrared Drying System for Wood Fiber			●			
•Pallet Production Using Post-Consumer Wastepaper					●	
Sensors and Controls						
•Non-Contact Laser Acoustic Sensor						●

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

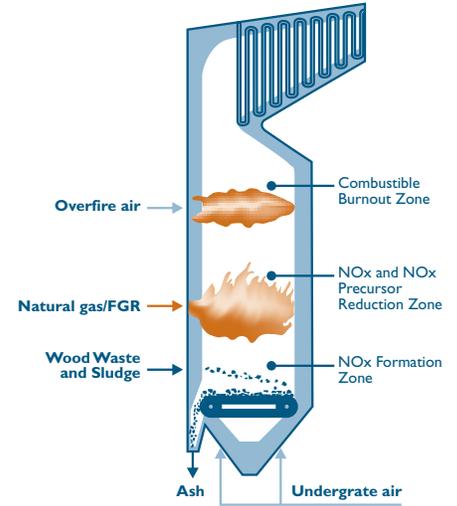
Selected Forest Products Portfolio Highlights



Researchers are developing tools to improve future planting stocks.

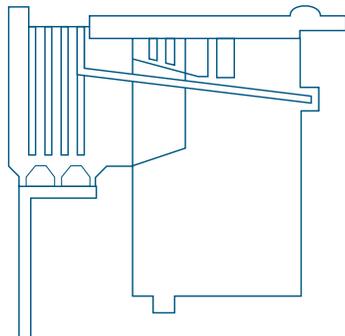


A charge of lumber loaded in a low-headspace vessel at Georgia Power's test center.

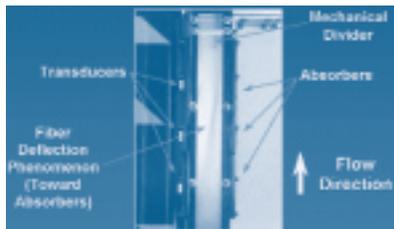


Spreader Stoker Boiler with Methane de-NOx[®] Reburn

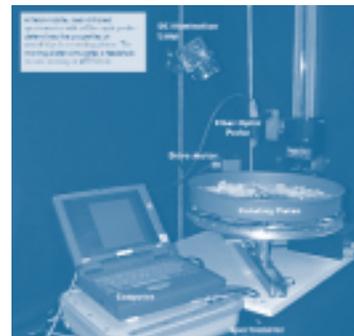
AREA	PROJECT	DESCRIPTION	PARTNERS
SUSTAINABLE FORESTRY	Marker-Aided Selection Methods for Wood Properties	Trees with certain genetic characteristics improve the quality of pulp, paper, and other wood products manufactured from them. Researchers at Oak Ridge National Laboratory and industry partners are using rapid analytical techniques to identify molecular markers in trees and associate these markers with the trees' genetic characteristics. This method provides foresters with tools to improve future planting stocks by selecting characteristics like overall wood density, fiber dimensions, and cellulose and lignin content.	Oak Ridge National Laboratory Institute of Paper Science and Technology National Renewable Energy Laboratory University of Washington U.S. Forest Service Weyerhaeuser Company
ENVIRONMENTAL PERFORMANCE	Low VOC Drying of Lumber	Conventional wood drying processes release volatile organic compounds (VOCs), which contribute to the formation of smog. The Institute of Paper Science and Technology is working with project partners to develop and demonstrate a radio-frequency unit that removes VOCs prior to conventional drying. Radio frequency pretreatment of lumber reduces energy and capital costs, while removing over 70% of VOCs. The VOCs (principally terpenes) can be condensed and sold for use in making turpentine. The technology can replace expensive, energy-intensive VOC control equipment that many federal and state regulations now require.	Institute of Paper Science and Technology American Kiln Electric Power Research Institute Georgia-Pacific Corporation Georgia Power Potlatch Corporation
ENERGY PERFORMANCE	Methane de-NOx[®] Reburn Technology	Biomass, wood waste solids, and sludges are difficult to burn in stoker boilers because of their low combustion temperatures and high NOx emissions. A new technology called METHANE de-NOx [®] reburner may help to overcome these problems. With its partners, IGT is demonstrating the retrofit in a waste wood and sludge-fired stoker boiler at a Boise Cascade papermill. Results show a three-fold increase in sludge firing rates, an increase in boiler efficiency, a 50% decrease in NOx emissions, and a 30% decrease in natural gas use in co-firing. Annual savings of about \$400,000 in sludge handling/disposal costs and \$270,000 in fuel costs are anticipated.	Institute of Gas Technology Detroit Stoker Boise Cascade Babcock and Wilcox Sargent and Lundy LCC



Researchers are developing tools to identify and minimize corrosion-related problems in black liquor recovery boilers.



A new separation technology takes advantage of the effects of acoustic radiation on fiber suspension.



An infra-red light helps researchers determine physical and chemical characteristics of wood chips.

CAPITAL EFFECTIVENESS

Materials for Kraft Recovery Boilers

Corrosion of boiler tubes reduces the energy efficiency of Kraft recovery boilers and can cause leaks that precipitate dangerous smelt/water explosions.

OIT's Advanced Industrial Materials program is working with Oak Ridge National Laboratory to identify the cause of cracking in coextruded tubing in black liquor recovery boilers. The objective is to develop alternative materials and procedures that minimize corrosion-related problems.

- Improve boiler safety
- Reduce downtime
- Decrease costs for equipment replacement

Oak Ridge National Laboratory and numerous industry and other partners

RECYCLING

Acoustic Separation Technology

Currently, the forest products industry uses inefficient pressure-screen systems to separate fibers. More efficient separation technologies can eliminate problems like clogging and fiber damage, while increasing controllability and other benefits.

The Institute of Paper Science and Technology has found that fibers suspended in water migrate and reorient themselves when they interact with acoustic radiation pressure. The institute is exploiting this principle to separate fibers based on fiber width.

Additional applications are related to deinking and pulp-thickening operations and improved particle removal in closed water systems.

Institute of Paper Science and Technology
State of Georgia
Beloit Corporation

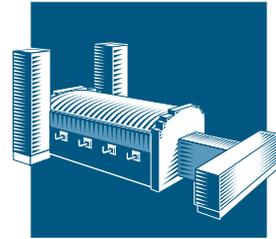
SENSORS AND CONTROLS

Near-Infrared Sensor

A project by the National Renewable Energy Laboratory and Ames Laboratory involves use of infra-red light to chemically analyze wood chips in real-time, which will help predict the quality of the final paper product. Researchers will use this technology on trees before they are harvested to determine physical and chemical characteristics of their feedstock, such as density, moisture, carbohydrate and lignin content. Pulp and paper mill operators will use this technology to monitor and control variations in the manufacturing processes.

National Renewable Energy Laboratory
Ames Laboratory
Weyerhaeuser Company
Champion International
Westvaco
Rayonier
Georgia-Pacific
Mead

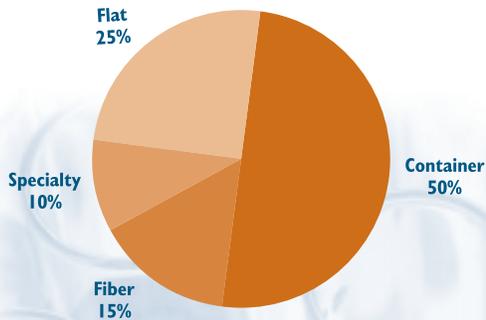
The American glass industry is among the most productive and technologically advanced in the world. It manufactures more than 20 million tons of consumer products each year with an estimated value of \$27 billion.



Glass Industry

PROFILE

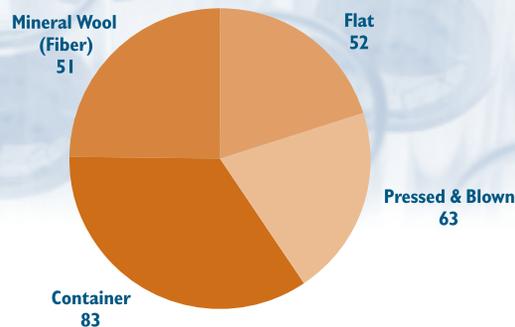
U.S. GLASS PRODUCTION BY SECTOR, 1997



Source: U.S. Dept. of Commerce and industry estimates

Value of Shipments	\$27.2 billion
Employment	150,400
Capital Expenditures	\$1.93 billion
Net Trade Balance	-\$151 million
Net Energy Consumption	249 trillion Btu

ENERGY USE BY SEGMENT, 1994 (trillion Btu)



Source: EIA

MARKETS

Glass is an integral part of the American lifestyle and a staple of the nation's economic success. Its popularity as a material stems from its transparent, recyclable, and nonpermeable qualities.

The U.S. glass industry is comprised of four major segments:

- Container glass
- Fiberglass
- Flat glass
- Specialty glass

COMPETITION

Over the past 25 years, the container and flat glass segments of the industry have become more streamlined—a result of competition from other materials, excess capacity, and rising costs for labor, energy, and environmental compliance. At the same time, the advent of fiber optics and other products have opened up new markets in the specialty glass segment. The industry is now more efficient and closely aligned with customer needs, yet increasingly dependent on improvements in basic processes and product innovations to gain a competitive edge.

Today, the U.S. glass industry's biggest competitive challenges come from (1) foreign glass producers, who typically enjoy lower labor costs and fewer environmental regulations, and (2) producers of alternative materials, such as plastics and aluminum. Meeting these challenges will require careful investment of resources to improve manufacturing processes, make more efficient use of energy and materials, and create new uses for glass.

EMPLOYMENT

Over 150,000 people are employed by the four segments of the U.S. glass industry or by firms manufacturing products of purchased glass. Their average hourly wage is \$15.53, which is above the manufacturing average of \$13.17 per hour.

ENERGY

Despite the many advantages of glass, glassmaking is energy-intensive. The industry spends over \$1.4 billion annually on the energy used in manufacturing. In 1994, glass industry processes consumed about 249 trillion Btu. Approximately 80% of this energy was in the form of natural gas, 17% in the form of electricity, and the remaining 3% in the form of fuel oil and other fuels.

Whereas melting one ton of glass should theoretically require only about 2.2 million Btu, in practice it requires at least twice that much due to various inherent inefficiencies. Overall, energy accounts for about 13% of the total cost of glass products.

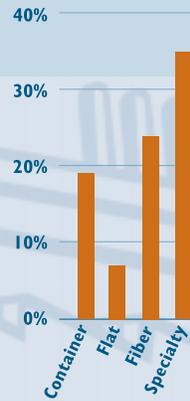
ENVIRONMENT

In comparison with other materials industries, the glass industry has a relatively modest impact on the environment. Its primary materials are in abundant supply and glass products are largely inert and highly recyclable. Nevertheless, the reduction of undesirable emissions and wastes is a central concern of the industry.

Over the past 20 years, increased government regulations have prompted the industry to modify many of its processes and equipment to reduce emissions of NO_x, SO_x, and particulates. For example, the introduction of oxyfuel firing, in which fuel is burned in a pure oxygen environment, has reduced emissions of critical air pollutants by 50% or more. In particular, oxyfuel furnaces significantly reduce NO_x emissions, but they present other operational drawbacks—primarily the high cost of oxygen.

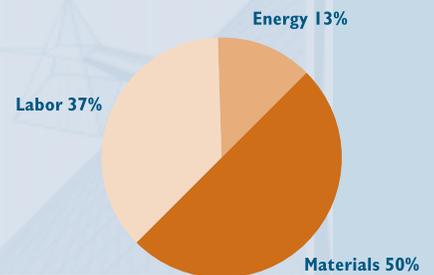
Since recycled glass or cullet can be melted at lower temperatures than raw materials, use of cullet can lower manufacturers' energy costs by \$2 to \$5 per ton (compared to use of virgin materials), depending on the industry segment. Recycling can also reduce the use of raw materials, decrease CO₂ emissions, and avoid landfilling. However, the level of glass recycling is currently far less than that of other materials, such as steel or aluminum.

OXYFUEL FURNACE MARKET PENETRATION BY INDUSTRY SEGMENT



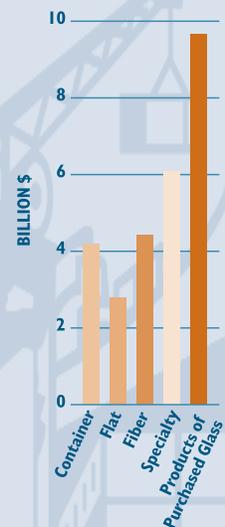
Source: Glass Industry Consulting

GLASS: A CLEAR PATH FOR A BRIGHT FUTURE
COST COMPONENTS OF GLASS PRODUCTS



Source: U.S. Department of Commerce

VALUE OF U.S. GLASS SHIPMENTS (1997)
Total - \$27.2 billion



Source: U.S. Census Bureau



Industry Vision and Roadmap

GLASS INDUSTRY VISION

In 1996, leaders of the glass industry produced *Glass: A Clear Vision for a Bright Future*, which outlined the industry's long-range vision for maintaining and building its market position. With leadership by a committee of chief executive officers, industry representatives on four subcommittees articulated

the desired competitive stance of the industry in 2020 and outlined broad goals in four subareas:

- Production Efficiency
- Energy Efficiency
- Environment
- Innovative Uses for Glass

THE GLASS INDUSTRY ROADMAP WORKSHOP ESTABLISHED INDUSTRY-WIDE PRIORITIES AND PERFORMANCE TARGETS...

SAMPLE PERFORMANCE TARGETS	Production Efficiency	<ul style="list-style-type: none"> • Reduce capital costs by 25-50% • Improve operating efficiency by 25% • Extend furnace life • Improve process yield and quality while lowering operating costs • Optimize processes through a better understanding of the chemistry and physics involved
	Energy Efficiency	<ul style="list-style-type: none"> • Preheat batch and cullet materials • Develop new melting technology and improve oxyfuel furnaces • Increase yield/decrease rejection rate of product • Improve process throughput
	Environment	<ul style="list-style-type: none"> • Reduce waste and emissions through proactive pollution prevention • Focus on high-value recycling
	Innovative Uses for Glass	<ul style="list-style-type: none"> • Pursue research in areas that will broaden the market for glass products: <ul style="list-style-type: none"> – Structural applications – High-strength and lightweight glass – Composites – Optical/Photonics – Electrical/Electronic products

GLASS INDUSTRY ROADMAP

Upon completion of the vision, leading representatives of the industry signed a compact with the Secretary of Energy, pledging to work together toward the accomplishment of the defined goals. The industry then took the important next step of organizing a workshop that would lay the groundwork for a glass industry roadmap with performance targets, prioritized research needs, and major milestones.

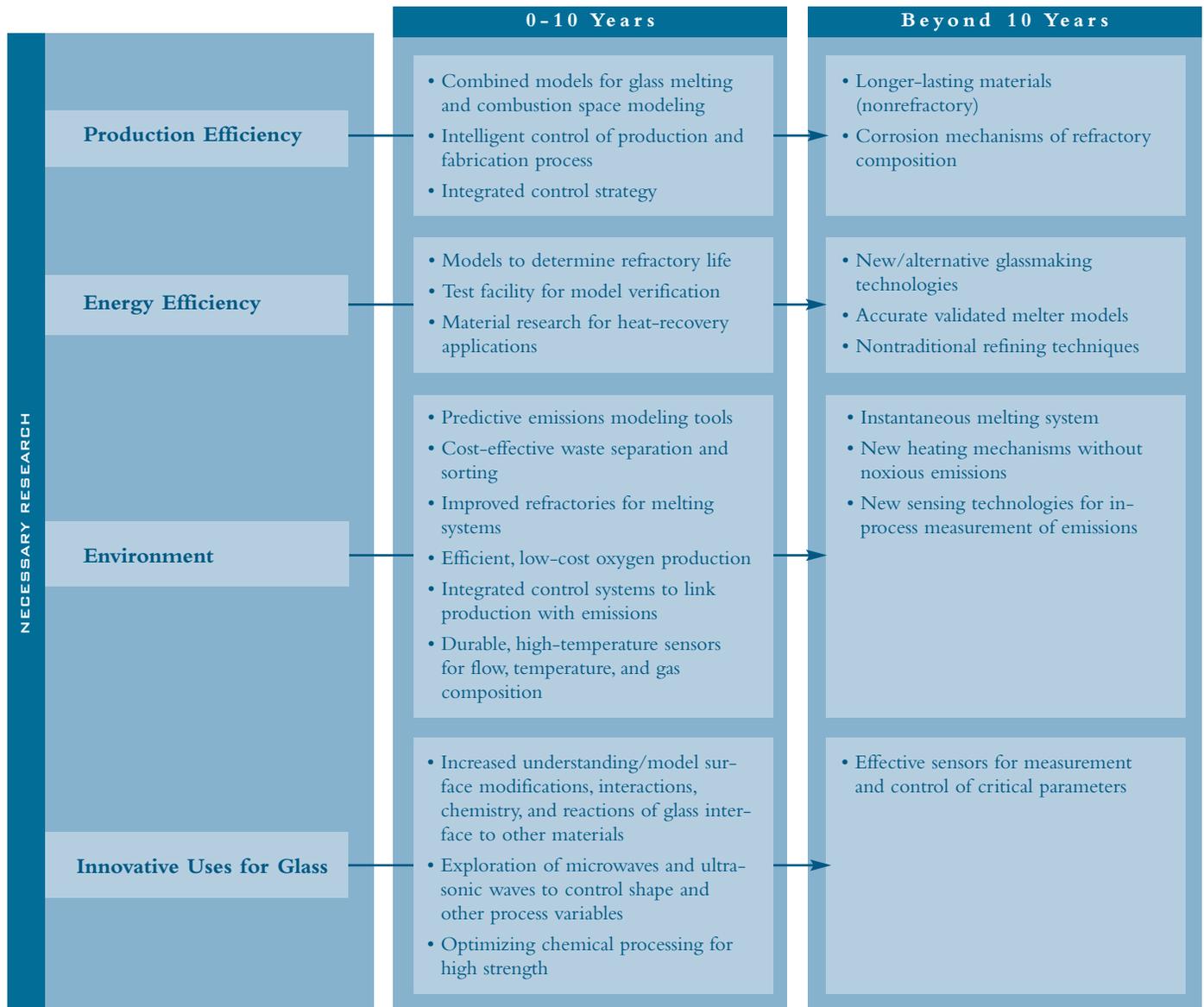
More than 40 participants from 15 glass companies, labs, universities, and

research organizations attended the April 1997 Glass Industry Technology Roadmap Workshop. The Workshop provided an opportunity to verify and validate the initial findings of the sub-committees and gain additional input and insight from a broader cross section of glass producers, research performers, and industry experts. The 1 ½-day workshop was facilitated by OIT and co-sponsored by several glass manufacturers. The participants identified over 130 specific research needs, of which 60 were deemed high priority.

GLASS VISION GOALS

- Reduce unit production costs by at least 20%
- Recycle 100% of available post-consumer glass in localities where consumption > 5 lb/capita
- Reduce by 50% the gap between current process energy use and the theoretical minimum
- Recycle 100% of glass production wastes
- Reduce air and water emissions by at least 20%
- Achieve Six Sigma quality control
- Create innovative products that broaden the marketplace
- Increase supplier and customer partnerships

...AND IDENTIFIED RESEARCH TO ACHIEVE THOSE TARGETS.



Team & Partnership Activities

Priorities established at the Glass Industry Roadmap Workshop guide the OIT Glass Team's R&D solicitations and project awards. The selected R&D projects help to attain specific performance targets set by the glass industry in its vision statement.

OIT's Glass Team also sponsors the annual *Glass Project Review*, in which technical managers from glass companies review the progress of ongoing glass R&D projects and advise the principal investigators on technical direction. These reviews have been highly successful and have attracted broad industry participation.

By virtue of its diverse contacts with a wide range of industry groups, the Glass Team is in a good position to spot potentially useful linkages. In September 1998, for example, the team and the U.S. Advanced Ceramics Association (USACA) jointly sponsored a workshop that brought together representatives of the glass and ceramics industries to begin identifying ways in which ceramic materials may help to

solve some of the problems facing glass producers. This initial, exploratory venture focused on refractories, molds, and shielding for sensors as the most likely areas for further investigation.

In addition to cost-sharing selected projects that specifically address the glass industry's top technology needs, OIT awards cost-shared funding for projects that enable or support cleaner and more energy-efficient manufacturing in a wide range of U.S. industries, including glass. OIT maintains active programs in combustion, sensors and controls, and advanced industrial materials. Several projects that started in these areas have been applied to the glass industry. Examples of such projects include oxyfuel firing from the combustion area and a tough, thermal shock-resistant material for sensors from the advanced materials area. The OIT Glass Team is now supporting a number of follow-on projects related to glass applications of these technologies.

A CENTRAL ORGANIZING COUNCIL FOR THE INDUSTRY

The success of the roadmap workshop convinced many industry leaders that certain common problems could be tackled more effectively through collaborative efforts. Pursuit of the priority technology areas, however, would require an increase in participation, collaboration, and organization among all members of the glass community. The competition and segmentation within the industry had historically hindered the ability of glass producers to collaborate efficiently on technology R&D.

To address this problem, key representatives of glass producers met in Novem-

“The GMIC provides a unified voice for the glass industry, facilitating cooperation and leveraging research resources to address issues of common concern.”

— Walter Scott, PPG Industries



ber 1997. They expressed the need to create an umbrella organization to serve as a focal point for technology collaboration, especially with respect to government agencies and laboratories. This led to the creation of the Glass Manufacturing Industry Council (GMIC) to coordinate pre-competitive R&D for glass manufacturers under the auspices of the American Ceramic

Society. The GMIC is dedicated to promoting the interests and growth of the entire U.S. glass industry through cooperation in the areas of technology, productivity, and the environment. On behalf of the glass industry, the GMIC renewed the compact to work collaboratively with DOE in a signing ceremony in February 1999.

REPRESENTATIVE GLASS-RELATED PROJECTS IN OIT'S PORTFOLIO

	PRODUCTION EFFICIENCY	ENERGY EFFICIENCY	ENVIRONMENTAL	INNOVATIVE USES FOR GLASS
Glass Team				
•Advanced Process Control System for Glass Production	●	●		
•Automated Infrared-based Inspection System for Automotive Heated Backlights	●	●	●	
•Auto Glass Process Control		●	●	
•Enhanced Cutting and Finishing of Handglass Using a Carbon Dioxide Laser	●			●
•Glass Furnace Combustion and Melting User Research Facility	●	●		
•High-Luminosity, Low-NOx Burner	●	●	●	
•Improved Refractories for Glass	●	●	●	
•Integrated Batch and Cullet Preheater System	●	●	●	
•Integrated Ion-Exchange Systems for High-Strength Glass Products		●		●
•Modeling of Glass Making Processes	●			
•Molybdenum Disilicide Composites for Glass Processing Sensors	●	●	●	●
•On-line Chemical Vapor Deposition of Coatings on Float Glass	●	●		
Inventions & Innovation				
•Producing Glass Fiber	●	●		●
•Rotary Electric Glass Furnace	●	●		●
•Single-Chip Color Sensor for Glass Recycling and Quality Control	●		●	
Sensors and Controls				
•Sensor Fusion for Intelligent Process Control	●	●		

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

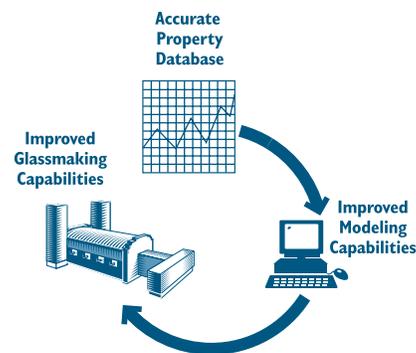
Selected Glass Portfolio Highlights



Infrared imaging system will eliminate defects and improve productivity.

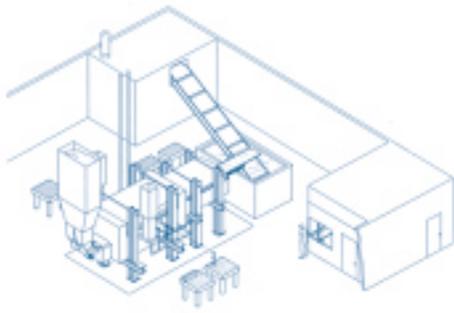


Laser-cutting glass while it is still hot will produce a finished edge.

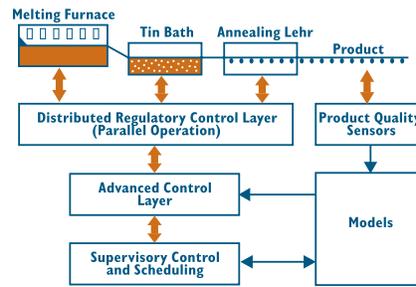


Property database will contribute to more efficient glassmaking processes for the entire industry.

AREA	ENVIRONMENTAL	INNOVATIVE USES	PRODUCTION EFFICIENCY
PROJECT	Automated Infrared-based Inspection System for Automotive Heated Backlights	Enhanced Cutting and Finishing of Handglass Using a Carbon Dioxide Laser	Modeling of Glass Making Processes
DESCRIPTION	<p>A new, automated inspection system can detect defective automotive backlights (the rear window with a defroster circuit) on-line during the manufacturing process. The system uses infrared imaging techniques to obtain an image of the heated backlight and analyzes it to spot defects such as hot spots or broken lines. Currently, the backlights are inspected manually or during infrequent tests; this new technology will reduce end waste.</p> <ul style="list-style-type: none"> • Reduces production and environmental waste at assembly station • Improves the competitive position of the U.S. glass industry 	<p>Laser-enhanced cutting and finishing methods will dramatically decrease waste and improve productivity in the manufacture of handblown glass. Researchers will develop a bench-scale prototype system using a sensor-controlled, moderate-power, carbon dioxide laser to precision-cut the glass and produce a finished edge. A major component of the work will involve development of the operating parameters to make the system feasible for use in handglass factories.</p> <ul style="list-style-type: none"> • Minimizes waste and defects • Improves product quality • Reduces material costs: current losses can be as high as 80% in some product lines or 40% total scrap • Improves production efficiency and decreases overall energy use • Reduces worker hazards, such as exposure to sharp edges and broken fragments 	<p>The Center for Glass Research is developing a database of all the important, physical properties of glass that will allow researchers to develop accurate computer codes for glass melting, refining, and homogenizing processes. The resulting modeling capabilities will improve manufacturing processes to consistently and economically produce high-quality glass.</p> <ul style="list-style-type: none"> • Improves production efficiency • Increases energy efficiency • Reduces production costs • Reduces waste and hazardous emissions
PARTNERS	Georgia Institute of Technology Ford Motor Company/Visteon Glass Systems	The Federal Energy Technology Center Fenton Art Glass Pilgrim Glass West Virginia University	The Center for Glass Research



A central research facility will facilitate development of more efficient glass furnaces.



Distributed and hierarchical control of flat glass production



New rotary electric glass furnace

ENERGY EFFICIENCY

Glass Furnace Combustion and Melting User Research Facility

All segments of the glass industry concur that the industry needs a central research facility to explore technology that can improve combustion and furnace efficiency. The goal of the project is to design and build a state-of-the-art user facility for developing improved monitoring instrumentation for batch reactions, melt properties, and combustion space conditions in glass furnaces in order to improve production efficiency.

- Benefits manufacturers in all industry segments
- Improves production and energy efficiency for combustion and melting processes

Sandia National Laboratories
Visteon Glass Systems

PRODUCTION EFFICIENCY

Sensor Fusion for Intelligent Process Control

Researchers are developing a fusion strategy for linking the sensors and expert control elements of production furnaces using an on-line control system that will improve energy efficiency while minimizing a variety of product defects. Although its target use is in flat glass production, this low-cost, adaptable system can be used in any facility that transforms raw materials into finished products using multistep processes with nonlinear behavior and slow output response to changing conditions.

- Reduces energy use in glass melting furnaces by 5%
- Increases flat glass production yield by 5%
- Reduces emissions of CO₂ and SO₂

Sandia National Laboratories
University of Utah
Visteon Automotive Systems

ENERGY EFFICIENCY

Rotary Electric Glass Furnace

Glass optical blanks manufactured for the photonics industry are generally molded in conventional gas-fired furnaces, which exhaust about 93% of the energy used. A new rotary electric furnace has no exhaust stack and, therefore, no waste heat. Additionally, electric heating can be accurately controlled by computer, improving the efficiency, capacity, and operating costs of the new furnaces.

- Increases energy efficiency of molding glass optical blanks at least threefold
- Improves product throughput, quality, and turnaround time
- Doubles production capacity without additional investment
- Reduces labor costs

Advanced Glass Industries

Cast metal products are essential to nearly all manufacturing industries. In the United States, approximately 2,950 foundries provide castings for 90% of manufactured durable goods and most manufacturing machinery. Major end-use markets include automotive, pipe, industrial machinery, transportation equipment, and aerospace.

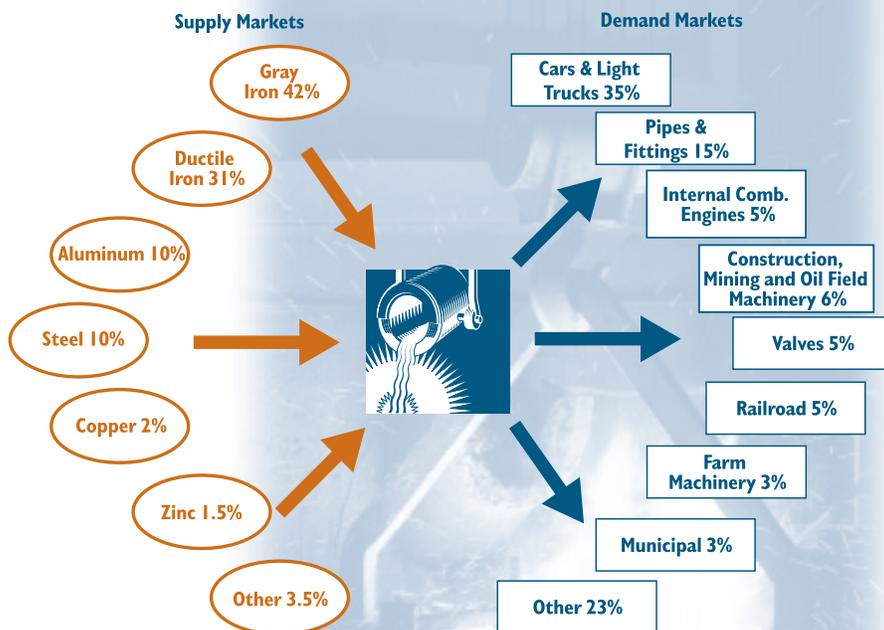


Metalcasting Industry

PROFILE

Value of Shipments.....	\$18 billion
Employment.....	227,100
Capital Expenditures	\$1.35 billion
Net Trade Balance	\$117 million
Net Energy Consumption	200 trillion Btu

METALCASTING SUPPLY AND END-USE MARKETS, 1998



PRODUCTION TRENDS

The metalcasting industry has been making a comeback after major declines in the 1980s. Although the industry had achieved record production levels of almost 20 million tons by the late 1970s, casting production declined significantly during the 1980s. This decline was due to decreased demand for cast products, increased foreign competition, and increased use of substitute materials such as plastics, ceramics, and composites. By 1990, U.S. metalcasting production had dropped to 11.3 million tons.

Source: American Foundry Society

The U.S. metalcasting industry has seen a resurgence in the 1990s. In 1998, the United States shipped approximately 14.1 million metric tons valued at \$18 billion. The United States is now the world's leading producer of metal-castings. This recovery is due to a variety of factors, including improved domestic and international demand.

Despite a continued strong economy in the United States, a weaker global economy is expected to affect exports of metalcastings. On a *volume* basis, industry production is expected to grow 1.7% annually between 2001 and 2008, when casting shipments are expected to total approximately 17.7 million tons. On a *value* basis, however, casting sales are expected to grow 4.7% during that period, with lighter and more expensive casting dominating the market.

EMPLOYMENT

Metalcasters are predominantly small businesses. Eighty percent of U.S. foundries employ fewer than 100 workers each, and only 6% employ more than 250 workers. Foundries are located throughout the country but are primarily concentrated in the Midwest and Southeast. The metalcasting industry employs approximately 227,100 workers with a payroll of \$7 billion.

COMPETITION

The U.S. metalcasting industry faces tough competition from foreign metalcasters and suppliers of alternative materials. Foreign competitors can offer lower product costs due to lower wage scales and less stringent environmental standards. Environmental constraints and the disposal of pollution and waste products are costing the U.S. industry more each year, cutting into profits. In addition, demand for lightweight products has increased the use of alternatives to cast metal, such as plastics and other materials.

ENERGY USE

Metalcasting is among the most energy-intensive industries in the United States. According to Department of Energy figures, 15% to 25% of production cost is related to the use of energy. The metalcasting industry consumes an estimated 200 trillion Btu annually. More than half of this energy is used in melting.

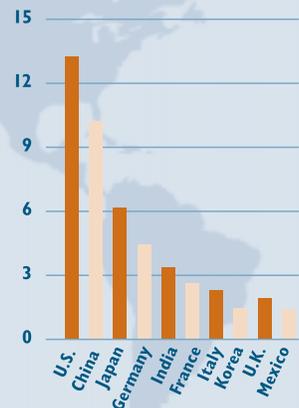
ENVIRONMENT

The metalcasting industry is a leader in both recycling and reusing scrap materials, and is responding to tougher environmental standards. Today, the industry invests more than \$1.25 billion annually to meet environmental regulations and to develop pollution prevention technologies.

RECYCLING

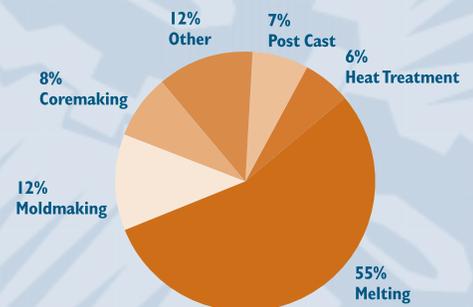
The metalcasting industry is exceptional in its reuse of scrap metal to produce new goods. The industry obtains 85% of its feedstock for ferrous castings from scrap—about 13.3 million tons or \$1 billion worth of scrap metal. In addition, the industry is finding new ways to recycle spent sand and to recover and reuse metals, chemicals, and other waste products.

CASTING SHIPMENTS OF TOP TEN METALCASTING COUNTRIES BY MILLIONS OF METRIC TONS, 1998



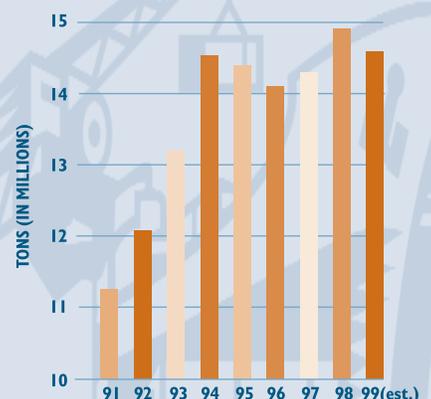
Source: American Foundry Society

BREAKDOWN OF PROCESS ENERGY COSTS, 1997



Source: Bates 1997

TOTAL U.S. CASTING SHIPMENTS, 1991-1998



Source: American Foundry Society, Modern Casting, January 1998 and December 1997.

Industry Vision and Roadmap

METALCASTING INDUSTRY VISION

In September 1995, the metalcasting industry—represented by the American Foundry Society, the North American Die Casting Association, and the Steel Founder’s Society of America—published a unified and focused vision of its future. This document, *Beyond 2000: A Vision for the American Metalcasting Industry*, sets broad industry goals and performance targets for the next 20 years.

According to the vision, the industry aims to

- Be the preferred supplier of net or near-net shape metal components
- Produce products in an efficient, environmentally friendly manner
- Have products considered necessary “engineered components” rather than commodities



The document also identifies key R&D needs to achieve these goals. Priority research areas include Products and Markets, Materials Technologies, Manufacturing Technologies, and Environmental Technologies. Additional focus areas include Human Resources, Profitability and Industry Health, and Partnerships and Collaboration.

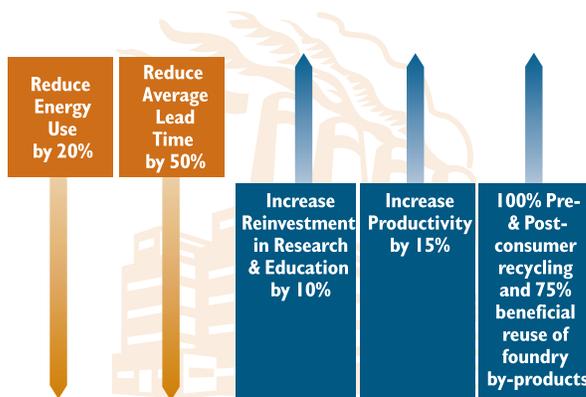
METALCASTING INDUSTRY ROADMAP

While *Beyond 2000* identifies performance targets, the *Metalcasting Industry Technology Roadmap*, published in January 1998, presents a detailed technology strategy to achieve the vision goals. Key research areas identified in the vision are important components of this strategy.

The roadmap details current status, critical trends, and driving forces affecting each technology area. It also identifies vision performance targets, barriers to reaching targets, and R&D activities needed to overcome these barriers.

In addition, the roadmap sets goals for educating and training the workforce, attracting and retaining quality personnel, addressing increased foreign competition, and responding to regulatory requirements.

GOALS FOR THE METALCASTING INDUSTRY OF THE FUTURE



Source: Beyond 2000, A Vision for the American Metalcasting Industry

HIGH-PRIORITY RESEARCH NEEDS FROM THE METALCASTING INDUSTRY ROADMAP

Products and Markets	Materials Technologies	Manufacturing Technologies	Environmental Technologies
<ul style="list-style-type: none"> • Transform foundries to tier-one suppliers • Develop computer design tools to move from design concept to a design for manufacturing • Develop methods to encourage/ systematize concurrent engineering partnerships within the metalcasting industry • Develop ways to demonstrate the quality and value of castings • Develop tools and technologies to reduce lead times in the metalcasting industry 	<ul style="list-style-type: none"> • Develop quantitative relationships among alloy chemistries, properties, and processing • Establish standard methodologies for materials testing • Develop a clean melting and remelting process • Develop methods for fast, accurate, and non-destructive evaluation of ingot and as-cast chemistries and properties (particularly for ferrous casting) • Develop improved technologies to measure the acceptability of liquid metal prior to casting • Develop a national initiative to foster interest in materials science and engineering 	<ul style="list-style-type: none"> • Develop low-cost rapid tooling technology • Improve tooling design to reduce the time to move castings to market • Develop cost-effective and dimensionally accurate patternmaking processes for use in sand casting • Improve the ability to produce size/ dimension • Develop smart controls and sensors for automation supervision • Develop a systems approach to scheduling and tracking • Figure out how die casting molds/dies actually fill • Understand folds for aluminum lost foam casting • Develop melting and pouring technologies that do not introduce gases to the process • Develop a mathematical model that describes process control and can control the machine 	<ul style="list-style-type: none"> • Develop environmentally benign, dimensionally stable molding materials for sand casting • Develop new uses for waste streams and/or new ways to treat wastes to make them more usable • Develop emissions database for foundries to use in educating regulators

Team & Partnership Activities

The Department of Energy's Office of Industrial Technologies has established a highly successful partnership with the metalcasting industry. This industry-government partnership, the Metal Casting Industry of the Future, is coordinated through the Cast Metals Coalition (CMC). The CMC is composed of the American Foundry Society (AFS), North American Diecasting Association (NADCA), the Steel Founders' Society of America (SFSa) and the Advanced Technology Institute (ATI). Collectively, this coalition represents the majority of the U.S. metalcasting industry.

Metalcasting research projects are selected through a competitive solicitation process. In coordination with CMC, OIT solicits research projects that address national energy goals as well as priority needs of the metalcasting industry as outlined in the roadmap. All proposals must undergo a Technical Merit Review. The results are provided to the OIT Metalcasting Team, which then makes the final project selections.

The vast majority of metalcasting research is performed by the researchers, educators, and students at over 20 universities and laboratories. This arrangement addresses a high-priority concern of the industry—the future availability of a well-trained labor force. Since the program's inception, the number of OIT partners from the metalcasting industry itself has increased significantly. In 1991, the program's first year, partners from industry, academia, and state government numbered 50. Today, more than 250 industry partners from 30 states provide critical technical and cost-shared support.

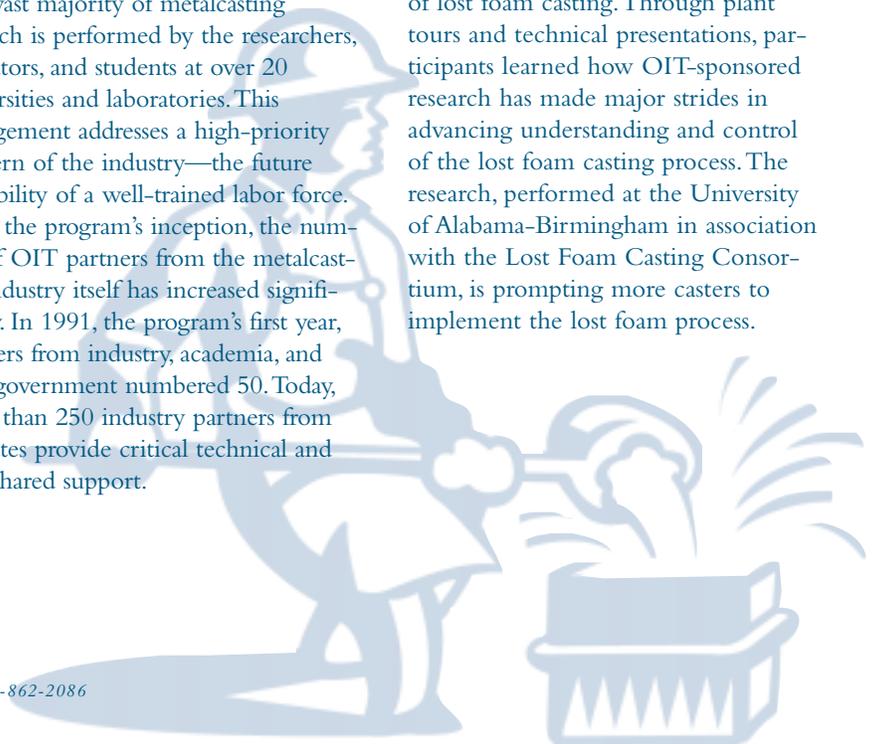
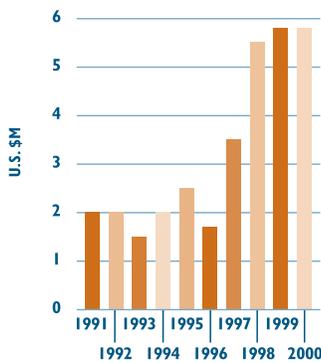
Industry and government partners review research projects on a regular basis to monitor progress. Research results are widely disseminated through various means, including conferences, journals, and workshops. Over the last three years, for example, over 70 articles on OIT-funded research have appeared in industry publications.

Along with increased program participation, indications of success include additional funding from Congress. Funding support for metalcasting R&D through OIT increased from \$2 million in 1991 to over \$5 million in 2000.

A technology showcase held in November 1999 at Lester Precision Diecasting in Twinsburg, Ohio, highlighted the progress of OIT's cost-shared research for the metalcasting industry. Plant tours, poster presentations, and seminars highlighted the results of 11 OIT-sponsored research projects. Visitors saw firsthand how these projects are helping to save energy while improving productivity and quality. Joseph Ponteri, President and CEO of Lester's parent company, GMTI, stated that "these technologies are assisting Lester Precision Die Casting in achieving world class status as a leading die casting company."

In October 1998, a showcase in Birmingham, Alabama, highlighted the energy, environmental, and cost advantages of lost foam casting. Through plant tours and technical presentations, participants learned how OIT-sponsored research has made major strides in advancing understanding and control of the lost foam casting process. The research, performed at the University of Alabama-Birmingham in association with the Lost Foam Casting Consortium, is prompting more casters to implement the lost foam process.

FUNDING SUPPORT FOR METALCASTING RESEARCH AND DEVELOPMENT THROUGH DOE'S OFFICE OF INDUSTRIAL TECHNOLOGIES



REPRESENTATIVE METALCASTING-RELATED PROJECTS IN OIT'S PORTFOLIO

	MATERIALS TECHNOLOGIES	MANUFACTURING TECHNOLOGIES	PRODUCTS & MARKETS	ENVIRONMENTAL TECHNOLOGIES
Metalcasting Industry				
•Advanced Lost Foam Technology		●		
•Clean Cast Steel	●	●		
•Clean Metalcasting	●			
•Consistent Casting of High-Strength Ductile Iron		●	●	
•Die Life Extension	●	●		
•Energy Saving Manual with Software				●
•Intelligent Control of the Cupola Furnace		●		●
•Macro-Inclusions Atlas	●			
•Semi-Solid Aluminum Alloys	●			
•Steel Foundry Refractory Lining Optimization				●
•Thin Section Steel Castings			●	
•Unconventional Yield Studies		●		
•Cast View		●		
Industrial Materials				
•Advanced Intermetallic Alloys	●			
•Ceramic Composite for Metal Casting	●			
Inventions and Innovation				
•Filtering Molten Metal			●	
•A Safer, Effective Resin Produced from Recycled Waste				●
NICE³				
•Atmosphere Recovery and Regeneration in Heat Treating				●
•High-Temperature Materials for Die Cast Copper Rotors	●			
•In-Situ, Real Time Measurement of Melt Constituents		●		
•Integrated Advance Oxidation—Underwater Plasma Processing				●
•A Process to Recover and Reuse Sulfur Dioxide				●
Sensors and Controls				
•Sensing and Control of the Cupola Furnace		●		
Other IOF				
•High-Efficiency, High-Capacity, Low NOx Melting		●		
•Improved Grain Refinement Process	●			
•Prevention of Molten Water Explosions		●		

See “Selected Metalcasting Portfolio Highlights” on the next two pages for additional information

Selected Metalcasting Portfolio Highlights



There are significant market opportunities for high-strength, thin-wall steel castings.



An integrated sensing and control system improves the productivity of cupola furnaces.



Aluminum transmission housing component with cast-in brass insert produced by lost foam process.

MATERIALS TECHNOLOGIES

Clean Cast Steel Technology

All foundries have oxide macroinclusions in their regular production castings. Macroinclusions can significantly degrade the machining of parts – even to the point of breaking tools. This research, being performed by the University of Alabama - Birmingham in conjunction with the Steel Founders' Society of America is helping to identify the causes of inclusions and minimize or eliminate their occurrence. In one foundry for example, the number of welds requiring repair dropped from an average of 21.1 per casting to 3.7 per casting.

Steel Founder's Society of America
University of Alabama - Birmingham
Over 20 industry partners

MANUFACTURING TECHNOLOGIES

Intelligent Control of the Cupola Furnace

Although the cupola furnace has historically been the primary method for melting iron, variability in cupola output and pollution have contributed to its recent decline in the domestic market. An integrated sensing and control system called I³PSC will enhance environmental performance and optimize output for cupola furnaces by regulating melt rate, temperature, and iron composition. The technology will increase energy efficiency and cast yield while decreasing coke requirements by up to 3.4 million tons annually with a similar reduction in carbon emissions.

American Foundry Society
Idaho National Engineering and Environmental Laboratory
Tennessee Technological University
Utah State University
and several companies

MANUFACTURING TECHNOLOGIES

Advanced Lost Foam Casting

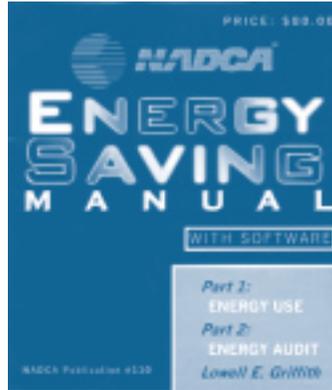
The lost foam casting process eliminates cores and core boxes and provides improved control of casting wall thickness. The process has significant cost and environmental advantages and enables metalcasters to produce increasingly complex parts.

To ensure consistently high-quality castings, researchers from the University of Alabama, the Cast Metals Coalition, and the American Foundry Society are sponsoring development of new process control measures, which will lead to improved analysis and control in each stage of the process. These measures are resulting in higher-quality castings, more cost- and energy-efficient foundry operations, and dramatic reductions in scrap.

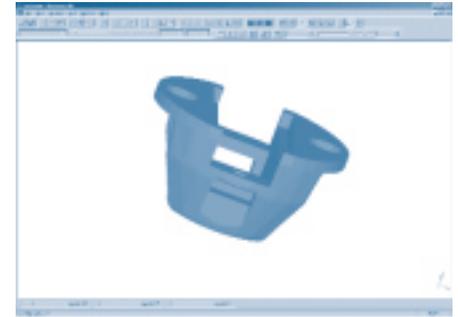
American Foundry Society
University of Alabama



Die casting research facility



The Energy Saving Manual helps die casting plants identify opportunities for saving energy.



CastView™ identifies die casting design problems in the design phase, saving energy and materials.

MANUFACTURING TECHNOLOGIES

Die Life Extension

Die production is a significant cost for the die casting industry. Researchers at Case Western Reserve University and industry partners are studying the effects of steel chemistry, heat treatment, and electro-discharge machining on the lifetime of dies for die casting. Extension of die life could result in annual savings of over \$200 million. Additional benefits of die life extension include reduced down-time associated with die production, as well as reduced energy consumption and emissions associated with die production. The results of this project have already saved \$1 million in die replacement costs.

Case Western Reserve University, Badger Metals Tech, CMI, Crown Equipment Corp., Harvard Industries, ITT Automotive, Lindberg, Universal, North American Die Casting Association

ENVIRONMENTAL TECHNOLOGIES

Energy Saving Manual with Software

Die casting plants can minimize energy waste by implementing energy-efficient best practices. L.E. Griffith Associates, the North American Die Casting Association, and Stroh Die Casting developed a manual that contains data on direct metalcasting energy usage and describes procedures to minimize this energy use.

The *Energy Saving Manual* analyzes use of process and non-process energy throughout the plant. It also describes the most energy-efficient practices for each area. Spreadsheets are included to calculate energy use.

L.E. Griffith Association
North American Die Casting Association
Stroh Die Casting

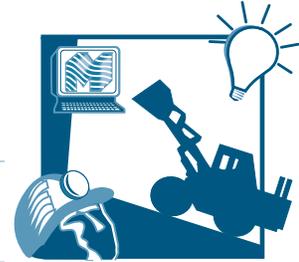
MANUFACTURING TECHNOLOGIES

CastView™

Reducing the number of die try-outs can reduce energy and scrap use as well as development lead times. CastView™ is a PC-based modeling program for die casting flow simulation. It is based on a qualitative analysis of part geometry, which yields extremely fast analysis times. This visualization tool is being used in the design stage to evaluate candidate gate, vent, and overflow locations and to quickly compare candidate designs. CastView™ is now available commercially from NADCA.

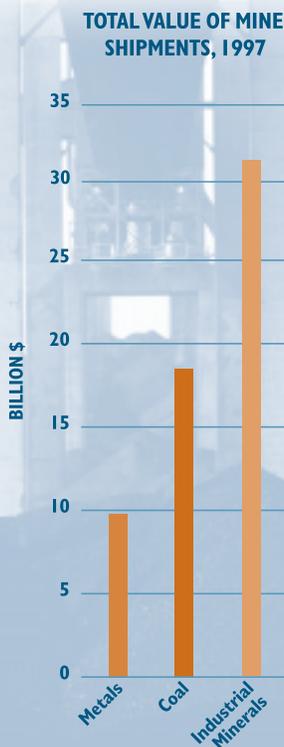
North American Die Casting Association
Ohio State University

The U.S. mining industry, which includes coal, metals, and industrial mineral mining, provides energy and raw materials to our economy. On average, each American uses 7,300 pounds of coal and about 46,000 pounds of other minerals annually.



Mining Industry

PROFILE



Source: EIA, 1999

Value of Shipments	\$69.7 billion
Employment	280,000
Capital Expenditures	\$6.55 billion
Net Trade Balance	\$1.6 billion
Net Energy Consumption	1.14 quads

MARKETS

The economic benefits of mining are significant. In 1996, the mining industry contributed about 0.4% of the GDP, worth approximately \$30 billion. In addition, mining equipment manufacturers shipped over \$2.6 billion worth of products in 1997.

In 1997, 1.09 billion short tons of coal were produced in the United States. As the least expensive source of fuel, coal averages nearly \$2 less than petroleum (per million Btu) and about \$1 less than natural gas on a comparable basis.

Coal is also more abundant than oil or natural gas; about 95% of U.S. fossil energy reserves are comprised of coal. Coal is the only energy source for which exports are greater than imports, with exports contributing over \$3 billion to the U.S. balance of payments.

Metal mining also contributes to the overall economics of the industry. In 1997, the mining industry produced metals worth over \$11.2 billion. Globally, the United States is a major producer of iron, copper, lead, zinc, and silver, and it is the second largest producer of gold.

Industrial minerals are the basic raw materials for most of the construction, agricultural, and inorganic chemical sectors in the United States. They are also the basic raw materials for a large portion of the transportation, manufacturing, organic chemical, and service sectors of the U.S. economy.

EMPLOYMENT

Mining occurs in 49 states, and the industry employs about 280,000 people. Because mining products serve as feedstocks for other industries, the mining industry indirectly impacts an additional 4.6 million American workers. Mining workers earn some of the highest wages among all industries, averaging \$51,000 annually versus a \$33,000 annual average for other industries.

ENERGY

The mining industry consumes over one quad of energy per year, which is about 3% of U.S. industrial energy use. However, coal and uranium mines supply power plants that generate over 77% of total U.S. electricity. The industry's energy costs represent an estimated 5% of the value of all mining products. Energy efficiency within the mining industry could be substantially increased through improved processes and techniques in areas such as exploration, excavation, and extraction.

The coal industry is the nation's largest energy-producing industry, representing nearly one-third of U.S. energy production. About 80% of the coal is used to produce electricity. More than half of that total is produced in Wyoming, Kentucky, and West Virginia.

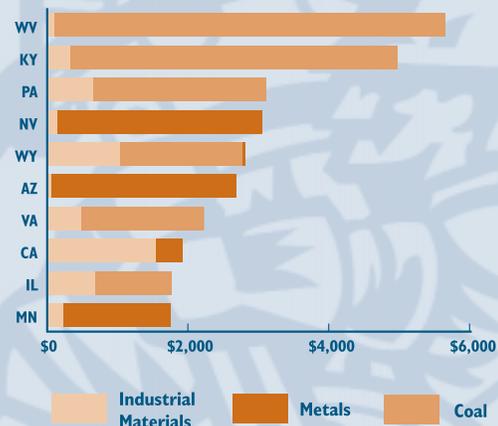
ENVIRONMENT

The mining industry has made significant strides in its pollution prevention and environmental protection efforts. For example, sulfur dioxide emissions from the mining industry have decreased to 27% below 1970 levels, despite the increased use of coal for electricity (more than double) since 1970. Mining production operations are continually increasing their use of clean coal technologies as well.

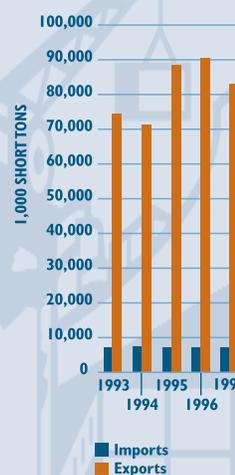
In the last 20 years, U.S. coal mining operators have reclaimed more than two million acres of land. Moreover, according to the U.S. Geological Survey, less than a quarter of 1% of the nation's land surface has been disturbed by mining.

Development of new energy-efficient mining technologies to replace inefficient crushing and grinding systems will reduce greenhouse gas emissions. New materials handling processes will result in decreased air emissions, and advances in mineral processing will reduce the amount of toxic wastes produced.

VALUE OF METAL, COAL, AND INDUSTRIAL MINERAL PRODUCTION IN TOP TEN STATES (IN \$MILLIONS)

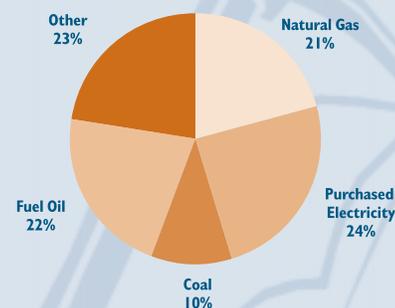


U.S. COAL EXPORTS & IMPORTS, 1993-1997



Source: Energy Information Administration

ESTIMATED ENERGY USE AT THE MINE



Source: U.S. Bureau of the Census and OIT estimates

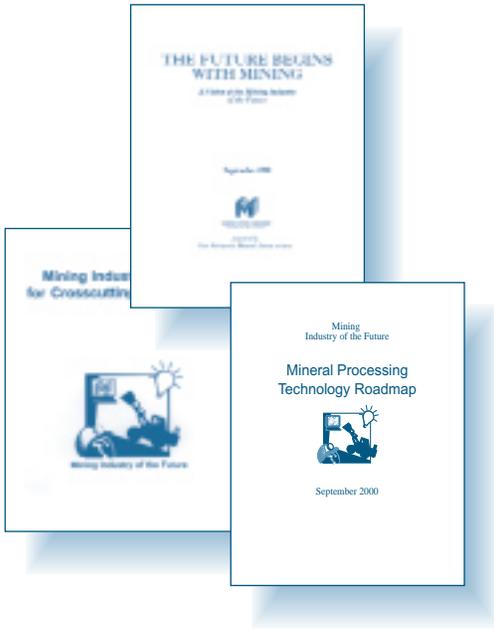
Industry Vision and Roadmap

MINING INDUSTRY VISION

In June 1998, the mining industry signed a compact with the Secretary of Energy, committing to government-industry partnerships that will allow the mining industry to competitively fulfill the growing national and international demand for mining products. The mining industry, under the leadership of the National Mining Association, then published its strategic vision, *The Future Begins with Mining*, in September 1998. The vision outlines the industry's goals for a positive and productive future, as well as the barriers and challenges that

must be addressed to achieve those goals:

- Responsible emission and by-product management—minimize environmental impact of mining, support development of emission-reducing technologies
- Safe and efficient extraction and processing—improve worker environment and reduce worker exposure to hazards
- Superior exploration and resource characterization—find and define larger high-grade reserves with minimal environmental impact.
- Low-cost and efficient production—use advanced technologies to improve process efficiency



THE MINING INDUSTRY ROADMAPS ESTABLISH INDUSTRY-WIDE PRIORITIES AND PERFORMANCE TARGETS...

Sample Performance Targets

Exploration and Resource Characterization

- Reduce the environmental impact of exploration and resource characterization
- Reduce the costs of exploration and resource characterization
- Increase the value of run-of-mine products
- Increase exploration efforts

Safe and Efficient Mining

- Use technology to increase output expressed as tons per employee hour by 100%
- Increase the output efficiency of capital by one-third
- Increase energy and other consumable efficiencies per unit of output by 50%
- Reduce discharge of solid, liquid, or gaseous emissions and waste to near zero
- Use advanced technologies and training to improve the worker environment, reduce worker exposure to hazards, and reduce recordable accidents and occupational diseases by 50%

Safe and Efficient Mineral Processing

- A 30% increase in energy efficiency
- A 20% reduction in emissions per unit of product produced
- A 20% increase in utilization of removed material per unit of product output
- Zero processing-related fatalities
- Zero processing-related health and safety reportable incidents
- Advances that will enable zero notices of violation of safety and health regulations
- A 20% increase in unit of product per labor hour
- A 20% increase in return on capital employed
- A 20% increase in value added at the processing facility
- A 50% increase in U.S. fuel and non-fuel mineral reserves

VISION GOALS

- Advanced products—maintain and create new markets by producing clean, efficient products and by forming inter-industry alliances to develop higher quality, environmentally friendly products
- Positive partnership with government—work with government to reduce development cycle, achieve equitable treatment for mining by working to make legal and regulatory framework rational and consistent
- Improved communication and education—attract best possible workforce by making mining careers attractive and promising, educate the public about the successes and importance of mining

MINING INDUSTRY ROADMAPS

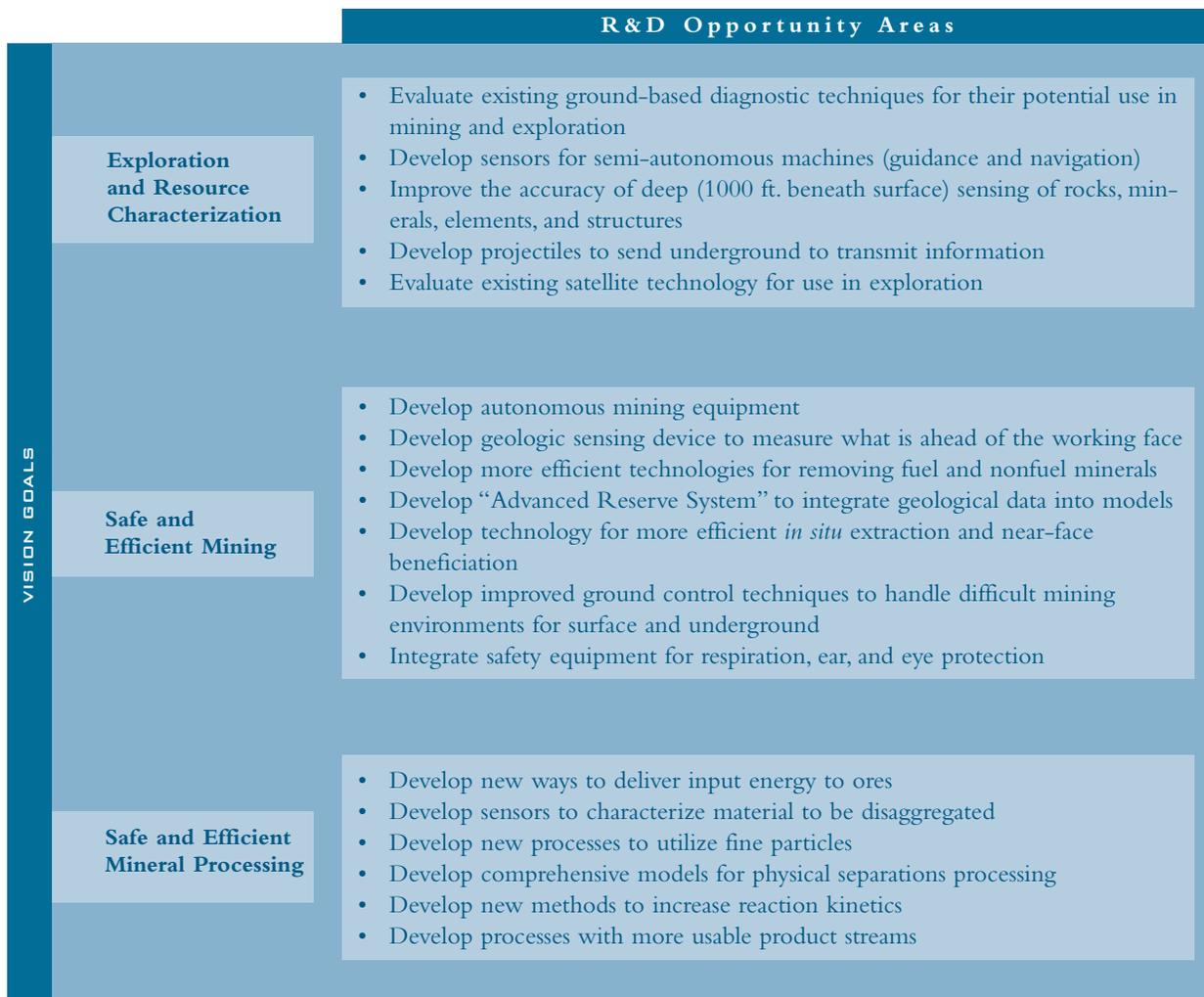
In October 1998, representatives from mining companies, suppliers, academia, and the government began the development of a mining industry roadmap to guide the industry in its efforts to achieve the goals of the vision. The resulting document, *Mining Industry Roadmap for Crosscutting Technologies*, establishes technology priorities, requirements, and pathways in three areas:

- Exploration and resource characterization—activities included in finding and defining a reserve
- Mining—activities, techniques, and methods for extracting minerals from the earth

- Mineral processing—activities, techniques, and methods for providing raw materials or by-products (up to and including beneficiation)

To better address the priority area of mineral processing, the *Mineral Processing Technology Roadmap* was published in September 2000. The Mining Industry of the Future is using the research priorities established in both of these roadmaps to guide its R&D investments. The industry also anticipates developing several additional technology roadmaps for other areas, such as mining and exploration.

...AND IDENTIFY R&D NEEDED TO ACHIEVE THOSE TARGETS.



VISION GOALS

Team & Partnership Activities

The OIT Mining Team conducted its first solicitation for DOE laboratory-led R&D projects during the summer of 1999. The team selected 10 projects (see facing page) to receive approximately \$5.2 million in government funding over three years to develop new, energy-efficient mining technologies. Another solicitation for industry- or university-led projects closed in August 1999; of the 62 proposals received, 16 were selected for award.

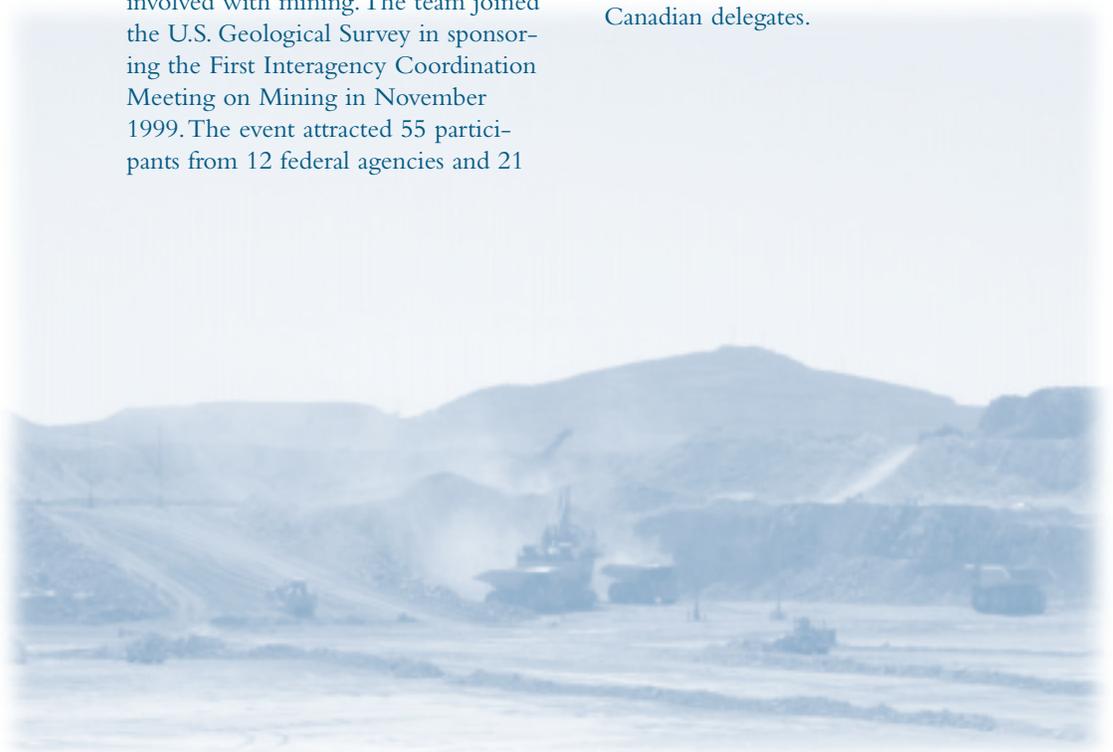
The OIT Mining Team leverages resources with other OIT teams, such as Chemicals and Steel, and crosscutting technologies to create an R&D portfolio focused on meeting the industry's goals as described in the vision.

The OIT Mining Team is spearheading an effort to promote coordination among the diverse government agencies involved with mining. The team joined the U.S. Geological Survey in sponsoring the First Interagency Coordination Meeting on Mining in November 1999. The event attracted 55 participants from 12 federal agencies and 21

representatives from industry and non-governmental organizations. This broad participation is indicative of the large number of agencies involved with various aspects of U.S. mining. The high level of participation also underscores the perceived value of coordinating the activities of these diverse agencies so that federal funds are invested wisely and in alignment with industry and national priorities. A second meeting is in the planning stage.

Networking activities by the OIT Mining Team are already paying off. Recognizing that many energy-efficient technologies for mining also improve health and safety, the National Institute of Occupational Safety and Health is committed to working with OIT on projects of mutual benefit. The agency is contributing to current projects in OIT's Mining portfolio and plans to collaborate on future projects.

On the international front, the Mining Team is talking with representatives of several foreign organizations interested in collaborating on technology R&D. Discussions have been held with Finnish, Australian, Russian, and Canadian delegates.

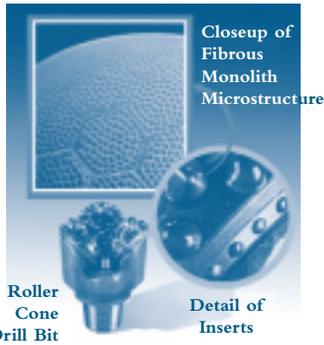


MINING INDUSTRY OF THE FUTURE—PROJECT AREAS

	ENERGY SAVINGS	PRODUCTION/ PROCESSING EFFICIENCY	ENHANCE RESERVE BASE	ENVIRONMENTAL QUALITY	HEALTH AND SAFETY
•Advanced Materials for Mining	●	●		●	
•Autonomous Mining	●	●		●	●
•Drilling and Blasting Optimization	●	●		●	
•Efficient Crushing and Grinding	●	●		●	
•Enhanced Roof Bolting	●		●		●
•Fuel Cell-Powered Mining Vehicles	●	●		●	●
•Mapping with Natural Induced Polarization	●	●	●	●	
•Mining By-product Recovery	●	●	●	●	
•Mining Equipment Condition-Based Maintenance	●	●		●	
•Projectile-Based Excavation	●	●		●	
•Reduction of Coal and Mineral Fines	●	●		●	
•Real-Time Mineral Grade and Content Analysis	●	●	●	●	
•Remote Sensing and Imaging Ahead of Mining	●	●	●	●	
•Underground Communications	●			●	●

See “Selected Mining Portfolio Highlights” on the next two pages for information on selected projects within these areas

Selected Mining Portfolio Highlights



Cellular composite materials offer an affordable route to increased component service life.



More efficient blast technology will save energy and enhance safety.



Reliable underground communications capability will enhance mine safety and productivity.

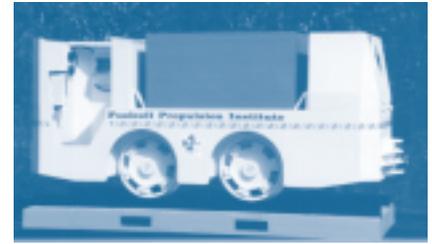
AREA	PRODUCTION/PROCESSING EFFICIENCY	ENERGY SAVINGS	HEALTH AND SAFETY
PROJECT	Cellular Composite Wear-Resistant Components	Drilling and Blasting Optimization	High-Temperature Superconductors in Underground Communications
DESCRIPTION	<p>Researchers are developing cellular composite materials that can overcome traditional cost/performance barriers to the use of advanced materials in mining and significantly increase the service life of critical components. Target components include drill bit inserts used for drilling of blast holes, dozer teeth used in a variety of earth-moving equipment, and hydrocyclone apex cones used for sizing of crushed ore.</p> <ul style="list-style-type: none"> • Save about 11 trillion Btu per year • Increase productivity by 15% 	<p>The grinding and crushing of extracted rock is the single largest energy-using process in mining. More efficient blast technology will optimize rock breakage and save substantial energy during the process. The technology will be widely applicable across the mining industry and has significant safety and environmental benefits as well.</p> <ul style="list-style-type: none"> • Reduce energy use and cost of downstream processing • Reduce mineral ore in waste • Improve mine safety 	<p>The development and application of underground communications will enhance both worker safety and mine productivity while increasing energy savings. Use of superconducting materials (SQUID) in communications equipment will increase the range of through-the-earth communications, allowing better transmission of orientation and position information to miners and machines.</p> <ul style="list-style-type: none"> • Increase productivity and energy efficiency of autonomous mining equipment • Enhance underground mine safety
PARTNERS	Pacific Northwest National Laboratory Conoco	Lawrence Berkeley National Laboratory Phelps Dodge Mining Split Engineering University of Arizona	Los Alamos National Laboratory Hecla Mining CONSOL Incorporated Phelps Dodge Asarco Harris Communications Waste Isolation Pilot Plant Colorado School of Mines RAG Coal Molycorp Inc. Stolar Horizon Inc.



By-product recovery at a copper mine



Continuous miner



Fuel cells use hydrogen and oxygen to produce electrical energy.

**ENVIRONMENTAL
QUALITY**

Mineral By-product Recovery

The project is designed to increase the amount of product generated per ton of material removed and reduce the overall amount of waste and toxic materials generated. An innovative rotary vacuum drying technology will allow recovery of valuable metals from process residues generated by smelter exhaust gas cleaning, bag house dust, and sludge.

- Avoid formation of dioxin and furane
- Eliminate need for complex off-gas treatment
- Enhance worker safety

Oak Ridge National Laboratory
SeptraDyne Corporation
Colorado School of Mines
University of Arizona

ENERGY SAVINGS

**Robotics Technology for
Improving Mining Productivity**

The partners will develop advanced sensors that, when mounted on mining equipment, will improve the machines' ability to measure the position, orientation, and motion of the material in the mineral seam. The new technology will help mines improve their control of underground mining machinery as well as reduce the amount of energy used to excavate and haul materials.

- Save 11.6 trillion Btu per year by 2020
- Improve underground mine safety
- Increase productivity and revenue of underground mines

Idaho National Engineering and Environmental Laboratory
CONSOL Incorporated
Joy Mining Machinery
Carnegie Mellon University

**ENVIRONMENTAL
QUALITY**

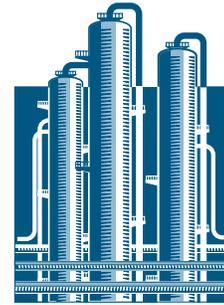
**Safe and Low-Cost Hydrogen
Storage for Fuel Cell Mining
Vehicles**

Project partners will research the use of fuel cells to replace diesel engines in mining transportation. Research will focus on mechanical alloying to lower the cost of metal hydrides—a compound that safely stores hydrogen in a solid metal powder.

- Save 1.7 trillion Btu per year by 2020
- Eliminate underground diesel exhaust
- Decrease underground ventilation requirements

Savannah River Technology Center
Hydro Quebec
University of South Carolina
Fuel Cell Propulsion Institute
Atlas Copco Wagner Inc.
Barrick Gold Corporation
H Power Corporation
Inco Ltd.
Long-Airdox Company
Sandvik Tamrock
Warren Equipment Ltd.
Westinghouse Safety Management Solutions, Inc.

Petroleum is the largest source of energy for the United States. On average, every U.S. citizen consumes about 20 pounds of refined petroleum products per day.

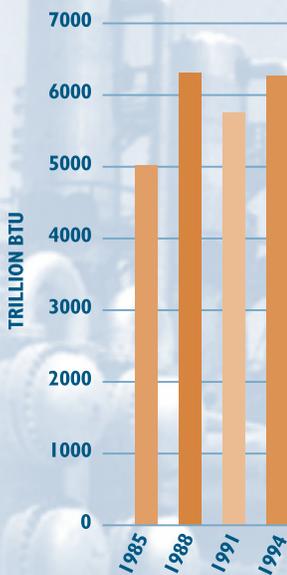


Petroleum Industry

PROFILE

Value of Shipments	\$157.9 billion
Employment.....	64,800
Capital Expenditures	\$4.25 billion
Net Trade Balance	-\$6.586 billion
Net Energy Consumption	6.26 quads

U.S. PETROLEUM REFINING ENERGY USE



Source: MECS Estimates

CHARACTERISTICS AND MARKETS

Petroleum refineries use physical and chemical methods to convert crude oil into fuels, petrochemicals, and other products. The industry is comprised primarily of a small number of large facilities. Most of the refineries in the United States are concentrated on the West and Gulf Coasts, which afford greater access to major shipping routes.

The supply of refined petroleum products has increased by over 3 million barrels per day since 1970. In 1997 U.S. refiners supplied over 17 million barrels per day. Crude inputs for these refined products come from both domestic and foreign producers.

Imports of crude and refined products have risen steadily over the past 10 years, reaching a record high of 10 million barrels per day in 1997. The main exports of U.S. refineries are fuel oils and petroleum coke, which account for 59% of the export total.

Although refinery output is dominated by the production of gasoline (over 43%), crude oil that enters a refinery is separated and ultimately converted into two finished products categories:

- Fuel products (e.g., gasoline, jet fuels, liquefied petroleum gases, coke, kerosene)
- Nonfuel products (e.g., asphalt and road oil, lubricants, waxes, and petrochemical feedstocks, such as naphtha, ethane, propane, butane, toluene)

EMPLOYMENT

The petroleum refining industry employs about 65,000 workers with average hourly wages of \$23.80—among the highest wages in the United States. These workers are responsible for refinery shipments worth \$158 billion, resulting in an annual value of shipments per production worker of \$3.7 million, significantly higher than other industries.

ENERGY

Petroleum refining is the most energy-intensive U.S. manufacturing industry. The industry consumed 6.263 quads of energy in 1994 (including about 2.4 quads for feedstocks), about 7% of total U.S. energy use that year. Fuel used for petroleum refining comes from a variety of sources—particularly natural gas, crude oil, electricity, and coal—but the industry also uses refining by-products (e.g., refinery gas and coke) as energy sources. In 1996, refinery by-products provided two-thirds of the energy used.

The total cost of energy for heat and power can often be as much as 40% of the industry's variable annual operating costs. Energy expenditures also represent a significant portion of manufacturing

costs; in 1997 the petroleum refining industry spent about \$4.2 billion on energy (i.e., fuels and purchased electricity).

ENVIRONMENT

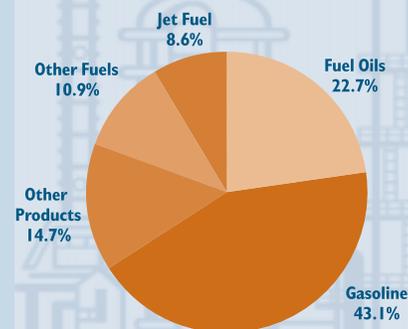
The petroleum refining industry generates a significant amount of air emissions and other residuals. The processes used to refine petroleum as well as the use of its products are subject to federal and state environmental regulations. As a result, the petroleum industry is one of the most heavily regulated industries in the United States.

Refiners are committed to improving the environmental performance of their industry. In 1994 the industry spent about \$5.4 billion on environmental compliance, about 47% of which went for capital expenditures. In addition, industry members take part in a variety of public and private initiatives for environmental improvement:

- Strategies for Today's Environmental Partnership (STEP) of the American Petroleum Institute
- Building Environmental Stewardship Tools (BEST) of the National Petrochemical Refiners Association
- 33/50 Program of the Environmental Protection Agency

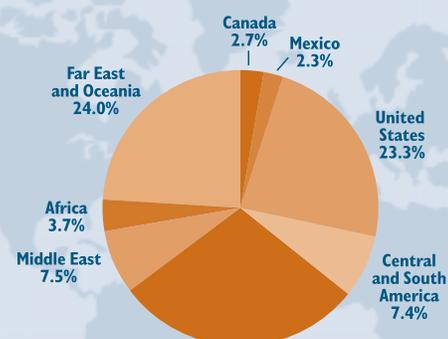
Petroleum refineries continue their efforts to increase recycling, reduce pollution, and decrease toxic chemical releases. In fact, about 40% of U.S. refineries conduct pollution prevention activities. In 1995 residual recycling for refineries reached 54%, up from 22% in 1987. Furthermore, total toxic chemical releases from refineries have declined about 40% since 1988.

U.S. PETROLEUM REFINERY OUTPUTS, 1997



Source: Energy Information Administration

WORLD OUTPUT OF REFINED PETROLEUM PRODUCTS, 1997



Source: Energy Information Administration

COMPARISON OF VALUE OF SHIPMENT PER PRODUCTION WORKER, 1997



Source: U.S. Bureau of the Census



Industry Vision and Roadmap

PETROLEUM REFINING INDUSTRY VISION

In February 2000, the petroleum industry issued its vision for the future, *Technology Vision 2020: A Technology Vision for the U.S. Downstream Petroleum Industry*. The vision outlines the industry's goal of ensuring that the United States continues to have an adequate supply of clean, safe, efficient, and competitive fuels. The vision also identifies

the challenges and key issues facing the downstream petroleum industry—the refining, distribution, and marketing component—and outlines broad goals for the future:

- Demonstrate continuous improvement in environmental impact on air and water and reduce solid waste production. Efforts are to be driven by flexible metrics that focus on environmental improvement over prescriptive solutions and control tactics. (Progress will be monitored through a comprehensive audit and report issued every five years beginning in 2000.)

THE PETROLEUM INDUSTRY HAS ESTABLISHED INDUSTRY-WIDE PRIORITIES AND PERFORMANCE TARGETS...

VISION AREAS	
Energy Efficiency and Process Improvements	<ul style="list-style-type: none"> • Use cost-effective, less energy-intensive technology • Exploit cross-industry opportunities • Be highly instrumented for structural integrity • Increase yields toward 100% raw materials utilization
Inspection and Safety	<ul style="list-style-type: none"> • Identify and implement economical routes to zero discharge • Reduce by 90% capital and operational losses due to abnormal situations/incidents
Environment	<ul style="list-style-type: none"> • Reduce emissions to air and water • Reduce wastewater flow out of refineries • Immediate detection/control of containment loss • Continually improve tools for risk evaluation

- Identify routes to improve the energy efficiency of manufacturing plants by 10% by 2020
- Improve the industry's leadership position versus all U.S. manufacturing industries on appropriate measures of safety and reliability by 2010

**PETROLEUM REFINING
INDUSTRY ROADMAP
WORKSHOP**

In order to keep the visioning strategy moving forward, the American Petroleum Institute and DOE cosponsored the Petroleum Refining Technology Roadmap Workshop in May 1999. Workshop

participants representing a cross-section of the industry gathered to outline performance targets and technology priorities to help achieve the goals of the vision. Technology development priorities for creating the ideal refinery of the future were designated in four areas:

- Energy efficiency—includes routes to reducing energy use in manufacturing plants and advancements in health and human safety
- Process improvements—includes improving general production efficiency and productivity of processing facilities with emphasis

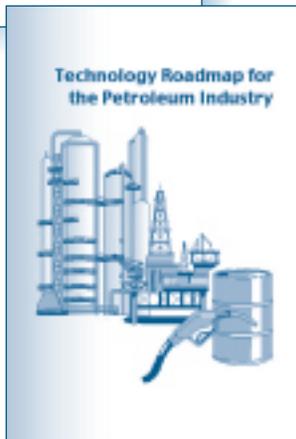
on refinery processing, process control, real-time analysis, and sensor technology

- Inspection and Safety
- Environment—includes processing and design changes that will provide continuous improvements in the environmental impact on air and water; also addresses reduction of solid waste

These preliminary workshop results will be a useful tool for helping the industry achieve the ambitious goals of its strategic vision. The roadmap draft was released in February 2000.

...AND IDENTIFIED R&D NEEDED TO ACHIEVE THOSE TARGETS.

	Ongoing	1-5 Years	5-10 Years	
ROADMAP PRIORITY AREAS		<ul style="list-style-type: none"> • Fouling mitigation • Membranes for hydrocarbon separation • Pursue equipment that combines mass and heat transfer, catalysis, and design • Focus on alternative technologies that increase fuel conversion efficiency and utilize waste stream 	<ul style="list-style-type: none"> • Explore direct pathways for hydrocarbon processing 	
	Energy Efficiency			
	Process Improvements	<ul style="list-style-type: none"> • Real-time process measurement • Measurement technology needed for models • Automated modeling tools • On-line intelligent processing (models) 	<ul style="list-style-type: none"> • Fouling onset measurement techniques • Sulfur-tolerant emission control technology • Catalysts for low-temperature environments 	<ul style="list-style-type: none"> • Alternatives for current separations (e.g., distillation)
	Inspection and Safety	<ul style="list-style-type: none"> • Nondestructive evaluation (NDE) for <i>in situ</i> material property degradation • Reliable quantification of corrosion rates with limited data sets 	<ul style="list-style-type: none"> • Global inspection technologies 	<ul style="list-style-type: none"> • Research on low-energy separation technologies (beyond membranes)
Environment	<ul style="list-style-type: none"> • Agree upon a method for risk analysis/assessment • Increase database for PM 2.5 emission factors • Improve remote sensing/smart leak detection and repair 	<ul style="list-style-type: none"> • Develop cost-effective techniques to clean up MTBE • Mitigate feedstock constituent effect on refinery environmental systems • Develop systems approach to fuel/engine technology interaction 		



Team & Partnership Activities

To remain viable and competitive in the future, the petroleum refining industry recognizes that it must be proactive in anticipating and adapting to change. The industry must work in partnership with suppliers, government, academia, and the national laboratories to pursue the technology and advance the goals identified in its vision and roadmap workshop.

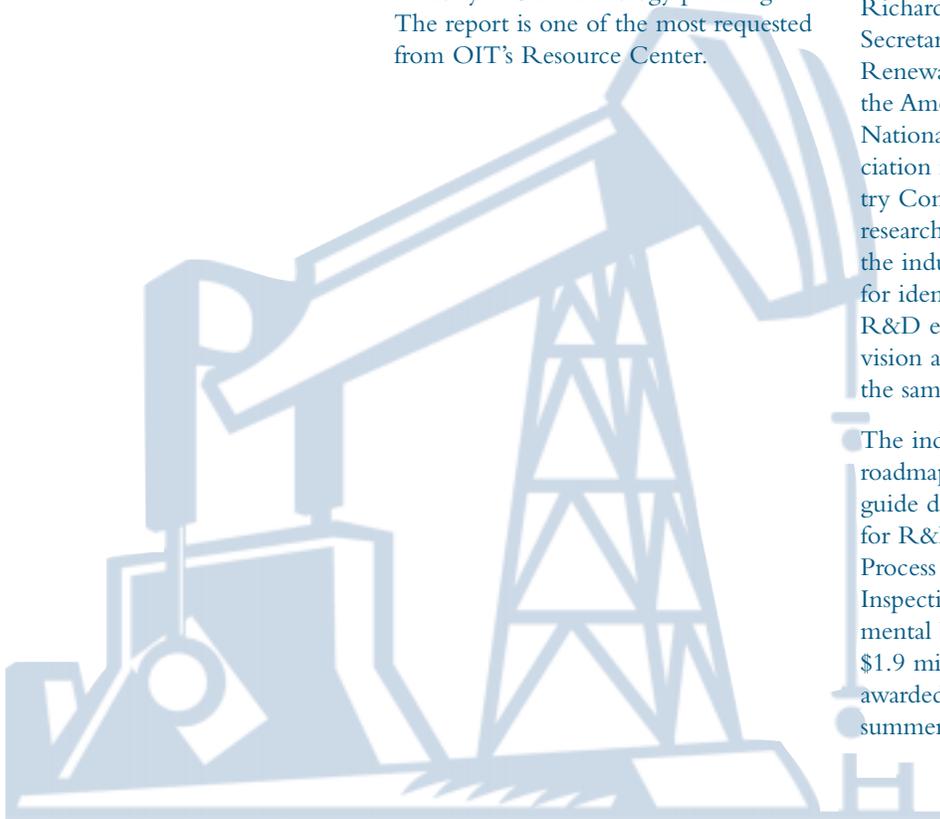
In support of the industry's efforts, OIT's Petroleum Refining Team has completed a report, entitled *Energy and Environmental Profile of the U.S. Petroleum Refining Industry*. The report presents benchmark energy use and environmental data for the petroleum refining industry as a whole and for each of the industry's major unit operations. By supplying current data for each process in the industry, the report provides a valuable reference for collaborative industry-DOE technology planning. The report is one of the most requested from OIT's Resource Center.



The team is also committed to fostering its government/industry partnership through a variety of outreach activities. A well-attended session on DOE-industry downstream petroleum opportunities was held at the 3rd Industrial Energy Efficiency Symposium and Exposition in 1999.

In February 2000, Energy Secretary Bill Richardson and Dan Reicher, Assistant Secretary for Energy Efficiency and Renewable Energy, joined members of the American Petroleum Institute and National Petrochemical Refiners Association in signing the Petroleum Industry Compact. The compact establishes a research partnership between OIT and the industry and provides a framework for identifying and pursuing joint R&D efforts. The industry's technology vision and roadmap were released in the same month.

The industry-defined priorities in the roadmap were subsequently used to guide development of a solicitation for R&D in the areas of Energy and Process Efficiency, Materials and Inspection Technology, and Environmental Performance. Approximately \$1.9 million in federal funds was awarded to selected projects in late summer 2000.



REPRESENTATIVE PETROLEUM-RELATED PROJECTS IN OIT'S PORTFOLIO

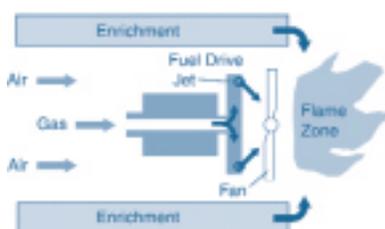
	SAFETY & RELIABILITY	PROCESS IMPROVEMENT	ENERGY EFFICIENCY	ENVIRONMENT & RECYCLING
Petroleum Team				
•Ammonia Absorption Refrigeration Unit			●	●
•CFD Model of Fluid Catalytic Cracking		●	●	
•Energy-Saving Separations Technologies		●	●	
•Fouling Minimization			●	
•Gasoline Biodesulfurization		●	●	●
•Global On-Stream Inspection	●			
•Hydrocarbon Leak Detector			●	●
•Rotary Burner Demonstration — Phase 1		●	●	
BestPractices				
•Advanced Motor Systems Upgrade			●	
Combustion				
•Forced Internal Recirculation (FIR) Burner			●	●
•Radiation Stabilized Burner			●	●
NICE³				
•Low-Profile Fluid Catalytic Cracker		●	●	
•Robotic Inspection System for Storage Tanks	●			

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

Selected Petroleum Portfolio Highlights



Ammonia absorption refrigeration unit recovers valuable products from waste gases.



Innovative burner is energy-efficient and produces low NOx emissions.

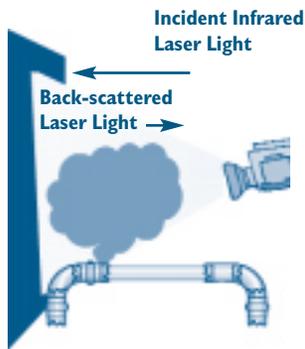


Inspection technology increases safety by accurately detecting and analyzing flaws in vessels and piping.

AREA	ENVIRONMENT & RECYCLING	PROCESS IMPROVEMENT	SAFETY AND RELIABILITY
PROJECT	Ammonia Absorption Refrigeration Unit	Rotary Burner Demonstration – Phase I	Global On-Stream Inspection for Mechanical Integrity
DESCRIPTION	<p>The unit is used to chill waste gases, allowing them to be condensed, blended into gasoline, or sold as liquefied petroleum gas. The Association of Energy Engineers designated this project as their Environmental Project of the Year.</p> <ul style="list-style-type: none"> • Recovers 2.1 million gallons of gasoline and liquefied petroleum gas per year • Decreases annual CO₂ emissions by 10,000 tons • Realizes increased profit of \$900,000 	<p>A new rotary burner design uses the "free energy" of the gas supply pressure as the means to provide high turndown ratio, fuel savings of 5%, low NOx emissions (below one ppmv), and operation with natural draft. This project will scale-up and field test a new burner (18 Mbtu) in an operating refinery. Phase I of the project will evaluate a single burner conversion to satisfy all safety and reliability conditions and collect data on energy savings and emissions reduction.</p>	<p>Researchers are developing monitoring and diagnostic technologies to insure the mechanical integrity of pressure equipment in a refinery. The technology will be able to detect, locate, and analyze flaws in pressure vessels and piping and to measure the surface temperatures of furnace and boiler tubes while equipment is being operated at high temperatures. Fiber-optic acoustic emission sensors will be used in conjunction with improved algorithms to reliably classify mechanical integrity.</p> <ul style="list-style-type: none"> • Increases annual productivity by 2% • Reduces environmental impact • Saves energy • Decreases catastrophic accidents
PARTNERS	<p>Ultramar Diamond Shamrock Energy Concepts Planetec</p>	<p>Calpos Engineering Equilon LLP Shell/Texaco Group API Gas Consultants Inc. Precision Manufacturing</p>	<p>Davidson Instruments, Inc. Industry Advisory Team Lawrence Berkeley National Lab Edison Welding Institute Ohio State University</p>



Membrane separations could provide alternatives to energy-intensive distillation.



Rapid detection of hydrocarbon leaks improves environmental performance and reduces feedstock losses.



The Maverick robotics inspection system eliminates the expense of draining, cleaning, and ventilating liquid storage tanks prior to inspection.

ENERGY EFFICIENCY

Energy-Saving Separations Technologies

Membranes are being explored as alternatives to energy-intensive vacuum and atmospheric distillation processes to separate hydrocarbons and recover hydrogen. Researchers are investigating several materials for use in pervaporation and reverse-selectivity membranes, including polyphosphazenes, ceramic, hybrid organic-ceramic, and polymer blends. Membrane materials that meet performance targets will be pilot tested in operating refineries.

- Improves energy efficiency 20%

Colorado School of Mines
Chevron Research and Technology Company
Marathon-Ashland

ENERGY EFFICIENCY

Hydrocarbon Leak Detector

Backscatter absorption gas imaging can be applied to the challenge of detecting hydrocarbon gas leaks in refineries. The technique uses an infrared laser light to illuminate an area, which is then viewed with an infrared video camera. Gases present in the imaged area that absorb at the laser wavelength appear as dark clouds. A portable gas imaging system is being developed to allow rapid inspection of multiple potential leak points. The technology offers an efficient alternative to EPA Method 21 leak detection protocol.

- Nationwide use projected to save 100 trillion Btu per year.

American Petroleum Institute
Laser Imaging Systems
Sandia National Laboratory
U.S. Environmental Protection Agency

SAFETY AND RELIABILITY

Robotics Inspection System for Storage Tanks

Conventional bulk liquid storage tank inspections are often hazardous, costly, and time-consuming. Solex Environmental Systems, in conjunction with the Texas Natural Resource Conservation Commission and supported by the NICE³ program, is demonstrating Maverick, a submersible robotic system designed to inspect in-service, above-ground petroleum and petrochemical storage tanks. Using the robotic system will eliminate the expense of draining, cleaning, and ventilating the tanks prior to inspection, as well as reduce the associated waste and emissions. The Maverick robotics inspection system won *R&D Magazine's R&D 100* award in 1999.

- Will reduce CO₂ emissions by more than 8,000 tons per year by 2010
- Will save almost 260 trillion Btu per year by 2010

Solex Environmental Systems
Texas Natural Resource Conservation Commission

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.

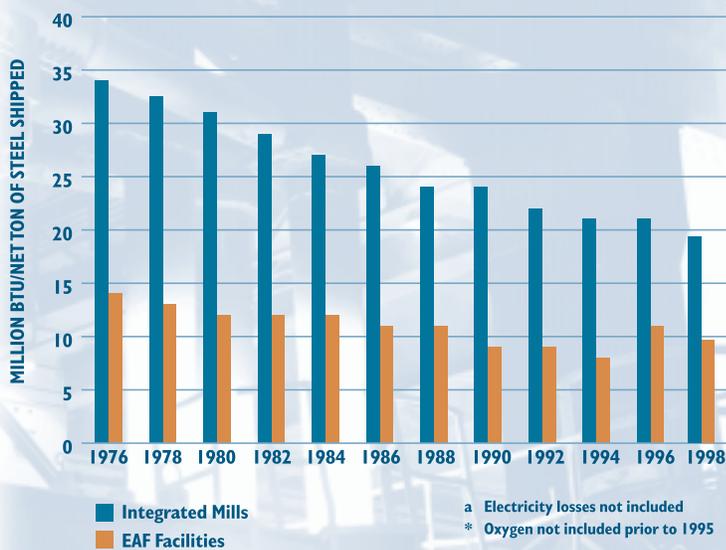


Steel Industry

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

STEELMAKERS HAVE STEADILY DECREASED THEIR ENERGY INTENSITY



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

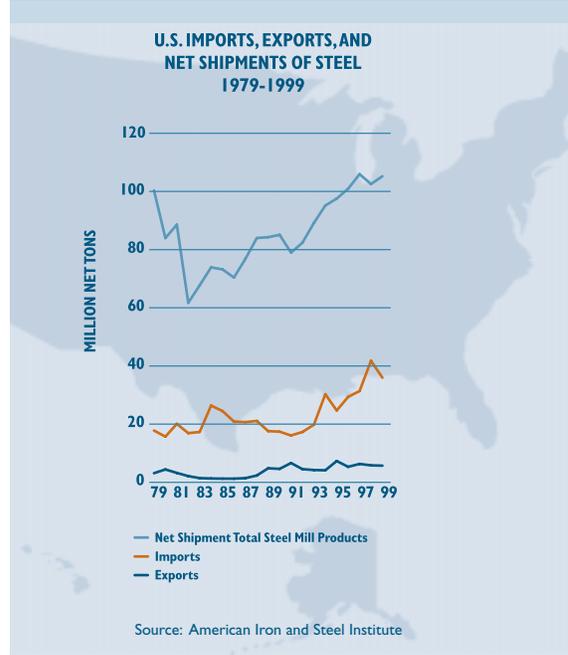
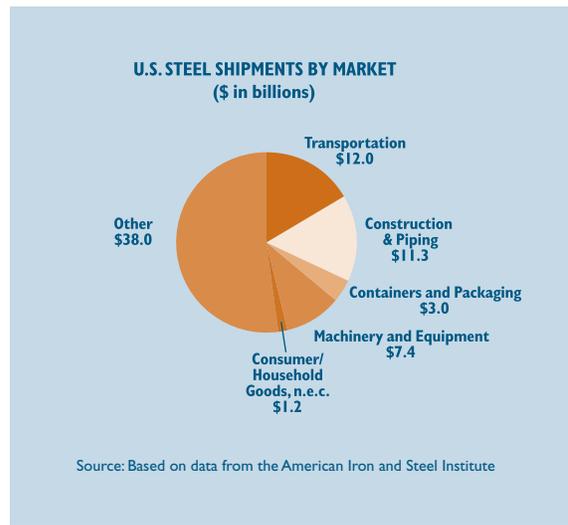
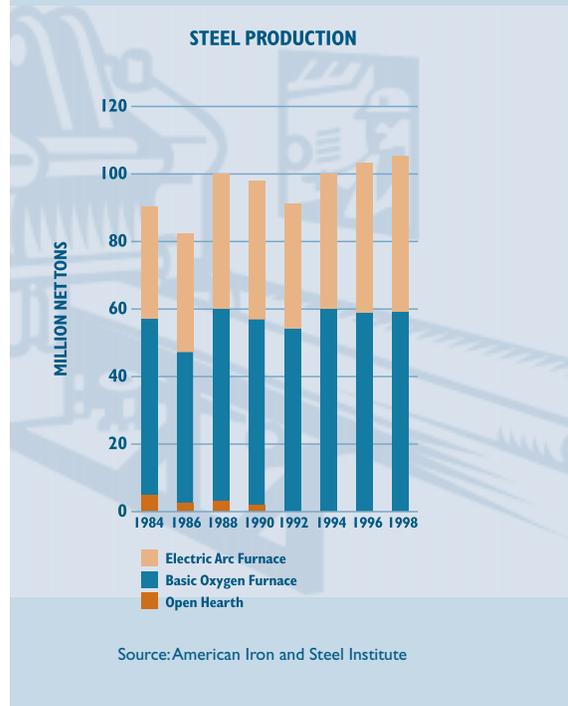
The energy-intensive steel industry accounts for about 2% of all energy consumed in the United States. This is easily understood when one considers that blast furnaces must reach temperatures of over 3,300°F to melt iron. For every ton of steel shipped, integrated mills require an average of 19 million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





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

		PROCESS DEVELOPMENT	ENVIRONMENT	RECYCLING	PRODUCT DEVELOPMENT
TECHNOLOGY AREAS	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

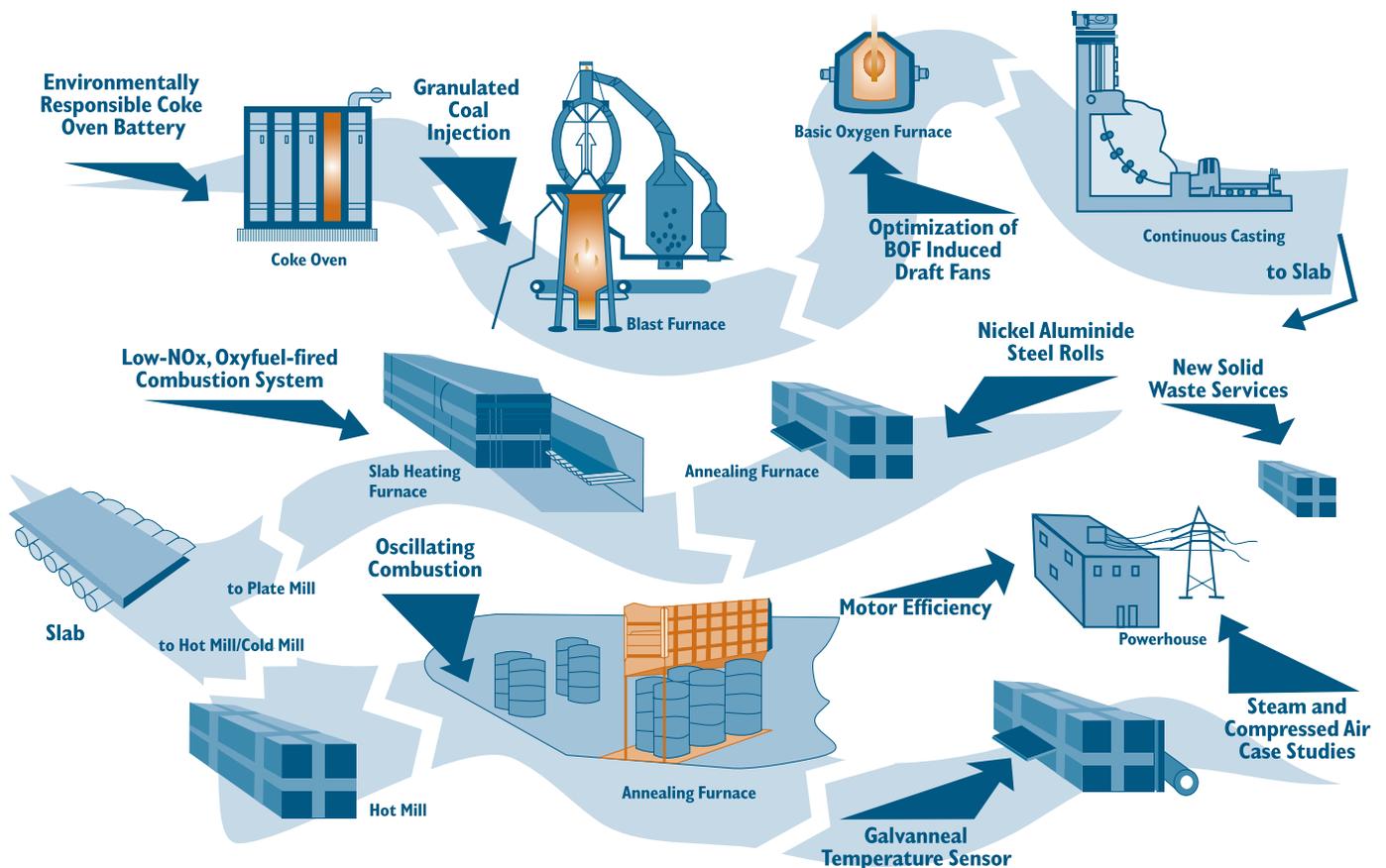
Led by the American Iron and Steel Institute and the Steel Manufacturers Association, the steel industry has formed research partnerships to pursue the priority research needs identified in the *Steel Industry Technology Roadmap*. Private steel companies, government, national laboratories, universities, 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 aluminate 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

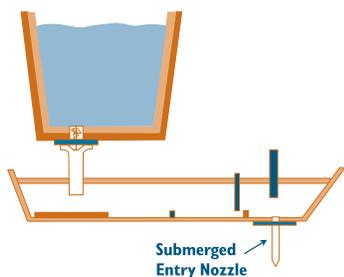
Collaborative partnerships continue to research and develop technologies that address priority needs in various aspects of the steel industry. Some of the steel-related projects in OIT's current portfolio are listed below, with selected projects highlighted on the following pages.

REPRESENTATIVE STEEL-RELATED PROJECTS IN OIT'S PORTFOLIO

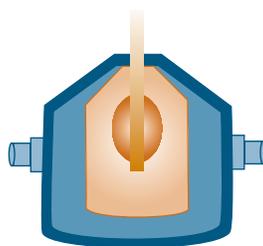
	IRONMAKING	STEELMAKING	CASTING	FORMING/ FINISHING	RECYCLING
Steel Industry					
•Advanced Control of Blast Furnace Operations	●				
•Enhanced Inclusion Removal in the Tundish			●		
•Hot Oxygen Injection into the Blast Furnace	●				
•Hot Strip Mill Model				●	
•Improving Refractory Service Life in EAFs		●			●
•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

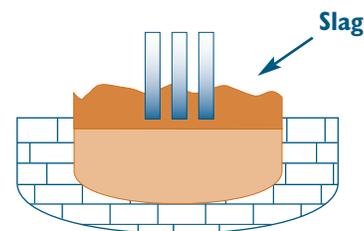
Selected Steel Portfolio Highlights



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

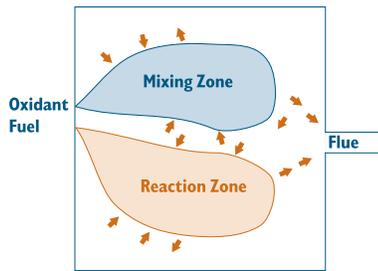


Operating practice to avoid slopping will facilitate recycling of waste oxide agglomerates directly into the steelmaking process.



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

AREA	CASTING	RECYCLING	STEELMAKING
	PROJECT	Recycling of Waste Oxides in Steelmaking	Improving Refractory Service Life and Recyclability
DESCRIPTION	<p>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.</p> <ul style="list-style-type: none"> • Reduces refractory costs • Increases steel quality • Increases productivity and energy efficiency 	<p>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.</p> <ul style="list-style-type: none"> • Avoids landfilling about 3 million tons of waste oxides annually • Saves up to \$180 million and 15 trillion Btu annually 	<p>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.</p> <ul style="list-style-type: none"> • Fewer spent refractories in landfills • Reduces furnace downtime • Economic savings on decreased rate of refractory replacement
PARTNERS	<p>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</p>	<p>Carnegie Mellon University Cleveland Cliffs, Inc. American Iron and Steel Institute Bethlehem Steel Corporation The Timkin Company Weirton Steel</p>	<p>Albany Research Center Argonne National Laboratory Baker Refractories Chaparral Steel Clemson University Martin Marietta Magnesia Specialties Steel Manufacturers Association University of Alabama</p>



Replacing combustion air with oxygen improves rehear 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 1/3 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

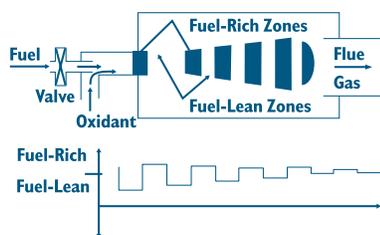
Hydrochloric Acid Recovery System

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 NICE³ 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.

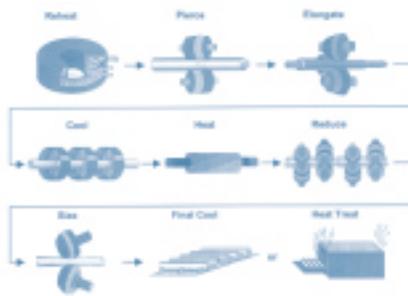
- Eliminates disposal costs and long-term liabilities of waste disposal
- Generates a saleable by-product (iron chloride) used in fertilizer, animal feed, and waste treatment

Beta Control Systems, Inc.

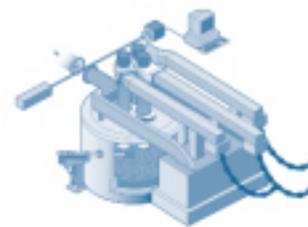
Selected Steel Portfolio Highlights



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.

STEEL

3

www.oit.doe.gov/steel

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	<p>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.</p> <ul style="list-style-type: none"> • Increases heat transfer by up to 13% • Increases efficiency by 5% or more • Reduces NOx emissions by up to 75% 	<p>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.</p> <ul style="list-style-type: none"> • Reduce scrap and rework • Reduce alloy content • Reduce post-processing heat treatment • Reduce greenhouse gas emissions 	<p>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.</p> <ul style="list-style-type: none"> • 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	<p>Air Liquide Bethlehem Steel Corporation CeramPhysics, Inc. Gas Research Institute Institute of Gas Technology Others</p>	<p>The Timken Company Daimler Chrysler Corporation Idaho National Engineering Laboratory USX-US Steel Group Ford Motor Company Others</p>	<p>American Iron and Steel Institute The Timken Company North Star Steel Sandia National Laboratory IPSCO Steel Georgetown Steel Corporation Stantec Global Technologies</p>

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

Crosscutting

Resources and Programs

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INVENTIONS AND INNOVATION	
NICE ³	

NICE³



The Industries of the Future strategy embraces the development and deployment of technologies that enhance energy and materials efficiency in a broad cross-section of U.S. industry.

Enabling Technologies



Several key technologies are ubiquitous in U.S. industry. Use of these technologies is so widespread that even a small improvement in their energy efficiency can mean substantial energy and cost savings. OIT is helping to focus public and private research investments on industry's most important needs in these crosscutting areas:

- Combustion
- Sensors and Controls
- Industrial Materials of the Future

The results enable improvements in productivity and energy efficiency throughout U.S. industry.

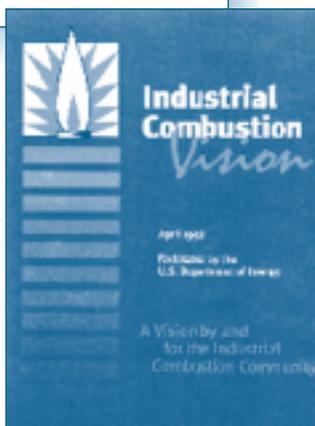
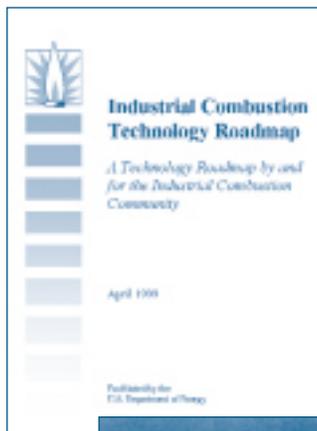
**ENABLING TECHNOLOGIES FACILITATE ENERGY-EFFICIENT
PROCESSING IN A BROAD RANGE OF INDUSTRIES**

Selected Projects	AGRICULTURE	ALUMINUM	CHEMICALS	FOREST PRODUCTS	GLASS	METAL- CASTING	MINING	PETROLEUM	STEEL
Combustion									
•NOx Emissions Reduction by Oscillating Combustion			■		■	■		■	■
•Forced Internal Recirculation Burner	■		■	■	■			■	■
•Radiation Stabilized Burner	■		■	■	■			■	■
•Dilute Oxygen Combustion		■	■			■			■
Sensors & Controls									
•Wireless Telemetry for Industrial Applications	■	■	■	■	■	■		■	■
•Thermal Imaging Control System		■	■		■	■			■
Advanced Materials									
•Nickel Aluminides	■	■	■	■	■	■	■	■	■
•Oxide Membranes			■					■	
•Metals Processing Laboratory	■	■	■	■	■	■		■	■



Combustion

(www.oit.doe.gov/combustion)



Combustion processes provide more than 85% of the energy used by U.S. industry. Industry uses combustion systems to meet process steam and heat requirements as well as to change the mechanical or chemical properties of materials and feedstocks. These functions are vital to the production of basic manufactured goods used in all segments of the U.S. economy.

To address increased competition and regulation, industry needs combustion equipment that offers better performance, lower environmental impact, and greater flexibility—all at a reasonable cost. With support from OIT's Combustion Program, users and manufacturers of industrial combustion equipment have joined forces to guide public and private R&D efforts in meeting the evolving needs of energy-intensive industry.

ACTIVITIES

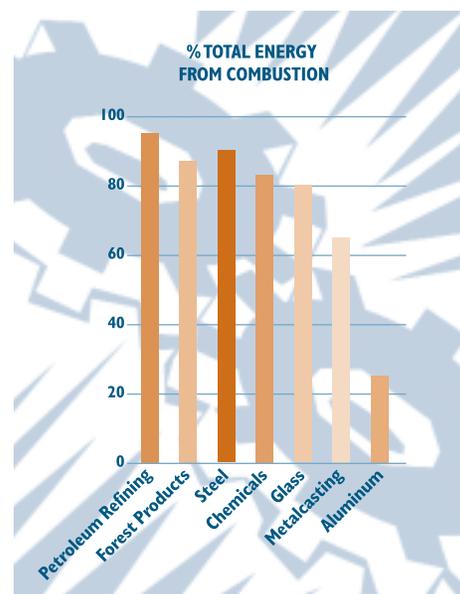
The extended combustion community developed the *Industrial Combustion Vision* in 1998, generating widespread interest in combustion research. The vision described the challenges and set strategic performance targets for advanced combustion technology over the next 20 years.

Equipment users, manufacturers, government, academia, and other research organizations collaborated on the development of the *Industrial Combustion Technology Roadmap* (April 1999), which established a long-term research agenda

for achieving the vision. The roadmap priorities include pre-competitive research, burner development, and efficiency improvements in industrial boilers and process heating systems. Industry-defined performance targets include energy-efficient, low-emission boilers that are fuel-flexible, cost-effective, reliable, and safe.

One of the industry's long-term goals is to significantly reduce emissions of NO_x and other criteria pollutants from industrial burners. Additional targets call for furnaces and process heaters that produce uniform, high-quality end products at high production rates with low specific fuel consumption and minimal environmental impacts. These combustion systems will be capable of using a variety of different fuels, including some derived from industrial by-products.

OIT's Combustion Program annually solicits proposals for collaborative R&D projects that address the combustion community's priority needs as identified in the technology roadmap.





Sensors and Controls

(www.oit.doe.gov/sens_cont)

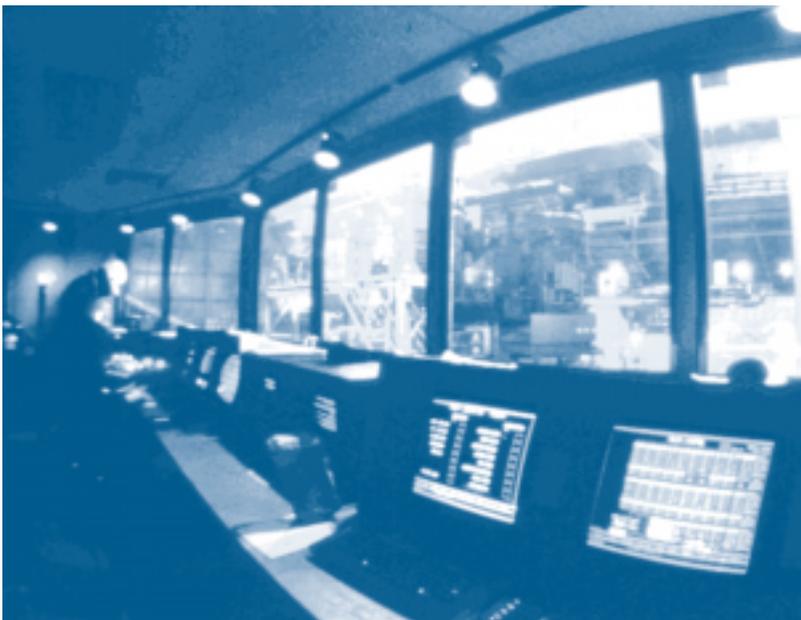
U.S. manufacturers need more accurate and intelligent sensor and control systems to improve energy efficiency, reduce waste and emissions, and boost productivity. The improved process control afforded by these systems can also enhance product quality.

The heat-intensive nature of many primary-processing industries poses special challenges for measurement devices. Sensors and controls have been identified as key technology needs in a variety of industry roadmaps. In particular, R&D is needed to develop sensors that can withstand extremely high temperatures and harsh environments. Advanced materials are opening the door to new possibilities in terms of sensor placement and accuracy, allowing greater proximity to (or immersion in) the materials to be measured. Advances are also needed in technologies for reliably integrating and processing input from different types of sensing devices in order to detect and make corrections to various processing parameters.

ACTIVITIES

OIT's Sensors & Controls (S&C) Program fosters the development and deployment of integrated measurement systems for operator-independent control of manufacturing processes. The S&C Program seeks to advance the key areas of science and technology that underpin the intelligent systems control industry: advanced sensor technology, information processing, and open-architecture systems. Major benefits of this program will include rapid adaptation of technology from one process application to another and avoidance of duplicate technology development efforts. The current goal is to develop a next-generation, intelligent control system capable of operating in harsh environments by 2004.

An S&C Steering Committee has been established to guide the selection of topic areas for upcoming S&C solicitations on the basis of the high-priority R&D needs identified in the technology roadmaps. The committee consists of subject-area experts and members representing six IOF teams, two National Science Foundation Centers, the National Institute of Standards and Technology's Process Measurements Division, and the DOE Laboratory Coordinating Council.



SENSORS & CONTROLS R&D NEEDS

Functions

- On-line, real-time, high-speed measurement
- Materials sorting and inspection
- Emissions and effluents
- Microstructure and inclusion
- Diagnostics and maintenance
- Physical property measurement and analysis

Characteristics

- Miniature sensors or micro-electromechanic systems
- Built-in failure sensing/self-calibration

Application Environments

- Harsh
- High temperature

Placement

- Embedded sensors
- Non-contact measurement

Improved Information Processing

- Advanced signal processing
- Imaging and data
- Modeling and simulation

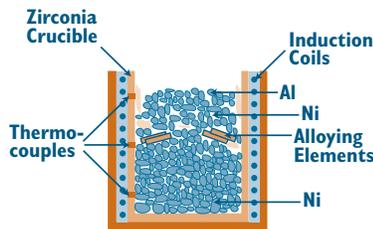
Open-Architecture, Intelligent Control Systems

- Sensor fusion
- Automation
- Control and optimization



Industrial Materials of the Future

(www.oit.doe.gov/materials)



The Exo-Melt Process developed with OIT support applies the energy released during initial exothermic reactions to the remaining melting process. The technology saves 50% of the energy formerly used in making nickel aluminide and was selected to receive an R&D 100 Award.

Improved materials are a crosscutting need of many industries and one of the keys to cleaner and more energy-efficient and productive manufacturing. OIT's Industrial Materials of the Future (IMF) program leads a national effort to research, design, develop, engineer, and test new and improved materials and to explore more profitable applications of existing materials. The IMF program conducts a mix of industry-specific and crosscutting R&D, core research, and other directed activities in coordination with the other OIT teams.

Roadmaps developed by several Industries of the Future specifically identify the need for industrial materials that are resistant to corrosion, tolerant of high-temperature and high-pressure environments, and capable of precision operations. Such materials will enable use of higher operating temperatures in processing, thereby increasing energy efficiency and reducing emissions. Stronger, more durable materials for manufacturing processes and equipment can also extend service life, reduce maintenance, increase productivity, and provide other benefits. Several of the

crosscutting technology roadmaps (e.g., combustion, sensors and controls) also identify materials as a priority need in developing cleaner and more efficient systems. The IMF program sponsors materials-related R&D to address these **industry-specific and crosscutting R&D** needs, with emphasis given to high-priority needs shared by two or more industries.

The program supports industry-specific R&D projects for one to three years until the technologies are sufficiently mature to compete for IOF team funding. Projects that address crosscutting research needs may be supported for one to five years, as necessary. For both types of projects, OIT's industrial partners contribute at least 50% of costs (averaged over the duration of each project). IMF-sponsored R&D projects do not include technology demonstration or field testing. At that stage of development, promising materials for industrial components, subsystems, and integrated systems are turned over to the appropriate industry-specific or crosscutting team in OIT.



MPLUS

The Metals-Processing Laboratory Users (MPLUS) Facility assists U.S. industry and university researchers in solving metals-based issues that affect energy efficiency, environmental performance, and U.S. competitiveness. Based at the Oak Ridge National Laboratory, MPLUS features four specialized centers:

- Metals processing
- Characterization and properties
- Joining
- Process modeling

In the last two years, MPLUS has received more than 85 proposals for joint projects by 65 companies in 25 states.



NICKEL ALUMINIDE STEEL ROLLS

Applications

- Transfer rolls in steel reheat furnaces (photo)
- Paper drying rolls
- Trays for carburizing steel automotive parts
- Forging dies for near net shape casting

Industry-specific and crosscutting R&D activities include projects to

- Develop functional and protective materials for sensors, actuators, and other devices subject to harsh environments
- Improve materials for refractories and other components of industrial furnaces, boilers, and gasifiers
- Develop materials that resist fatigue, corrosion, and wear in caustic, high-temperature environments
- Develop membranes and other materials for cost-effective separations
- Develop economically viable processing methods
- Analyze factors affecting emissions
- Develop comprehensive property databases for industrial materials
- Characterize microstructures and thermophysical properties
- Analyze life cycle costs and benefits

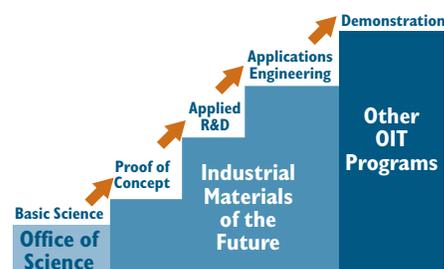
Industrial efficiency may also benefit from advances in the basic sciences that are enabling the development of cost-efficient “smart” materials such as electrochromics, controlled-release devices, and shape-memory alloys. These developments are opening a new world of possibilities—materials that can self-repair, actuate, and transduce. New coatings, films, and microstructures are also making it possible to create materials with a variety of unique and tailored properties.

To take advantage of developments in the basic sciences that may benefit the Industries of the Future, the IMF program devotes a portion of its budget to

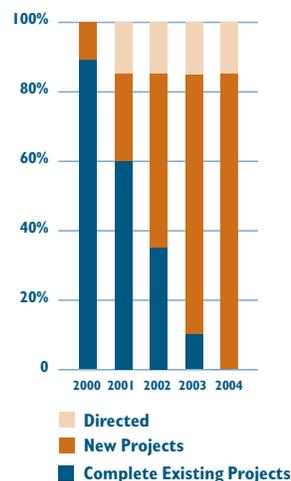
core research activities. Core activities include support for projects that strengthen fundamental understanding of the physical and chemical properties of materials as well as processing methods for materials of interest to the IOFs. These activities bridge the gap between the basic science research conducted by the DOE Office of Science and the advanced materials R&D projects sponsored by OIT. Core activity research projects may receive support from three to seven years.

Finally, the program supports a variety of **directed activities** that provide analysis, guide program development, and otherwise support program objectives. For example, the program will shortly undertake a comprehensive evaluation of the benefits of advanced industrial materials to help clarify the program focus. In particular, this evaluation will assess processing methods and potential for commercialization, determine priorities for the development of fundamental knowledge, and define the decision-making process for continuation or termination of project funding. Other directed activities include support of the Materials Processing User Center (MPlus) and other facilities as necessary to assist the IOFs in addressing short-term materials needs.

The Industrial Materials of the Future program represents a consolidation of OIT’s former Advanced Industrial Materials and Continuous Fiber Ceramic Composites Programs. There will be a transition period during which earlier projects will be completed and the new program activities gain momentum.



Industrial Materials of the Future PROGRAM FUNDING TARGETS

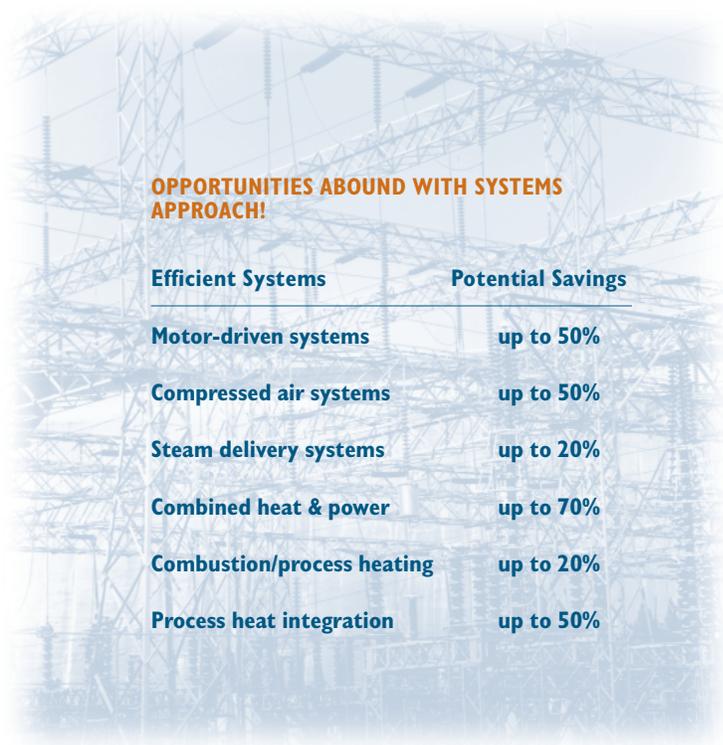


By improving the efficiency of systems that support the manufacturing process, U.S. industry can realize substantial cost savings. Improvements can be readily achieved with existing technologies and through the application of recognized principles and practices.



Best Practices

www.oit.doe.gov/bestpractices



OPPORTUNITIES ABOUND WITH SYSTEMS APPROACH!

Efficient Systems	Potential Savings
Motor-driven systems	up to 50%
Compressed air systems	up to 50%
Steam delivery systems	up to 20%
Combined heat & power	up to 70%
Combustion/process heating	up to 20%
Process heat integration	up to 50%

OIT's BestPractices program delivers energy-saving products, services, and technologies to the energy-intensive Industries of the Future. The BestPractices team has an ever-expanding portfolio of tools—technical experts, software packages, Web sites, and publications—that improve not only energy efficiency, but also the related productivity and environmental performance of manufacturing plants across the country.

BestPractices focuses on plant-wide systems—motors, steam, compressed air, and process heat—where large gains in energy efficiency can be realized. In fact, BestPractices is a collection of all the resources that once made up OIT's Challenge programs—Motor Challenge, Steam Challenge, and Compressed Air Challenge. Manufacturers can benefit from that experience and the BestPractices partnership with Industries of the Future to learn about the most energy- and cost-efficient technologies and practices available.

BestPractices Tools

BestPractices provides the tools, listed below, to help manufacturers identify opportunities for significant energy savings and application of emerging technologies.

INDUSTRIAL ASSESSMENT CENTERS

The Industrial Assessment Center (IAC) Program pairs engineering students and faculty with small- and medium-sized manufacturers that qualify for no-cost energy audits. The IAC team conducts one- or two-day site visits and then delivers energy-use reports to its manufacturing clients detailing its analyses, findings, and recommendations. Within six to nine months, the team follows up with the plant managers.

Since the IAC program was established in 1976, participating manufacturers have achieved an average of \$20,735 annually in energy savings and \$34,195 in annual waste and productivity savings, totaling a cost savings of \$54,930 per assessment. In addition, as a result of decreased energy consumption, manufacturers have reduced emissions of greenhouse gases by 4.89 million metric tons of carbon equivalent. And, not only do manufacturers and the environment benefit from the IAC program, engineering students gain theoretical and hands-on experience in energy and waste management.

PLANT ASSESSMENTS

BestPractices also offers cost-shared plant-wide energy assessments. Annually, BestPractices requests proposals from Industries of the Future manufacturers who are interested in increasing their plants' energy efficiency, productivity, and global competitiveness. Typically, OIT awards 10 to 20 fixed-price subcontracts based on technical quality, approach, cost, and availability of funding. Results of the energy assessments are often documented in BestPractices case studies and articles in the BestPractices newsletter, *Energy Matters*.

SOFTWARE

BestPractices, in partnership with industry associations, has produced three software programs—MotorMaster+, 3E+, and the Pump System Assessment Tool—that manufacturers can use to assess their existing components, make repair and replace decisions, and review equipment lists. In addition, a program that analyzes compressed air systems is currently being developed.

TRAINING

Throughout the year and across the country, BestPractices offers training courses to help end users increase the energy efficiency of their manufacturing plants. Classes range from specific training on using BestPractices tools, for example the Pump System Assessment Tool training series, to more general courses on energy management.

WEB SITE

The BestPractices Web site is the portal to all the BestPractices tools. It provides downloadable software and publications, order information on materials not available on-line, access to industrial partners and their industry associations, the training calendar, general information on the BestPractices initiative, and specific information on how end users and their service providers can get involved with the program.

OIT CLEARINGHOUSE

The BestPractices Program offers its clients, industrial end users, access to technical experts at the OIT Clearinghouse. The Clearinghouse can answer specific inquiries about optimizing the energy efficiency of industrial systems and can provide publications and contacts for further information.

INDUSTRY PARTNERS

By virtue of its partnerships with industry, service providers, and industry associations, BestPractices has a direct pipeline to end users. The BestPractices team can provide manufacturers with OIT's existing tools, up-to-date information on emerging technologies, and news on improved processes.

WHO IS ELIGIBLE?

IAC clients are small and medium-sized manufacturing plants in Standard Industrial Codes 20-39. Plants should be located within 150 miles of a host campus and meet the following criteria to qualify for these free assessments:

- gross annual sales below \$100 million
- fewer than 500 employees at the plant site
- annual utility bills of more than \$700,000, but less than \$2 million
- lack of in-house professional staff to perform the assessment

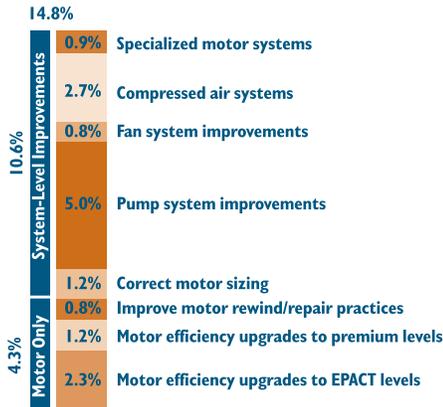


DETAILS OF IAC ASSESSMENTS CONTAINED IN DATABASE

The Office of Industrial Productivity and Energy Assessment at Rutgers University maintains an IAC Database that contains the results of more than 9,500 IAC assessments. The database contains detailed data available by Standard Industrial Classification (SIC), fuel type, base plant energy consumption, and recommended energy-efficiency improvements. Information on projected energy savings, cost savings, implementation cost, and simple payback are provided for each recommended measure.

Specific Industrial Systems

POTENTIAL MOTOR SYSTEMS SAVINGS OPPORTUNITY*



* as a % of total motor system energy use by the manufacturing sector

The BestPractices tools can be applied plant-wide or can be used to analyze and upgrade specific components. Many of the tools are currently focused on the most energy-intensive plant systems—those profiled below—that show the greatest potential for delivering savings.

MOTOR SYSTEMS

More than 1 billion electric motor systems are currently in use in industrial, commercial, residential, and utility power plant applications. Motor driven equipment accounts for 64% of the electricity

consumed in the U.S. industrial sector. The motor systems of the Industries of the Future consume approximately 290 billion kWh per year, or 54% of all energy consumed by industrial motor systems.

BestPractices recognizes the potential energy savings that motor systems represent and has built many of its resources around motor systems energy efficiency improvements. Motor tools include the software collection of MotorMaster+, the Pump System Assessment Tool, and ASDMaster; a large selection of publications from motor-specific tip sheets to motor market assessments to case studies; and an assortment of training programs.

POTENTIAL MOTOR SYSTEMS SAVINGS

TOP 10 MANUFACTURING INDUSTRIES FOR MOTOR SYSTEM ELECTRICITY CONSUMPTION

More than half of the electricity used by motor-driven equipment in the U.S. industrial sector is consumed by just ten industries.

Potential savings from motor systems efficiency improvements in the paper mill industry alone range from nearly \$100 million (low estimate) to \$250 million (high estimate). At the high end, these savings represent nearly 5% of the industry's net income.

Industry	Industry-Manufacturing Motor Systems Electricity Consumption (GWH/Year)	Potential Cost Savings Low to High Range \$MM/Year
Paper mills	55,777	\$103-248
Petroleum refining	40,805	\$119-287
Industrial inorganic chemicals	37,232	\$71-170
Paperboard mills	27,007	\$50-120
Blast furnaces and steel mills	25,323	\$47-112
Industrial organic chemicals	28,721	\$55-131
Industrial gases	21,733	\$41-99
Plastics, materials, and resins	13,667	\$26-62
Cement hydraulic	9,147	\$26-61
Pulp mills	6,402	\$12-28

STEAM SYSTEMS

Two-thirds or approximately 9.3 quads of all fuel burned by U.S. industry is used to produce steam. Steam is used to heat raw materials and treat semi-finished products at a constant temperature. It is also a power source for prime movers and equipment, as well as for building heat and electricity generation.

Because steam is generally produced from inexpensive fuels, it is often viewed as free. Actually, steam accounts for \$21 billion per year of U.S. manufacturing energy costs and 196 million metric tons of carbon equivalent emissions. These emissions represent 13% of total U.S. emissions and 40% of U.S. industrial emissions.

The BestPractices steam systems team is a public-private initiative sponsored by OIT and the Alliance to Save Energy. The steam team works with a broad coalition of participants including steam-related product suppliers and service providers. Among its tools are a Web site; the on-line newsletter, Steaming Ahead; the 3E+ steam system pipe insulation software program; tip sheets; training programs; and handbooks.

COMPRESSED AIR SYSTEMS

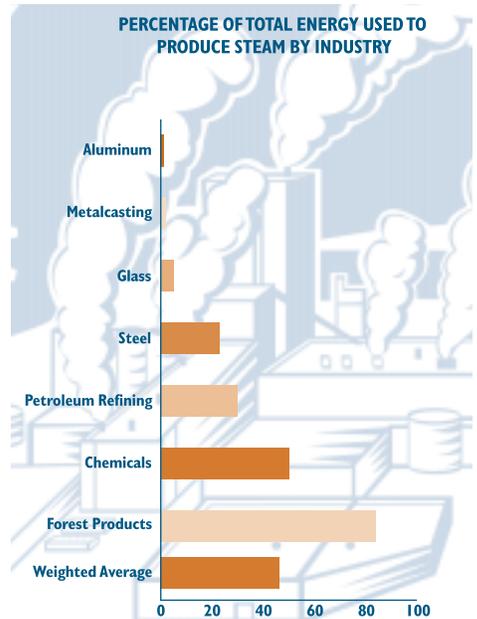
Compressed Air Systems account for \$1.5 billion per year of U.S. energy costs and .5% of U.S. emissions. The chemicals, mining, glass, pulp and paper, and petroleum refining industries, among others, use compressed air systems as a power source for tools and equipment and in industrial processes for pressurizing, atomizing, agitating, and mixing applications.

Optimization of compressed air systems represents one of the largest non-process, industrial energy efficiency opportunities. System improvements of 20-50% are achievable through the introduction of a BestPractices approach.

BestPractices' compressed air tools include market and technical reports, fact sheets, and a training series. A compressed air assessment software program is in development.



U.S. industrial compressed air systems consume an estimated 90 billion kWh/year.



OIT's financial assistance programs help move energy-saving ideas and technologies past some of the early hurdles to development and demonstration.

Financial Assistance



The NICE³ program demonstrated that indirect-fired IDEX kilns provide secondary aluminum smelters with higher-quality feedstock.

The Inventions & Innovations (I&I) and National Industrial Competitiveness through Energy, Environment, and Economics (NICE³) programs work closely with the Industries of the Future to provide financial assistance to support stages of technology that research and development solicitations omit.

The Inventions and Innovation program provides financial assistance to inventors and small businesses at two levels: Category 1 funds up to \$40,000 for conceptual ideas, and the competition will be restricted to specific topics considered priorities by DOE. The Category 2 portion will fund up to \$200,000 for more developed inventions moving toward prototype development or commercialization.

OIT also provides grants to help fund technology **demonstrations** through its National Industrial Competitiveness through Energy, Environment and Economics (NICE³) program. The (NICE³) program funds up to \$525,000 (50% cost sharing is required) for the first commercial demonstration of innovative industrial technologies.



Inventions and Innovation

(www.oit.doe.gov/inventions)

INDEPENDENT INVENTORS AND SMALL BUSINESSES

OIT's Inventions and Innovation program (I&I) provides financial and technical assistance to independent inventors and small companies that solve an energy-related problem or develop an innovative energy-saving technology.

I&I provides financial assistance at two levels: up to \$40,000 for technologies in early-stage development or up to \$200,000 for those in late-stage development. Ideas that have significant energy-savings and commercial market potential in industry, power, transportation, or buildings are chosen for financial support through a competitive solicitation process. I&I is particularly interested in projects in the nine OIT Industries of the Future.

OIT provides overall project assistance in the form of commercialization planning, work guidance, a market assessment of the innovation, and access to regional service providers. The assistance can include helping innovators find technical partners, commercial sponsors, business plan resources, and financial resources.

To date, more than 500 inventions have received financial support from DOE, and nearly 25% of these have reached the marketplace. Cumulative sales of these inventions have reached more than \$710 million, resulting in energy savings of 0.6 quadrillion Btus.



The Inventions and Innovation program is working with members of the forest products industry to develop a more energy-efficient dryer, called the Delta T Dryer.

Five Regional Resource Centers for Innovation

Centers help grantees to

- Find technical partners, manufacturers, licensing partners, and marketing specialists
- Link with regional, state, and local organizations that promote economic development
- Locate commercial sponsors
- Support preparation of business and project plans
- Leverage additional funding

1. Richland, WA
2. Idaho Falls, ID
3. Golden, CO
4. Oak Ridge, TN
5. Washington, DC

Inventions and Innovation Program Support and Resources

- **Technical evaluation of your idea**
- **Mentoring for project development planning and management**
- **Regional training and learning centers for business planning**
- **Regional, state, and local level support for economic development**
- **Incubation centers specializing in small start-up, energy-related technology**
- **Internet sites and information relevant to energy-related innovations**
- **Technology conferences and trade shows**
- **Forums for financial investors with particular interest in energy-related businesses**



NICE³ PROGRAM GOALS

- Accelerate industrial demonstration, deployment, and dissemination of energy-efficient technology
- Implement efficiency improvements in processes, material inputs, and waste streams
- Demonstrate successful applications of innovative, clean manufacturing techniques in conjunction with energy-efficient technologies
- Target technologies, processes, and procedures that are transferable to a broad range of industrial applications
- Enhance U.S. industrial competitiveness

NICE³

NATIONAL INDUSTRIAL COMPETITIVENESS THROUGH ENERGY, ENVIRONMENT AND ECONOMICS (NICE³)

(www.oit.doe.gov/nice3)

TECHNOLOGY DEMONSTRATION PARTNERSHIPS

OIT's NICE³ program provides grants to state and private sector partnerships to demonstrate emerging, energy-efficient technologies that will benefit the Industries of the Future. The program provides up to \$525,000 (50% cost sharing is required) for the first commercial demonstration of innovative industrial technologies that reduce energy consumption, waste generation, and operating costs. Applications must be submitted by an authorized state agency with an appropriate industrial partner.

The NICE³ program emphasizes funding projects within the following OIT focus industries: Agriculture, Aluminum, Chemicals, Forest Products, Glass, Metalcasting, Mining, Petroleum, and Steel. Since OIT is part of the Office of

Energy Efficiency and Renewable Energy (EE/RE), consideration will also be given to projects that involve non-OIT focus industries and industrial processes in the buildings, transportation, and power sectors.

In the eight years since NICE³ was initiated, 48 states and territories have submitted 560 proposals. To date, the program has sponsored 85 projects, 23 of which have been fully commercialized.

OIT FINANCIAL ASSISTANCE PROGRAMS

Financial Assistance Support Resources:

- Mentoring for project development planning and management
- Regional state and local level support for economic development
- Web sites with information and links relevant to energy-related innovations
- Technology conferences and trade shows
- Forums for financial investors with particular interest in energy-related business
- Market assessment for the technology



INNOVATIVE PLATING BARREL MINIMIZES WASTE

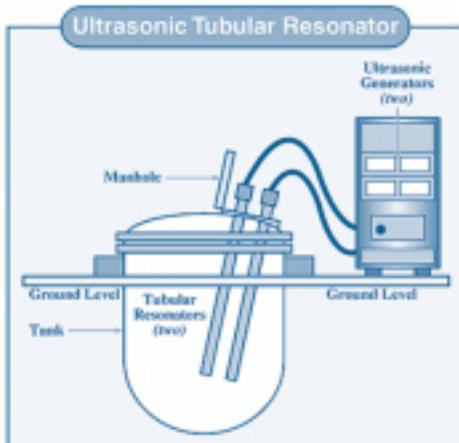
Whyco Technologies, Inc., a metal finishing and electroplating company, developed an advanced plating barrel to improve current flow and increase solution transfer. With the assistance of a NICE³ grant, Whyco began producing and marketing its barrel, which can increase plating productivity by 40% and decrease loss due to chemical "drag out" by 60%. Since June 1997, electroplating companies have purchased more than 750 of the energy-saving barrels.

**OIT'S FINANCIAL ASSISTANCE PROGRAMS
SUPPORT THE INDUSTRIES OF THE FUTURE**

INDUSTRY	I&I	NICE ³
Agriculture	<ul style="list-style-type: none"> • Continuous Cascade Fermentation System • Stalk and Root Embedding Plow 	
Aluminum	<ul style="list-style-type: none"> • Aluminum Roofing System 	<ul style="list-style-type: none"> • Aluminum Scrap Decoater
Chemicals		<ul style="list-style-type: none"> • Powder Paint Coating System • Ultrasonic Tank Cleaning
Forest Products	<ul style="list-style-type: none"> • DELTA T Dryer Control System • Lignin Separation and Epoxide-Lignin Manufacturing 	<ul style="list-style-type: none"> • Chemical for Increasing Wood Pulping Yield
Glass	<ul style="list-style-type: none"> • Electric Rotary Glass Furnace • Glass Fiber Manufacturing 	
Metalcasting	<ul style="list-style-type: none"> • Laminated Object Manufacturing • Reactive Sintered Nickel Aluminide 	<ul style="list-style-type: none"> • Process to Recover and Reuse Sulfur Dioxide
Mining		<ul style="list-style-type: none"> • Magnetic Elutriation for Clean and Efficient Processing of Iron Ore
Petroleum Refining	<ul style="list-style-type: none"> • Sulfide Reduction and Increased Oil Recovery 	<ul style="list-style-type: none"> • Robotics Inspection System for Storage Tanks
Steel	<ul style="list-style-type: none"> • Portable Ultrasonic Inspection System for Testing Tubular Goods • Recovery of Acids and Metal Salts from Pickling Liquors 	<ul style="list-style-type: none"> • Hot-Dip Batch Galvanizing • Hydrochloric Acid Recovery System

NICE³ PROJECT SELECTION CRITERIA

- **Technical Feasibility and Innovation**
- **Commercialization and Market Potential**
- **Energy Savings and Associated Benefits**
- **Statement of Work**
- **Applicant Capabilities**



ULTRASONIC TANK CLEANING PROJECT

Chemical and pharmaceutical companies have long used solvents to clean tanks. Many of these solvents emit volatile organic substances both during the cleaning process and during subsequent incineration of the waste. Now companies have a viable alternative for tank cleaning: the use of the power of sound.

TELESONIC Ultrasonics of New Jersey has successfully demonstrated, using NICE³ funding, the new Ultrasonic Tubular Resonator system to clean tanks at the DuPont-Merck Pharmaceutical facility in Deepwater, N.J. The successful demonstration showed an 80% reduction in solvent waste generated as well as reduced energy use, increased worker safety, and reduced downtime for tank cleaning. **TELESONIC** is now actively marketing and selling the ultrasonic systems throughout the country.

Competitive Solicitations

The Inventions and Innovation and NICE³ grants are awarded using a competitive solicitation that include the following steps:

- Companies can submit short “pre-proposals” (two pages maximum) describing their ideas to:
DOE Golden Field Office
1617 Cole Blvd., 17-3
Golden, CO 80401
- The submitter receives a quick response regarding the idea’s program relevance and information on how to submit a proposal for detailed review.
- DOE announces the RFP in the *Commerce Business Daily* and on the DOE Web site and makes the solicitation package available.
- For I&I funding, proposers submit proposals to the DOE Golden Field Office.
- For NICE³ funding, applicants present their innovative technology ideas to various state government agencies for review. State offices then partner with the firms offering the most promising concepts and submit proposals to OIT for possible NICE³ funding.
- After detailed review, DOE awards financial assistance grants to winning applicants based on merit and available funding.

The I&I and NICE³ programs select for funding those grant applications that demonstrate the greatest innovation, market, and economic development potential and save the greatest amount of energy.

What's Next?

You've learned about the Industries of the Future and how partnerships with OIT are helping industry use energy and materials more efficiently—today and in the future. If you're not yet involved, consider one or more of the following actions. If you're already active in one area, consider additional ways your company can benefit.

R&D (MANUFACTURERS, SUPPLIERS, UNIVERSITIES)

- Join a working group under a participating professional or industry association to help guide public and private R&D investments.
- Step forward to champion a state-level effort; contact your state economic development office or OIT's States Team leader.
- Select your R&D team and propose a cost-shared R&D project in response to one of OIT's published solicitations; monitor our Web site for the latest information.
- Join us at our biennial Industrial Energy Efficiency Symposium and Expo in Washington, DC, to hear about the latest trends, technologies, and tools that can affect your company.

TECHNOLOGY FOR TODAY

- Order a free catalog of OIT publications, CDs, tools, and videos to gain a clear idea of what's available. Just call the OIT Clearinghouse.
- Request training in techniques to improve the efficiency of your plant's motor, pump, or steam systems; contact the OIT Clearinghouse.
- Propose your large plant for a cost-shared, plant-wide, energy efficiency assessment in response to our next solicitation; watch our Web site for announcements or ask to be placed on our mailing list.
- Request a no-cost energy and environmental assessment for your small- to mid-sized plant within range of one of our participating engineering schools.
- Attend a showcase of emerging technologies designed for your industry.

A GOOD PLACE TO START

- Check out the news, activities, projects, and solicitations on our Web site.
- Request your free subscription to the *OIT Times* and *Energy Matters* newsletters.
- Call the OIT Clearinghouse for guidance on the best fit for your company.

www.oit.doe.gov

OIT Clearinghouse: (800) 862-2086

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U.S. Department of Energy

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