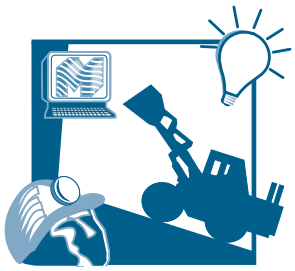
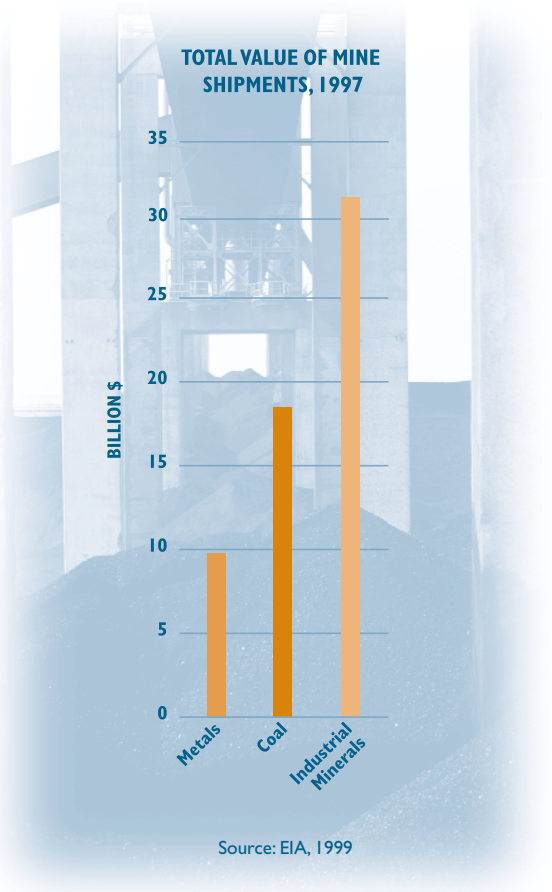
The U.S. mining industry, which includes coal, metals, and industrial mineral mining, provides energy and raw materials to our economy. On average, each American uses 7,300 pounds of coal and about 46,000 pounds of other minerals annually.



Mining Industry

PROFILE



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.

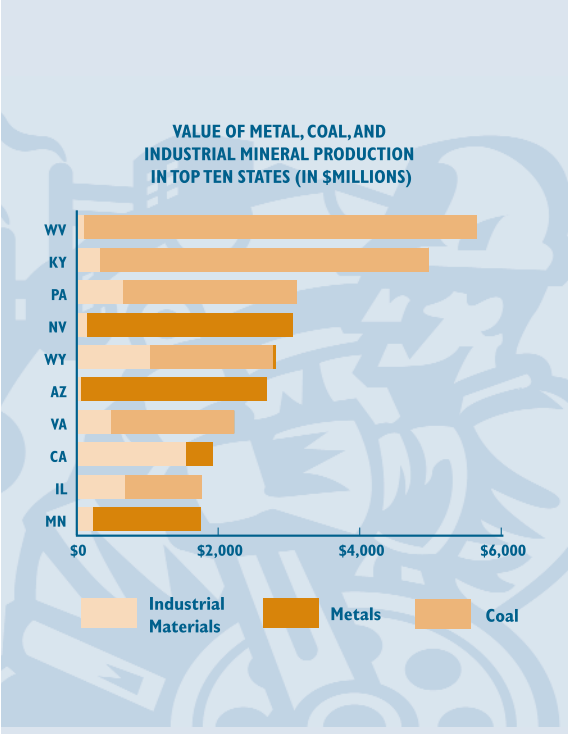
The coal industry is the nation's largest energy-producing industry, representing nearly one-third of U.S. energy production. About 80% of the coal is used to produce electricity. More than half of that total is produced in Wyoming, Kentucky, and West Virginia.

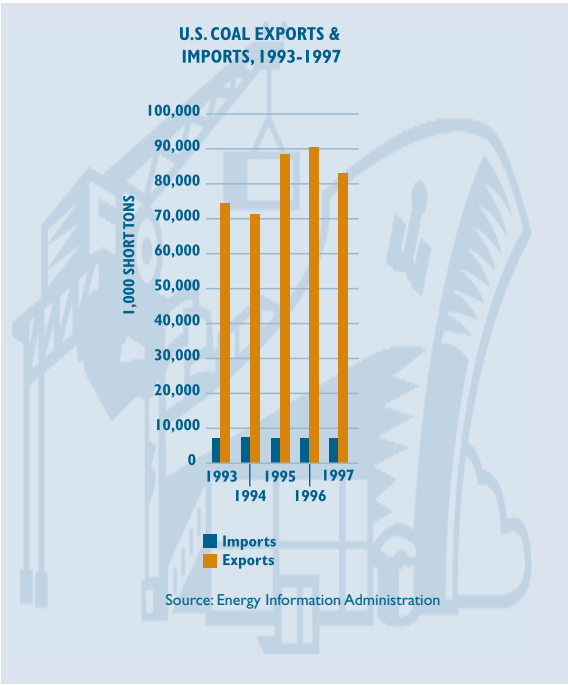
ENVIRONMENT

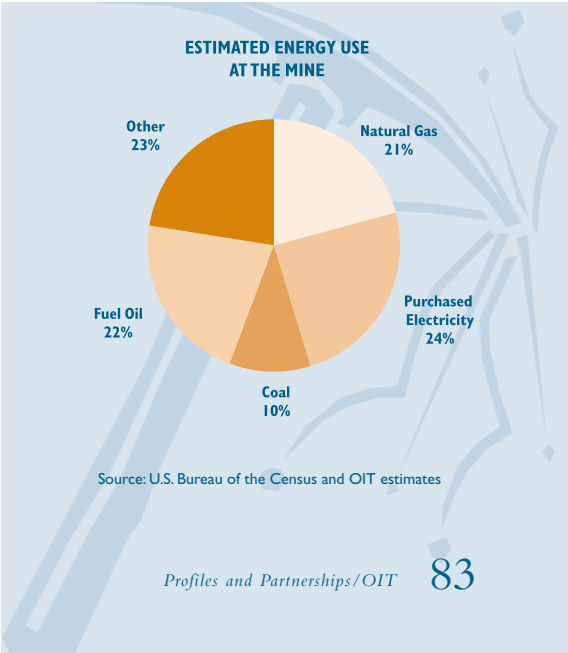
The mining industry has made significant strides in its pollution prevention and environmental protection efforts. For example, sulfur dioxide emissions from the mining industry have decreased to 27% below 1970 levels, despite the increased use of coal for electricity (more than double) since 1970. Mining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

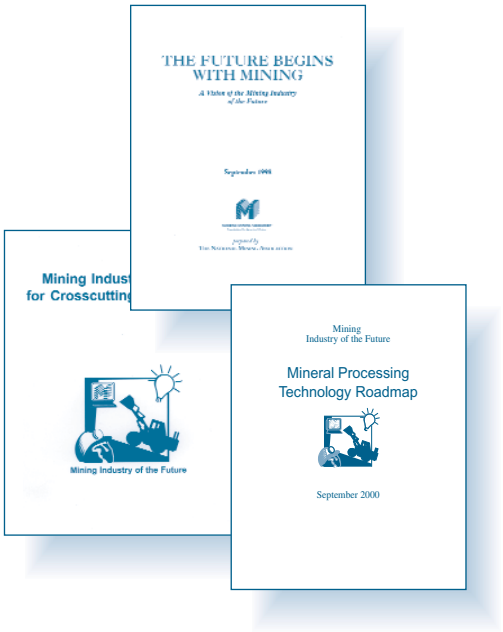
In the last 20 years, U.S. coal mining operators have reclaimed more than two million acres of land. Moreover, according to the U.S. Geological Survey, less than a quarter of 1% of the nation's land surface has been disturbed by mining.

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.









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...

VISION GOALS	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

- 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

	R&D Opportunity Areas
Exploration and Resource Characterization	• Evaluate existing ground-based diagnostic techniques for their potential use in mining and exploration • Develop sensors for semi-autonomous machines (guidance and navigation) • Improve the accuracy of deep (1000 ft. beneath surface) sensing of rocks, minerals, elements, and structures • Develop projectiles to send underground to transmit information • Evaluate existing satellite technology for use in exploration
Safe and Efficient Mining	• Develop autonomous mining equipment • Develop geologic sensing device to measure what is ahead of the working face • Develop more efficient technologies for removing fuel and nonfuel minerals • Develop "Advanced Reserve System" to integrate geological data into models • Develop technology for more efficient *in situ* extraction and near-face beneficiation • Develop improved ground control techniques to handle difficult mining environments for surface and underground • Integrate safety equipment for respiration, ear, and eye protection
Safe and Efficient Mineral Processing	• Develop new ways to deliver input energy to ores • Develop sensors to characterize material to be disaggregated • Develop new processes to utilize fine particles • Develop comprehensive models for physical separations processing • Develop new methods to increase reaction kinetics • Develop processes with more usable product streams

Team & Partnership Activities

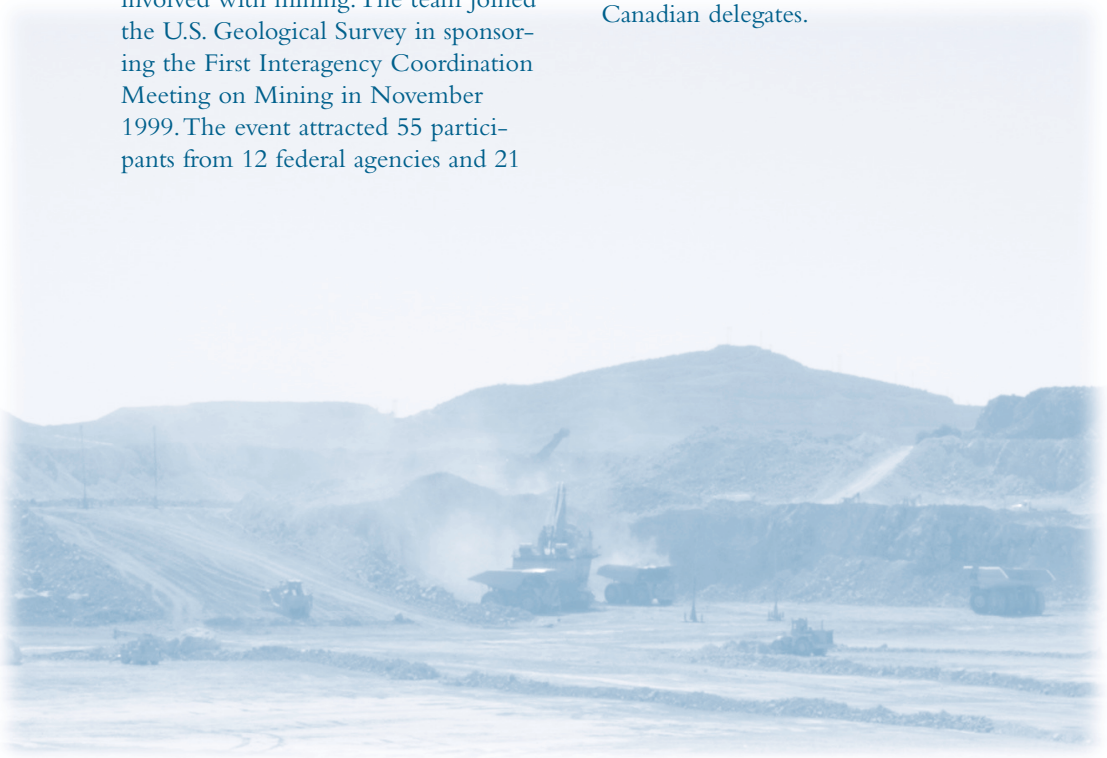
The OIT Mining Team conducted its first solicitation for DOE laboratory-led R&D projects during the summer of 1999. The team selected 10 projects (see facing page) to receive approximately $5.2 million in government funding over three years to develop new, energy-efficient mining technologies. Another 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	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. • Save about 11 trillion Btu per year • Increase productivity by 15%	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. • Reduce energy use and cost of downstream processing • Reduce mineral ore in waste • Improve mine safety	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. • 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

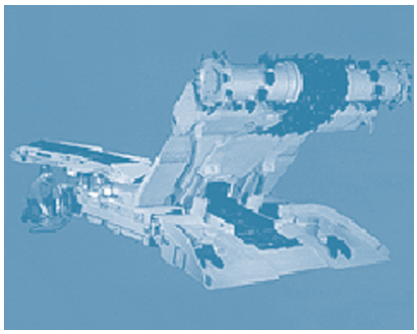
ENVIRONMENTAL QUALITY

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
SepraDyne Corporation
Colorado School of Mines
University of Arizona



Continuous miner

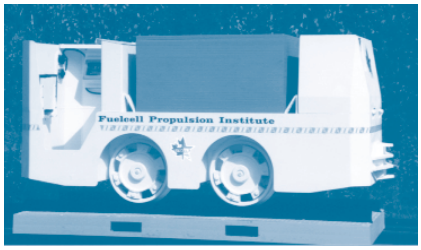
ENERGY SAVINGS

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



Fuel cells use hydrogen and oxygen to produce electrical energy.

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.

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