Metal Casting
Industry of the Future

Fiscal Year 2004 Annual Report

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

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

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

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

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

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

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

ITP uses a leveraging strategy that maximizes the energy and environmental benefits of its process-specific technology investments by coordinating and cooperating with energy-intensive industries. By working closely with the private sector, ITP is able to effectively plan and implement comprehensive R&D agendas and help disseminate and share best energy management practices throughout the United States. The ITP public-private partnerships also facilitate voluntary efforts, such as the President's Climate VISION initiative, to encourage industry and government to reduce greenhouse gas emissions. ITP also conducts R&D projects on enabling technologies that are common to many industrial processes such as industrial energy systems, combustion, materials, and sensors and process control systems. In addition, ITP funds technical assistance activities to stimulate near-term adoption of best energy-saving technologies and practices within industry. These activities include plant assessments, tool development and training, information dissemination, and showcase demonstrations.

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

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EXECUTIVE SUMMARY

The metal casting industry purchases an estimated 328 trillion Btu annually to manufacture components for transportation, aerospace, medical, national defense, and many other manufacturing industries. In fact, 90 percent of all manufactured goods contain one or more cast metal components. Energy-intensive processes include melting, moldmaking, coremaking, and post-casting operations.

The U.S. metal casting industry is diverse, employing a variety of casting processes and alloys to make a wide range of products. Because the majority of metal casters are a small business — 80 percent of the 2,700 metal casters operating in the United States employ fewer than 100 people — most metal casters cannot assume the high cost and risk associated with research and development (R&D), particularly long-term R&D. Public-private research partnerships, such as the Cast Metals Coalition (CMC), have proven vital for performing long-term research needed to maintain a productive and healthy U.S. metal casting industry.

Transformational R&D, such as that funded by the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Industrial Technologies Program (ITP), is critical to maintaining the global competitive position of the U.S. metal casting industry. Studies sponsored by EERE have quantified the opportunity for saving energy in metal casting (defined as the difference between today's energy use and the practical minimum energy use). DOE's goal in this area is to develop transformational technologies that will reduce the energy required to produce a ton of castings by 20 percent - 65.6 trillion Btu per year in 2020.

A Successful Strategy with Industry

DOE's Office of Energy Efficiency and Renewable Energy leads federal development of advanced energy-efficient and environmentally-friendly industrial technologies. Metal casting industry R&D is a component of the overall EERE strategy, contributing to a reduction in energy intensity of industry, a goal outlined in the National Energy Policy.

EERE/ITP is working to build the Industries of the Future through a strategy that is based on multi-year planning, industry involvement and input during the planning process, and careful analysis and data-based decision making. This strategy not only takes into consideration the interests of the industry as described in their R&D Technology Roadmaps, but also consists of an agenda of analytical studies that provide the basis for decision making. For instance, the *Metalcasting Industry Technology Roadmap: Pathway for 2002 and Beyond*, published in 2003 and the *Metalcasting Industry Technology Roadmap* published in January 1998, have provided the basis for focusing the R&D by identifying industry research interests. The *Metal Casting Energy and Environmental Profile*, Bandwidth study, and Footprint study were developed using both government and industry data and information, and industry expertise to provide the next level of prioritization for the portfolio. By using these studies, the portfolio is able to design a multi-year R&D plan based on the focus area, barrier, and pathway approach. In this approach, a limited number of critical technology focus areas are identified along with the technical barriers preventing their successful implementation. A multi-year plan (called a "Pathway") is then developed that will guide the R&D activities leading to a successful development of the focus area technology. The "Pathways" are then the basis for solicitations of pre-competitive R&D that addresses both energy efficiency goals outlined in the National Energy Policy and metal casting industry research priorities. This successful strategy has now evolved to a point where it provides focus on potentially high-impact research to make revolutionary improvements in metal casting.

Strong industry involvement ensures direct application of research results and testifies to the importance of this cost-shared research partnership. Broad industry and university participation (over 270 active R&D partners) in the Metal Casting portfolio is facilitated through the Cast Metals Coalition, which is composed of the American Foundry Society (AFS), the North American Die Casting Association (NADCA), and the Steel Founders' Society of America (SFSA). Collectively, this coalition represents approximately 80 percent of the U.S. metal casting industry. Involving industry in the early R&D stages helps accelerate the development and application of energy efficiency technologies. The ITP Metal Casting portfolio also emphasizes university-based research in order to tap into the technical resources of our nation's educational institutions and ensure a well-trained, well-educated work force.

Achieving Energy Savings: Portfolio Strategy

The ITP Metal Casting portfolio, comprised of pre-competitive research, addresses technological needs that have broad applicability throughout the metal casting industry. The program fosters both revolutionary technologies and incremental improvements to existing processes, thereby addressing long-term goals without neglecting short-term opportunities to improve energy efficiency. ITP also strives to expand the industry's fundamental base of knowledge to optimize key processes and resource efficiency.

As the Metal Casting portfolio continues to shift towards supporting a smaller number of high-impact projects, research activities are organized into the following categories: *Advanced Melting* and *Innovative Casting Processes*. The FY 2004 portfolio of 35 metal casting research topics (see Exhibit 11, p. 10) is performed in partnership with 270 university, industry, and national laboratory partners across the United States. The FY 2004 portfolio leverages 14 percent of research funding to the "Advanced Melting" focus area and 86 percent to the "Innovative Casting" focus area. The ITP Metal Casting portfolio also maintains a healthy balance of research targeted at both ferrous and nonferrous alloys with 17 percent of the funds addressing ferrous issues, 33 percent nonferrous, and 50 percent crosscutting.

FY 2004 Highlights

- Researchers have developed an advanced high-temperature rheological measurement system that can help to improve the accuracy and capabilities of various simulation tools used to determine flow patterns during die filling while using Semi-Solid Metal (SSM). This project will expand the use of SSM technology because the billets require a lower temperature (as compared to traditional casting operations), thereby reducing the amount of energy expended.

- Steel foundries generally have 10 times the process inventory workload in comparison to traditional iron foundries. These high inventory levels inhibit the ability to detect quality problems and lead to extended delivery times. Researchers at Iowa State University have been able to identify the problems leading to these high inefficiencies and are developing recommendations that will reduce the amount of heat treatment, scrap castings, and casting reworks.

- Quantitative gas evolution measurements taken at the University of Alabama - Birmingham have assisted in the development of a new model that is heated by molten metal. This model recognizes the formation of undercut in lost foam patterns. The model enables the user to correctly predict the filling speed and a weak thickness dependence. General Motors is using this model to make production decisions to improve the quality of its lost foam casting lines.

- ITP conducted a solicitation for competitive cost-shared research proposals which resulted in four newly-awarded research topics. These research topics will make advances in the melting systems and innovative casting processes for the metal casting industry.

- EERE's BestPractices and Industrial Assessment Centers provide hands-on technical assistance that metal casters can apply immediately, saving them thousands of dollars annually. For example, a plant-wide assessment at Sawbrook in Ohio identified 15 plant and process modifications that would result in an annual savings of $169,000 per year in costs and energy.

- In FY 2004, the ITP published two reports, *Energy Use in Selected Metal Casting Facilities - 2003* and *Theoretical/Best Practice Energy Use In Metalcasting Operations*. These two studies evaluate energy use in casting operations, taking into consideration the diversity of the industry in terms of casting processes, facility size, and other factors. These reports will assist the ITP to direct efforts to high-impact, revolutionary processes research.

- In October 2003, ITP conducted a survey of all university participants in the Metal Casting portfolio to determine the level of student participation. The results concluded that over 326 students participated in ITP Metal Casting portfolio research. Of these students, 152 are now working in the metal casting industry, and 52 are in the process of pursuing advanced degrees.

INDUSTRY OVERVIEW

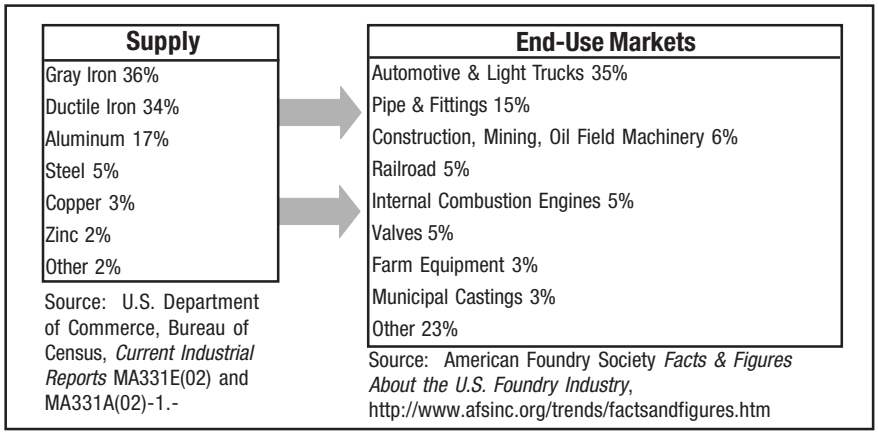
The metal casting industry has been integral to U.S. growth and has helped the United States become the world benchmark in fields such as manufacturing, science, medicine, and aerospace. This industry, dominated by small businesses, continues to fuel the nation's prosperity and national defense into the 21st century.

The metal casting industry consists of 2,700 facilities located in all 50 states. Eighty percent of these facilities employ fewer than 100 people, 14 percent employ between 100 and 250 people, and only 6 percent employ more than 250 people.[1] The industry employed approximately 199,000 people, providing $9.4 billion in wages.[2]

Metal Casting In Brief

Metal casting enables the production of simple and complex parts that meet a wide variety of needs. Nearly all manufactured goods contain one or more cast components. Major end-uses include power generation equipment, defense systems and machinery, motor vehicles, transportation equipment, oil field machinery, pipelines, industrial machinery, construction materials, and other products vital to our economic and national security. Oil field machinery and equipment sales alone represent approximately $259 million in casting sales per year.[3] Exhibit 1 illustrates raw material supplies and end-use markets for metal castings.

Exhibit 1
Metal Casting Supply and End-Use Markets



The basic metal casting process consists of pouring or injecting molten metal into a mold or die containing a cavity of the desired shape. The most commonly used method for small- and medium-sized castings is green sand molding, accounting for approximately 60 percent of castings produced. Other methods include die casting, shell molding, permanent molding, investment casting, lost foam casting, and squeeze casting.

Markets for metal castings are increasingly competitive and casting customers are placing greater emphasis on high-quality, competitively priced castings. There is an increasing demand for lighter-weight, high-strength ferrous and nonferrous cast metal components and castings that meet demanding design specifications. Casting processes must continually evolve and improve to remain competitive in today's marketplace.

Metal Casting Industry Shipments

As shown in Exhibit 2, in 2002, the metal casting industry shipped a total of 11.9 million short tons of castings valued at $16.2 billion (shown in Exhibit 3). This was a 2.5 percent decrease in total tonnage shipped and a 9.6 percent decrease in the value of castings shipped from the previous year. Over the period 1996-2001, there has been an average annual decline of 3 percent in casting shipments.[4]

[1] American Foundry Society, *AFS Trends Facts and Figures,* www.afsinc.org/Trends/FactsandFigures.htm
[2] U.S. Department of Commerce, Bureau of Census, *Annual Survey of Manufactures 2001*, Table 3 NAICS code 3315.
[3] Lessiter, Michael J. *Modern Casting* "Oil Field Equipment & Machinery," November 2002, pg. 36.
[4] U.S. Department of Commerce, U.S. Census Bureau, *Current Industrial Reports*, Iron and Steel Castings 2002, MA331A(02)-1, Table 3; Non-Ferrous Castings 2002, MA331E(02)-1, Table 1.

Exhibit 2
U.S. Producers' Shipments of Nonferrous and Ferrous Castings (short tons)

Nonferrous Castings	1996	1997	1998	1999	2000	2001	2002	Avg. % change (96-02)
Aluminum and aluminum-based alloy	1,521,081	1,593,876	1,921,137	1,976,343	2,037,213	1,942,930	2,079,903	6%
Copper and copper-based alloy	284,560	276,480	286,360	310,449	273,739	351,389	337,264	4%
Magnesium and magnesium-based alloy	25,724	19,257	20,741	21,956	29,599	24,378	24,378	1%
Zinc and zinc-based alloy	221,543	228,933	239,169	225,058	225,528	207,948	199,949	-2%
Sub-Total Nonferrous	2,052,908	2,118,546	2,467,407	2,533,806	2,566,079	2,526,645	2,641,493	4%
Ferrous Castings	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Avg. % change (96-02)**
Ductile iron	4,312,000	4,325,000	4,583,000	4,658,000	4,599,000	4,194,000	4,066,000	-1%
Gray iron	6,198,000	5,938,000	6,047,000	5,955,000	5,606,000	4,803,000	4,401,000	-5%
Malleable iron	263,000	272,000	247,000	207,000	186,000	135,000	127,000	-11%
Steel[1]	1,271,000	1,218,000	1,325,000	1,202,000	972,000	779,000	660,000	-10%
Sub-Total Ferrous	12,044,000	11,753,000	12,202,000	12,022,000	11,363,000	9,887,000	9,254,000	-4%
Total Nonferrous and Ferrous	**14,096,908**	**13,871,546**	**14,669,407**	**14,555,806**	**13,929,079**	**12,194,400**	**11,895,493**	**-3%**

Exhibit 3
Value of Shipments of Nonferrous and Ferrous Castings ('000 dollars)

Nonferrous Castings	1996	1997	1998	1999	2000	2001	2002	Avg. % change (96-02)
Aluminum and aluminum-based alloy	$4,724,290	$5,172,590	$5,669,532	$5,556,386	$6,028,183	$5,604,727	$5,982,421	4%
Copper and copper-based alloy	983,955	991,974	1,053,833	1,120,292	1,089,881	1,311,793	1,184,796	4%
Magnesium and magnesium-based alloy	272,842	225,685	256,852	245,677	256,274	191,462	201,853	-4%
Zinc and zinc-based alloy	809,127	818,963	914,648	928,341	873,831	787,215	688,229	-2%
Sub-Total Nonferrous	$6,790,214	$7,209,212	$7,894,865	$7,850,696	$8,248,169	$7,895,197	$8,057,299	3%
Ferrous Castings	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2001**	**Avg. % change (96-02)**
Ductile iron	$3,971,500	$4,148,900	$4,428,400	$4,299,000	$4,381,100	$3,928,800	$3,325,500	-3%
Gray iron	4,463,000	4,719,500	4,635,100	4,446,000	4,406,200	3,817,900	3,345,800	-4%
Malleable iron	266,100	272,400	257,900	238,000	229,400	176,300	156,800	-8%
Steel[1]	2,295,600	2,343,500	2,499,000	2,161,000	1,806,800	1,587,200	1,285,100	-9%
Sub-Total Ferrous	$10,996,200	$11,484,300	$11,820,400	$11,144,000	$10,823,500	$9,259,100	$8,113,200	-5%
Total Nonferrous and Ferrous	**$17,786,414**	**$18,693,512**	**$19,715,265**	**$18,994,696**	**$19,071,669**	**$17,895,197**	**$16,170,499**	**-1%**

[1] Does not include steel investment castings.
Sources: U.S. Department of Commerce, U.S. Census Bureau, *Current Industrial Reports*, Iron and Steel Castings, MA331A(02)-1, and Non-Ferrous Castings, MA331E(02)-1.

2002 World Casting Production

As shown in Exhibit 4, the United States was second in world ferrous casting production, with 16 percent of the world market. China continued to lead the world in ferrous casting production with 26 percent of the world market. From 2001 to 2002, China experienced a 9 percent growth in ferrous casting shipments, while the United States experienced a 0.5 percent decline in casting shipments in 2002.[5]

As shown in Exhibit 5, the United States was the leader in nonferrous casting production across nearly all alloy types, with 26 percent of the world market, up slightly from 24 percent during 2001. Japan followed the United States with 13 percent of the world market. Aluminum represented 97 percent of Japan's nonferrous casting shipments, whereas the United States was more diversified, with aluminum accounting for 77 percent of the nonferrous casting shipments. China held 11 percent of the world market. Mexico continued to have strong nonferrous production with 6 percent of the world market. This is a significant increase from 1995, when Mexico held only 2.9 percent of the world market.[6]

Although the United States is one of the largest producers of metal castings, its manufacturing sector is dependent upon imports to meet the casting demand. It is estimated that in 2004, the United States will rely on imports to meet 18 percent, or 2.6 million tons, of its total casting demand. The United States will rely on imports to supply 29 percent of its gray iron casting demand, and 13 percent of steel casting demand. Moreover, the United States will rely on imports to meet 18 percent of its total demand for aluminum castings and 20 percent of its requirements for bronze castings.[7]

Exhibit 4
2002 World Ferrous Casting Production
(Share of Tonnage Produced)

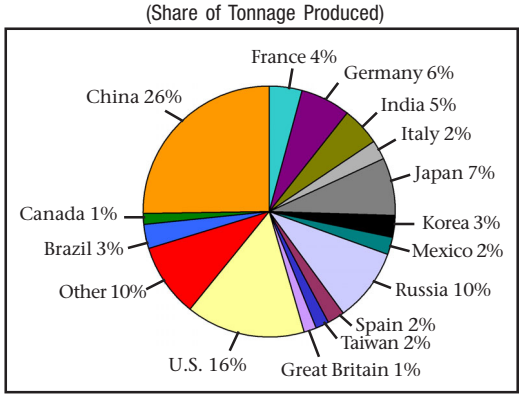
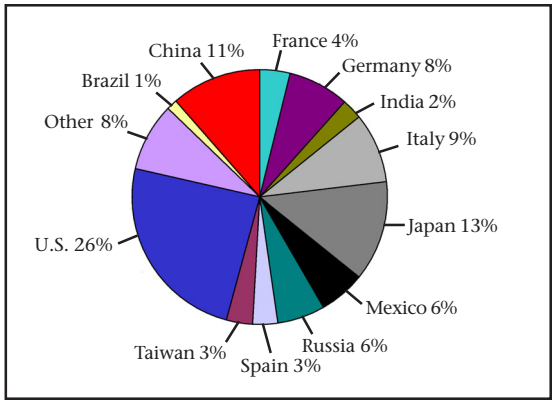


Exhibit 5
2002 World Nonferrous Casting Production
(Share of Tonnage Produced)



[5] Stratecast, Inc., AFS *Metalcasting Forecast & Trends 2004* American Foundry Society, Des Plaines, October 2003, pg. 32.
[6] Ibid.
[7] Ibid pg. 35.

Energy Use in Metal Casting

The metal casting industry requires more than 460 trillion Btu annually.[10] This includes an estimated 328 trillion Btu consumed in metal casting operations, and an estimated 132 trillion Btu lost in off-site power generation and distribution losses. Non-captive foundries consume 70 percent of the energy, and captive foundries consume the remaining 30 percent. [Note: A "captive" foundry is one where the cast products are consumed on-site by the company, usually as the parts are incorporated into higher value-added products.]

The major energy-consuming processes in metal casting include melting of metal, coremaking, moldmaking, heat treatment, and post-cast activities.[11] The industry spent $1.3 billion in 2001 on purchased fuels and electricity. Energy purchases equalled about 11 percent of the material cost and 5 percent of the value of shipments. Energy costs were highest in iron foundries (13 percent of material costs) and lowest in nonferrous die casting foundries (6 percent of material costs).[12] Purchased fuels and electricity on average represented about 10 percent of the value of shipments in 2002. The amount of energy that is consumed by a typical casting foundry is equivalent to the energy consumption of 100 residential homes per year.[13] Exhibit 6 shows the industry's energy use by fuel type and electricity. A majority of the industry's on-site energy (73 percent) is supplied by fuels (83 percent natural gas, 16 percent coke and breeze, and 1 percent other fuel sources). Electricity provides the remaining 27 percent of the industry's on-site energy needs with 89 trillion Btu being consumed.[14] The onsite electric energy demand requires nearly 221 trillion Btu, of which nearly 132 trillion Btu are needed for the generation and transmission of power to the industry.

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[10] Using *AFS 2002 Metalcasting Forecast & Trends*, the ratio of metal casting shipments (NAICS 3315) to captive foundry casting production was calculated. This ratio was applied to industry energy consumption for NAICS 3315, *1998 Manufacturing Consumption of Energy Report*, U.S. Department of Energy, Energy Information Administration Tables N.11.1, to estimate energy consumption in captive foundries. The tacit energy was then calculated based on EIA tacit energy conversion factors.

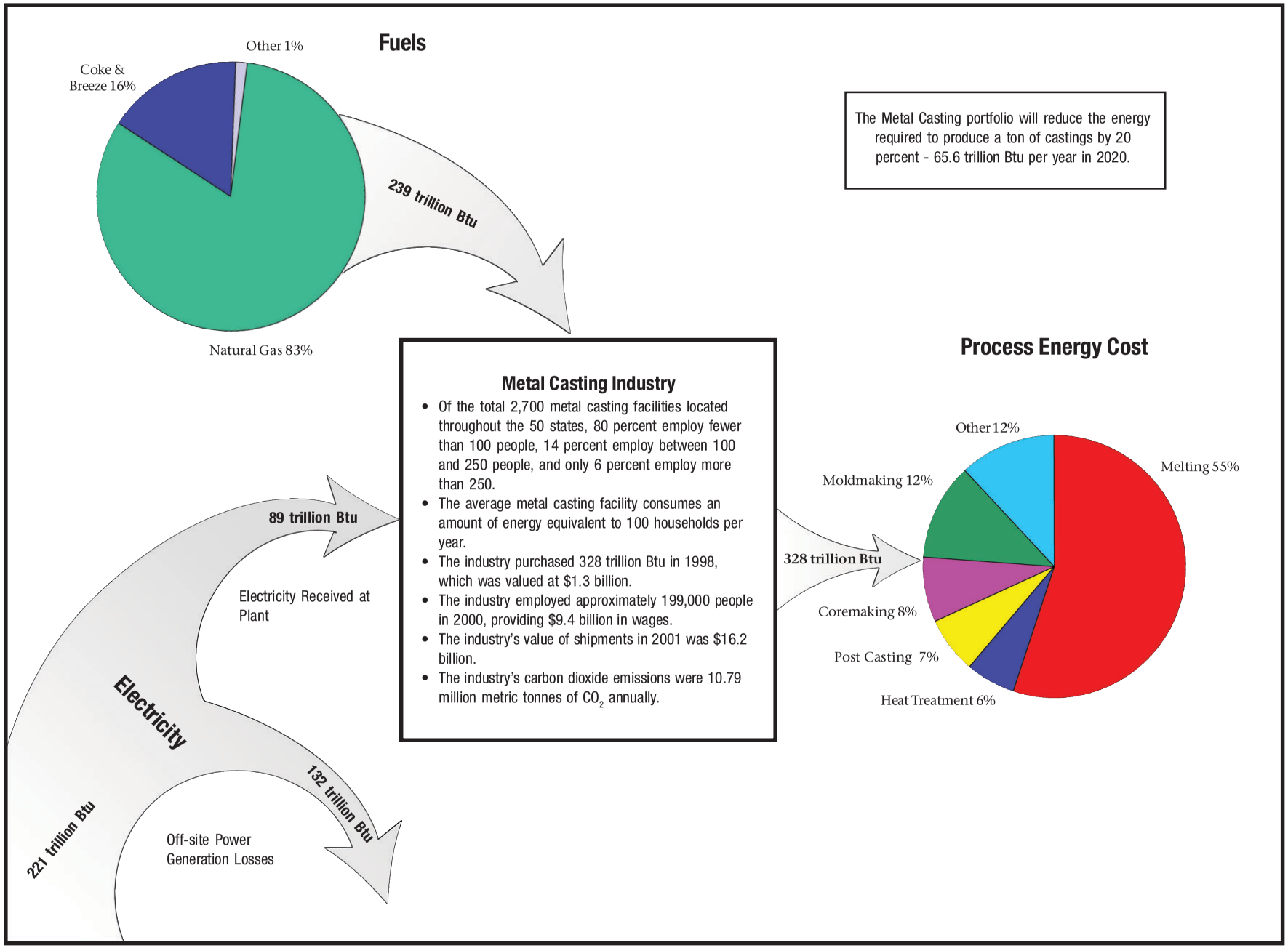
[11] U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Metal Casting Industry of the Future, *Energy and Environmental Profile of the U.S. Metal Casting Industry*, 1999, pg. 10.

[12] U.S. Department of Commerce, U.S. Census Bureau, *2001 Annual Survey of Manufactures*, Manufacturing Industry Series, Tables 2 and 4, *Detailed Statistics by Industry: 2000* for NAICS codes 3315, 331511, 331512, 331513, 331524, 331525, 331528, 331521, and 331522.

[13] Used the U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Surveys*, to find the average Btu consumption in a year per house. Divided the number of foundries by the annual Btu consumption and found the average Btu consumption in a foundry. Calculated the ratio of number of houses to energy consumed in average foundry.

[14] U.S. Department of Energy, Energy Information Administration, 1998 Manufacturers Energy Consumption, Table N1.2. "First Use of Energy for All Purposes," NAICS code 3315; 331511; 331521; 331524.

Exhibit 6
Energy Use in Metal Casting



THE CHALLENGE

The metal casting industry is critical to the U.S. economy, as 90 percent of all manufactured goods contain one or more cast metal components. Metal castings are integral in U.S. transportation, energy, aerospace, manufacturing, and national defense. Metal casting is also one of the only major U.S. manufacturing industries that is dominated by small businesses. Moreover, the industry is widely dispersed throughout the country, limiting opportunities for geographic-based, intra-industry coordination. These unique characteristics have helped drive the need for public-private R&D collaboration.

The U.S. metal casting industry is diverse, employing a variety of casting processes and alloys to make a wide range of products. Because the majority of metal casters are small businesses, many lack the resources to perform high-risk, high-impact research on their own. Public-private research partnerships, such as the Cast Metals Coalition (CMC), have proven vital for performing long-term research needed to maintain a productive and healthy U.S. metal casting industry.

The U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Industrial Technologies Program (ITP), supports these partnerships by sponsoring cost-shared R&D funding to improve energy efficiency in metal casting. This partnership is encouraged by ITP in collaboration with the CMC. The CMC is composed of the American Foundry Society (AFS), the North American Die Casting Association (NADCA), and the Steel Founders' Society of America (SFSA). Collectively, this coalition represents approximately 80 percent of the U.S. metal casting industry.

The partnership emphasizes university-based research with strong industry participation. This strategy taps into the technical resources of our nation's educational institutions, and positions industry partners to quickly apply the results of metal casting research, thereby saving energy and improving U.S. competitiveness in world markets. The involvement of industry in the early R&D stages helps to speed the pace of technology transfer.

Strong industry involvement ensures direct application of research results and gives evidence to the importance of this cost-shared research partnership. ITP's Metal Casting portfolio research partners represent the diversity of the metal casting industry, including suppliers, end-users, designers, ferrous and nonferrous foundries, and die casters. The partnership is also introducing hundreds of students to the industry and helping to sustain vital casting-related curricula at the U.S. universities. Since the inception of the Metal Casting portfolio, approximately 326 students participated in Metal Casting portfolio research, of which 152 are now working in the metal casting industry. Ensuring a well-educated and well-trained workforce is imperative for the metal casting industry to remain innovative and competitive in world markets.

Key Pathways

The ITP Metal Casting portfolio strategy was designed to foster government-industry partnerships in economically imperative, energy-intensive U.S. industries, including metal casting. This strategy has fostered industry partnerships and created the impetus for industry to develop long-term visions and roadmaps. Visions assist in the development of long-term goals for the future, while roadmaps provide an outline of the R&D pathways to achieve vision goals. The Metal Casting vision and roadmap, along with in-depth analysis of energy use in the industry, are the pillars for open and competitive solicitations for pre-competitive R&D that addresses both energy efficiency goals outlined in the *National Energy Policy,* as well as industry research priorities. This successful government-industry partnership is now focusing on high-impact research to make revolutionary improvements in the energy efficiency of the metal casting process.

The Metal Casting portfolio has been successful in improving energy efficiency and market competitiveness in the industry. For example, research in lost foam casting, co-funded by the ITP Metal Casting portfolio and in partnership with the Lost Foam Casting Consortium, has resulted in significant improvements in the lost foam process; these results have been implemented throughout the industry. Currently, the Metal Casting portfolio is targeting additional opportunities for high-impact research. ITP conducted in-depth analyses to map energy consumption in the industry by evaluating energy demand in each of the various

processes and technologies used in metal casting. Further analysis revealed the theoretical/best practice energy use that may be attainable in the industry. The results of these analyses are assisting the ITP Metal Casting portfolio in identifying areas of focus for high-impact research, and setting the groundwork for future research solicitation.

The Metal Casting portfolio also participated in the ITP Corporate Peer Review that was held March 9-10, 2004. This Peer Review brought industry stakeholders and government partners together to review the mission, strategies and future direction of the Industrial Technologies Program, including a strategic overview of the metal casting R&D portfolio. The participants of the meeting provided useful suggestions that can be used to strengthen the Metal Casting portfolio. Examples of some of the feedback ITP received from the portfolio review included:

1. More R&D efforts required on molten metal containments, and

2. R&D efforts required to provide more properties data to support casting design.

Research Categories of the Metal Casting Portfolio

The success of the Metal Casting portfolio is the result of a strong partnership between the Cast Metals Coalition (CMC) and EERE. This partnership is directing its efforts to address high-impact research to make revolutionary improvements in energy efficiency in metal casting. Research is grouped into three categories:

- **Advanced Melting:** Research that establishes new melting practices, and/or new design methodologies to significantly improve the energy efficiency of melting and save costs for metal casters. Research in this area will improve melt efficiency, reduce metal transfer heat loss, reduce scrap/revert, and improve mold yield.

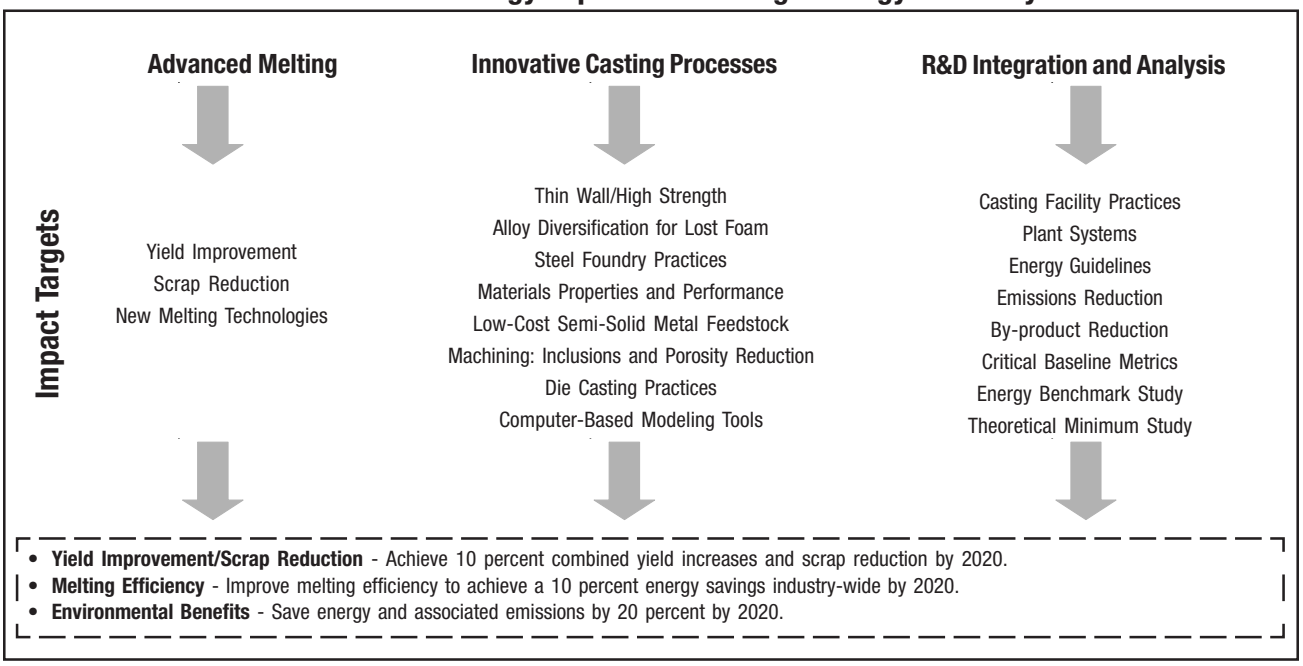
- **Innovative Casting:** Research that advances energy-efficient casting processes and practices that will increase yield and reduce scrap. Research in this area is developing: accurate simulation tools, the ability to produce thin-wall, high-performance castings, real-time sensors and controls, improvements in rapid prototyping, and expanding the knowledge base of various material properties and performances.

- **R&D Integration and System Analysis:** Integration of applicable ITP technologies for improving energy efficiency and reducing emissions in metal casting practices. This includes other ITP portfolios and ITP's BestPractices program for energy demand management.

In FY 2004, ITP reorganized its Metal Casting research portfolio into three categories: Advanced Melting, Innovative Casting Processes, and R&D Integration and System Analysis. These research categories align with the *Metalcasting Industry Technology Roadmap: Pathway for 2002 and Beyond*. Exhibit 7 shows the target areas for each of these research categories. Advanced Melting and Innovative Casting Processes formed the basis for the ITP Metal Casting portfolio solicitation offered in March 2003, of which four new projects were awarded in the fall of 2004. (More information on these projects is provided in the Highlights & Accomplishments section).

Research in the Advanced Melting focus area is not only concentrating on new melting technologies, but also includes upstream processes such as the chemistry and purity of the melt stock and alloying ores, and the role they play in efficiency factors. Research is also examining ways to improve melt loss, which directly affects the net melting energy consumption.

Exhibit 7
Process & Technology Improvements Target Energy Efficiency



FY 2004 HIGHLIGHTS & ACCOMPLISHMENTS

The ITP Metal Casting portfolio supports a diverse portfolio of cost-shared, pre-competitive research. Research projects address high-risk/high-impact needs that have broad application throughout the metal casting industry.

All metal casting research projects are selected through a competitive review process. ITP's Metal Casting portfolio research must address both the priorities outlined in the *Metal Casting Industry Technology Roadmap,* as well as DOE's national energy efficiency goals. Solicitations are announced in trade society publications and meetings, the *Commerce Business Daily, FedBizOpps*, the Metal Casting portfolio Web site, and industry Web sites. In FY 2004, the metal casting portfolio began to transition to fewer, yet larger, research projects (with higher impact per project) that will have the opportunity to produce revolutionary improvements in metal casting energy efficiency.

Maintaining a strong and well-balanced portfolio requires careful attention throughout the competitive solicitation, evaluation, and selection process. The FY 2004 ITP Metal Casting portfolio consists of 35 active projects, addressing the diverse research needs of the industry. Four are newly-awarded projects that resulted from the Metal Casting IOF solicitation in March, 2004. Many of the projects in the portfolio have applications across various casting processes and alloys. All projects address the need to improve energy efficiency in the industry.

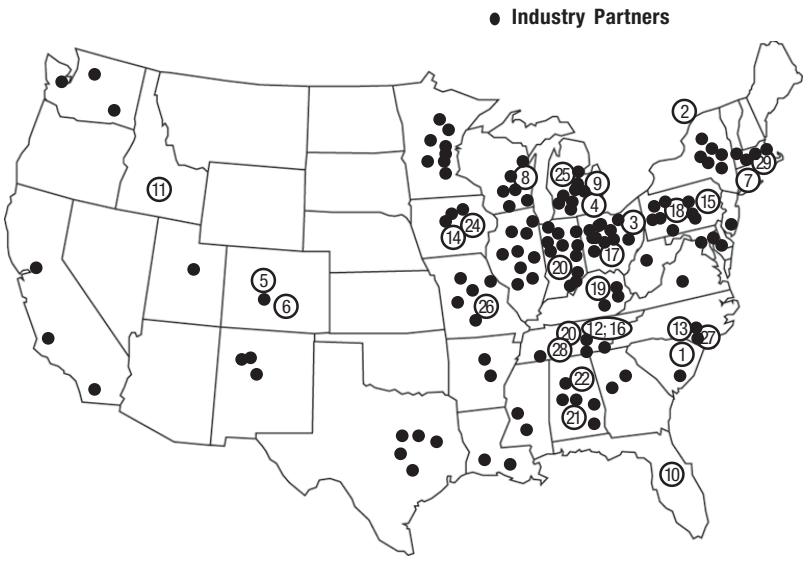
Broad Industry Partnership

One of the strengths of the Metal Casting research portfolio is the large participation of both industry and universities, providing both cost-share and in-kind support. Currently, the portfolio is partnering with 270 industry members, universities, and national laboratories in 33 states across the United States. The geographic reach of the Metal Casting portfolio is illustrated in Exhibit 8.

Exhibit 8
Broad Industry Partnership
Metal Casting Research Performers and Project Partners

Primary Research Performers

1 Advanced Technology Institute
2 CANMET
3 Case Western Reserve University
4 Climax Research Services
5 Colorado School of Mines
6 Colorado State University
7 Copper Development Assoc., Inc.
8 ECK Industries
9 General Motors Powertrain
10 GKS Engineering Services
11 Idaho National Engineering and Environmental Laboratory
12 Industrial Analytics Corporation
13 Intl. Lead Zinc Research Organization
14 Iowa State University
15 Lehigh University
16 Oak Ridge National Laboratory
17 Ohio State University
18 Pennsylvania State University
19 SECAT, Inc.
20 Tennessee Technological University
21 Tri-State University
22 University of Alabama
23 University of Alabama - Birmingham
24 University of Iowa
25 University of Michigan
26 University of Missouri - Rolla
27 University of North Carolina -Charlotte
28 University of Tennessee
29 Worcester Polytechnic Institute

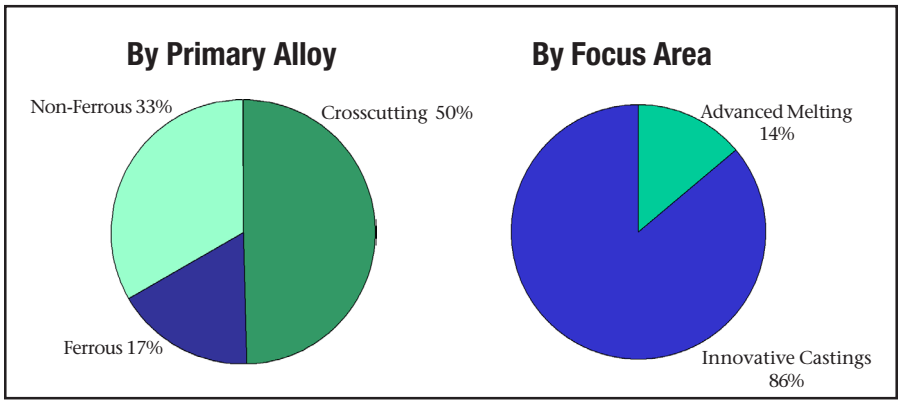


The Metal Casting Industry of the Future is partnering with 270 university, industry, and laboratory partners in 33 states across the U.S.

A Diverse Research Portfolio

Exhibit 9 illustrates ITP's Metal Casting portfolio funding by alloy and its focus areas. As illustrated, the program maintains a healthy balance of research targeted at both ferrous and nonferrous alloys. However, the majority of research in the program's portfolio crosscuts all alloy types, further leveraging research investment. Exhibit 9 also illustrates how the Metal Casting portfolio leverages funds within its focus areas of Advanced Melting and Innovative Casting Processes. In FY 2004, 86 percent of the funds were allocated to the Innovative Casting area. Because ITP leverages funds to melting in other portfolios, the Metal Casting portfolio allocates a majority of its funds to various casting processes other than melting. Still, recognizing the energy-saving potential, the Metal Casting portfolio leverages approximately 14 percent of their budget to advancing melting R&D.

Exhibit 9
Research Funding



On page 10, Exhibit 11 displays a list of metal casting projects organized by focus area. Lead research organizations are shown in italics. Those projects identified as "Energy SMARRT" are tasks under the newly-awarded *Energy SMARRT* project led by Advanced Technology Institute (ATI). This project consists of 28 tasks that address both the Advanced Melting and Innovative Casting Processes focus areas.

Integrated Assistance for the Metal Casting Industry

The ITP Metal Casting portfolio has funded $22 million in research, with an additional $27 million provided by industry cost-share over a period of seven years.

A number of other EERE program activities have performed research related to metal casting, including Inventions & Innovation, and the Aluminum and Steel portfolios. Combined, they have provided an additional $20 million in funding on current research and technical assistance relevant to metal casters and leveraged an additional $20 million in cost-share.

Beyond the research funding provided by the Metal Casting portfolio, many EERE technical and financial assistance programs and services are available to the metal casting industry to improve energy efficiency and competitiveness in casting processes. Exhibit 10 provides a couple of examples of EERE program assistance. Exhibit 12 lists recent examples of research performed by other ITP portfolios that pertain to the metal casting industry.

Exhibit 10
Examples of EERE Technical and Financial Assistance

- **Weatherization's I&I Subprogram:** Inventions and Innovation (I&I) provides financial assistance for conducting early development and establishing technical performance of innovative, energy-saving ideas and inventions.
- **IAC:** Industrial Assessment Centers enable eligible small and medium-sized manufacturers to receive comprehensive industrial assessments performed at no cost to the manufacturer.
- **Plant-Wide Assessments:** Plant-Wide energy assessments investigate overall energy use in industrial facilities, which can account for 10 percent or more of an industry's total operating costs, and highlight opportunities for best energy management practices for industry, including the adoption of new, efficient technologies.

In addition to those portfolios listed in Exhibit 10, EERE provides funding for research on cutting-edge enabling technologies, including Sensors & Automation, Industrial Materials, Combustion, and others. The program enables risk-sharing on industry-specific, pre-competitive, long-term high-impact research available through other ITP portfolios, such as Aluminum and Steel. The program also provides financial assistance for small businesses through Small Business Innovative Research grants. In addition, the Metal Casting portfolio is working with Allied Partners to help deploy the results of metal casting research

and improve energy efficiency in the industry. Allied Partners are manufacturers, trade associations, industrial service and equipment providers, utilities, and other organizations that agree to promote increased energy

Exhibit 11
Metal Casting Portfolio by Focus Area

(Fact sheets are available at: http://www.eere.energy.gov/industry/metalcasting/active_rd.html)

Advanced Melting

- Improvement in Melt Efficiency for Die Casting (Case *Western Reserve University)*) **- Energy SMARRT**
- Advanced, Scalable Clean Aluminum Melting System *(SECAT, Inc.)*
- Advanced Steel Casting Technology *(University of Iowa)*
- Simulation of Dimensional Charges & Hot Tears During Solidification of Steel Castings *(University of Iowa)* **- Energy SMARRT**
- Melting Efficiency Improvement *(University of Missouri-Rolla)* **- Energy SMARRT**

Innovative Casting Processes

- Clean Steel Casting Production *(CANMET)***- Energy SMARRT**
- Feasibility of Producing Lost Foam Casting in Aluminum and Magnesium Based Alloys *(CANMET)***- Energy SMARRT**
- Light Metals Permanent Mold Casting *(CANMET)***- Energy SMARRT**
- Casting Porosity-Free, Grain Refined Magnesium Alloys *(Case Western Reserve University)***- Energy SMARRT**
- Effects of Die Design & Dimensional Features on Thermal Fatigue Cracking of Die Casting Dies *(Case Western Reserve University)*
- Gating of Permanent Mold Aluminum Casting (Phase II) *(Case Western Reserve University)*
- Evaluation of Heat Checking and Washout of Heat Resistant Superalloys for Die Insert *(Case Western Reserve University)*
- Improved Die Casting Process to Preserve the Life of the Inserts *(Case Western Reserve University)***- Energy SMARRT**
- Improvement in Die Design to Improve Die Life as Affected by Thermal Fatigue Cracking, Erosion and Soldering *(Case Western Reserve University)***- Energy SMARRT**
- Improved Yield and Production Rates in Metal Mold Casting Processes by Advanced Thermal Management *(Case Western Reserve University)***- Energy SMARRT**
- Metallic Reinforcement of Direct Squeeze Die Cast Aluminum Alloys for Improved Strength and Fracture Resistance *(Case Western Reserve University)*
- Prevention of Porosity in Iron Casting *(Climax Research Services)*
- Development of a Fatigue Properties Database for Use in Modern Design Methods *(Climax Research Services)*
- Development of Surface Engineered Coating Systems for Aluminum Pressure Die Casting Dies: Towards a "Smart" Die Coating *(Colorado School of Mines)* **- Energy SMARRT**
- Development of Surface Engineered Coatings for Die Casting Dies *(Colorado School of Mines)*
- Integration of RSP Tooling with Rapid Prototyping for Die Casting Applications *(Colorado State University)*
- Grain Refinement of Permanent Mold Cast Copper Base Alloys *(Copper Development Association)*
- Development of Elevated Temperature Aluminum MMC Alloy and Process Technology *(Eck, Industries)* **- Energy SMARRT**
- Prediction of Wax Pattern Tooling and Final Investment Casting Dimensions *(EMTEC and Oak Ridge National Laboratory* **- Energy SMARRT**
- Tools for the Assurance of High Strength and Fatigue Resistant Aluminum Castings *(General Motors Powertrain)*
- Development Program for Natural Aging Aluminum Alloys *(GKS Engineering Services)*
- Conformal Cooling in Die Casting and Permanent Mold Casting *(Idaho National Engineering and Environmental Laboratory)***- Energy SMARRT**
- Quantification and Standardization of Pattern Properties for the Lost Foam Casting Process *(Industrial Analytics Corporation)*
- Development of Thin-Section Zinc Die Casting Technology *(International Lead Zinc Research Organization)***- Energy SMARRT**
- Development of CCVT Diagrams *(Iowa State University)***- Energy SMARRT**
- Energy Efficient Instrumentation *(Iowa State University)***- Energy SMARRT**
- Reduction in Energy Consumption and Variability in Steel Casting *(Iowa State University)*
- Control of Soldering and Thermal Fatigue During Die Casting *(Oak Ridge National Laboratory)*
- Castability Assessment and Data Integration for Die Casting Design *(Ohio State University)*
- Computer Modeling of the Mechanical Performance of Die Casting Dies *(Ohio State University)*
- Design Support for Tooling Optimization *(Ohio State University)* **- Energy SMARRT**
- Effects of Externally-Solidified Product on Wave Celerity and Quality of Die Cast Products *(Ohio State University)*
- Improvements in Sand/Mold/Core Technology: Effects on Casting Finish *(Ohio State University)*
- Investigation of Flow Regimes in High-Pressure Die Casting *(Ohio State University)* **- Energy SMARRT**
- Prediction of Part Distortion in Die Casting (Phase III) *(Ohio State University)*
- Energy Consumption of Die Casting Operations *(Ohio State University)*
- Mechanical Performance of Dies *(Ohio State University)* **- Energy SMARRT**
- Understanding the Relationship Between Pattern Filling and Part Quality in Die Casting *(Ohio State University)*
- The Use of Laser Engineered Net Shaping for Rapid Manufacturing of Dies with Protective Coatings and Improved Thermal Management *(Ohio State University)* **- Energy SMARRT**
- Development of Technical Data to Validate Performance of Foundry By-products in Hot-Mix Asphalt and Controlled Low-Strength Material *(Pennsylvania State University)*
- Heat Treatment Procedure Qualification for Steel Castings *(Pennsylvania State University)*
- In-Situ Real-Time Monitoring and Control of Mold Making and Filling Processes *(Tennessee Technological University)*
- Investment Shell Cracking *(Tri-State University)*
- Metallic Recovery and Ferrous Melting Processes *(Tri-State University)*
- Thin Wall Cast Iron: Phase 2 *(University of Alabama)*
- Advanced Lost Foam Casting, Phase V *(University of Alabama - Birmingham)*
- Advanced Steel Casting Technology *(University of Alabama-Birmingham)*
- Manufacturing Advanced Engineered Components Using Lost Foam Casting Technology *(University of Alabama-Birmingham)* **- Energy SMARRT**
- Surface/Near Surface Indications - Characterization of Surface Anomalies from Magnetic Particle and Liquid Penetant Indications *(University of Alabama-Birmingham)* **- Energy SMARRT**
- Simulation of Dimensional Changes and Hot Tears During Solidification of Steel Castings *(University of Iowa)***- Energy SMARRT**
- Simulation of Distortion and Residual Stress Development During Heat Treatment of Steel Castings *(University of Iowa)***- Energy SMARRT**
- Yield Improvement and Defect Reduction in Steel Castings *(University of Iowa)*
- Investigation of Heat Transfer at the Mold/Metal Interface in Permanent Mold Casting of Light Alloys *(University of Michigan)*
- Aging of Graphite Cast Irons and Machinability *(University of Missouri-Rolla)* **- Energy SMARRT**
- Precision Castings *(University of Missouri-Rolla)* **- Energy SMARRT**
- Determination of Bulk Dimensional Variation in Castings *(University of North Carolina at Charlotte)*
- Service Performance of Welded Duplex Stainless Steel Castings and Wrought Materials *(University of Tennessee)*
- Innovative Semi-Solid Metal (SSM) Processing *(Worcester Polytechnic Institute)* **- Energy SMARRT**

efficiency and productivity for those industries that participate in the Industries of the Future strategy. The metal casting industry is working with the technical societies, state casting associations, research institutes, and others to formalize Allied Partnership agreements. Through Allied Partners, EERE will be well equipped to deliver the results of research programs and technical assistance.

Currently, ITP and the Metals Processing Institute at Worcester Polytechnic Institute have an Allied Partnership. The objectives of this partnership are to increase knowledge and end-user awareness of opportunities in the operation and/or design of metal processing systems, leading to improved productivity, energy efficiency and reliability, and reduced life-cycle costs for industrial customers.

Exhibit 12
Additional Industrial Technologies Research Related to Metal Casting
(Fact sheets are available at http://www.eere.energy.gov/industry/metalcasting/completed_rd.html)

Financial Assistance
- A New "Pour-In-Mold" (DPI) Technology for Producing Ductile and Compacted Graphite Iron Castings (Inventions & Innovation)
- Casting Quality Measurements for Polystyrene Foam Patterns (Inventions & Innovation)
- Ceramic Composite Die for Metal Casting (Inventions & Innovation)
- Computer Process Model for the Cupola Furnace (Inventions & Innovation)
- High-Frequency Eddy-Current Separator for Foundry Sand (Inventions & Innovation)
- Highly Efficient Rapid Tooling Using Optimized Cooling Passages (Inventions & Innovation)
- Lost Foam Casting Quantifier Program (Inventions & Innovation)
- Meta-Lax Stress Relief Process (Inventions & Innovation)
- Method and Apparatus for Production of Three-Dimensional Objects by Photosolidification (Inventions & Innovation)
- Titanium Matrix Composite Tooling Material for Enhanced Manufacture of Aluminum Die Castings (Inventions & Innovation)

Crosscutting Applications
- A Bubble Probe for Optimization of Bubble Distribution and Minimization of Splashing/Droplet Formation (Aluminum)
- Continuous Severe Deformation Processing of Aluminum Alloys (Aluminum)
- Coolant Characteristics and Control in Direct Chill Casting (Aluminum)
- Degassing of Aluminum Alloys Using Ultrasonic Vibrations (Aluminum)
- Development of an Innovative Vertical Floatation Melter and Scrap Dryer (Aluminum)
- Development of a Two-Phase Model for the Hot Deformation of Highly-Alloyed Aluminum (Aluminum)
- Effect of Impurities on the Processing of Aluminum Alloys in Casting, Extrusion, and Rolling (Aluminum)
- Energy-Efficient Isothermal Melting (Aluminum)
- Fundamental Studies of Structural Factors Affecting the Formability of Continuous Cast Aluminum Alloys (Aluminum)
- Gating of Permanent Mold Aluminum Casting Phase-II (Aluminum)
- High-Efficiency, Low-Dross Combustion System for Aluminum Remelt Reverberatory Furnaces (Aluminum)
- Improved Energy Efficiency in Aluminum Melting (Aluminum)
- Molten Aluminum Treatment by Salt Fluxing with Low Environmental Emissions (Aluminum)
- Reduction of Annealing Times for Energy Conservation in Aluminum Processing (Aluminum)
- Reduction of Oxidative Melt Loss of Aluminum and its Alloys (Aluminum)
- Selective Absorption of Salts from Molten Aluminum (Aluminum)
- Surface Behavior of Aluminum Alloys Deformed Under Various Processing Conditions (Aluminum)
- Alloys for Ethylene Cracker (Chemicals)
- Improving the Efficiency of Electric Arc Furnace in the United States (Steel)
- Optical Sensors for Post Combustion Control in Electric Arc Steelmaking (Steel)

Technical Assistance
- BestPractices - Plant-Wide Assessments and Hands-on Technical Assistance
  - AMCAST
  - Sawbrook
  - Techni-cast
- Industrial Assessments
  - Over $12 million in energy-saving recommendations implemented in the metal casting industry since 1992

The ITP Metal Casting portfolio posted a number of important accomplishments in FY 2004. The following describes accomplishments in several key areas:

- Applying R&D Results
- Newly-Awarded Projects
- Improving Energy Efficiency Today
- Energy Analysis – Targeting Energy Efficiency
- University-Based Research
- Disseminating Research Results to Industry

Applying R&D Results

Industry is rapidly adopting ITP Metal Casting portfolio research results in their casting operations. The following provides examples of metal casting research developments and applications.

- ***CastView Assists in Designing the Xlerator Hand Dryer*** – Researchers at the Ohio State University developed a software tool, "CastView," to help die casters predict the complex metal flow within metal dies. This tool has assisted in the designing of dies by providing a simulation of die filling conditions. Recently, this software has been used in improving the design of an Xlerator Hand Dryer. This hand dryer is a seven-pound zinc die casting that is manufactured by Excel Dryer. The hand dryer is designed to be the most efficient and fastest hand dryer available, with the ability to dry hands in less than 10 seconds. The product also uses only one-third the energy used in standard hand dryers, and one-tenth of the energy used to make paper towels. This software tool is expected to significantly reduce defects and improve yield in die casting. ITP estimates that this tool will save 2.61 trillion Btu and $14.72 million in energy cost-savings in 2020. To learn more about this tool and ITP's involvement, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/vistool.pdf.

- ***Surface-Engineered Coatings for Die Casting Dies*** – Researchers at the Colorado School of Mines have made significant strides with the development of multi-layer graded die coating systems that extend the life of dies. The researchers examined the major mechanisms leading to premature die failure including heat checking, gross cracking, erosive-wear soldering, and corrosion/oxidation. This research concentrated on developing a coating system for dies used in aluminum die casting. The research has yielded promising coating systems which are now undergoing in-plant trials with five aluminum pressure die casting plants. Ultimately, these coating systems developed by this research will increase die life, increase surface quality of die cast components, and decrease downtime during scheduled production due to die failure. ITP estimates that these coating systems will save 30 billion Btu and $140 thousand in energy costs in 2020. To learn more about this tool and ITP's involvement, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/csm_surfacecoating.pdf.

- ***Semi-Solid Metal Transient Rheological Behavior Characterization: A New Approach*** – Commercial Semi-Solid Metal (SSM) forming operations take place in seconds or fractions of seconds. Therefore, the transient rheological behavior of SSM is critical in determining the flow patterns during die filling. At present, there is no standard technique or rheological measurement instrument available for the SSM community. Researchers at Worcester Polytechnic Institute developed an advanced high-temperature rheological measurement system, and corresponding methodologies with ITP Metal Casting portfolio funding. The new system consists of a high-temperature rheometer coupled with an optimized rotating vane in cup geometry. Thus far, validation experiments with the standard materials indicate that the system can be used to characterize the rheological behavior of SSM under both steady and transient shear conditions. Specifically, the optimized vane-cup design circumvents some critical problems encountered in traditional methods, such as the wall slip effect. Using the system, a vast set of transient rheological data of commercial MHD A356 alloy has been generated. These valuable data are being employed to improve the accuracy and capabilities of the simulation tools developed by the research team. This project will expand the use of SSM technology because the billets require a lower temperature (as compared to traditional casting operations), thereby reducing the amount of energy expended. Researchers estimate that this research program has the potential to save 2.54 trillion Btu per year. To learn more about this tool and ITP's involvement, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/wpi_ssm.pdf.

- ***Service Performance of Welded Duplex Stainless Steel Castings and Wrought Materials*** – Duplex stainless steels are used because of their excellent corrosion resistance and high strength. To meet the specification requirements and to provide confidence to the user, a specification test (ASTM A923) was developed for wrought material. The purpose of the screening test was to identify if intermetallic precipitates have a detrimental effect on mechanical properties and corrosion resistance. Their presence can lead to premature failure and unscheduled shutdowns of industrial equipment with consequential energy losses. Researchers at the University of Tennessee with ITP Metal Casting portfolio funding, developed a data package that demonstrated that cast material responded in a similar manner. The data package included information on three heats of material compared to the one from the wrought

material. In addition, the researchers showed that the impact test was a much better discriminator than the corrosion test in ASTM A923. This data was submitted as a ballot item to ASTM and was approved within six months, providing efficient technical transfer of these research findings. These findings increase yield, thus saving the energy associated with remelting. ITP estimates that this research will save approximately 700 million Btu and $470 thousand in energy costs in 2020. For more information, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/ut_welded_duplex.pdf.

- ***Heat Treatment Procedure Qualification*** – Heat treatment is underdeveloped in the national and international specifications currently in use. There is a need to develop a method to bring this process step under control. Equipment failures due to inadequate heat treatment are unpredictable and costly in terms of energy and lost production. A procedure is being developed to document the critical control issues and the hurdles that must be cleared. To date, this work has been split into two sections, one dealing with carbon and low-alloy steels and the other dealing with high-alloy steels. Researchers at Pennsylvania State University, with ITP Metal Casting portfolio support, have identified an easy way to deal with the carbon and low-alloy steels. These same researchers are now addressing the issues surrounding the high-alloy steels. The most critical goal here is to gain industry acceptance by producer and users. Presentation of the scope of this work at ISO has ensured that a specification will be developed. ITP estimates that this research will save 900 billion Btu and $900 thousand in energy cost savings in 2020. To learn more, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/psu_heat_treat.pdf.

- ***Reduction in Energy Consumption and Variability in Steel Casting*** – Steel foundries generally have 10 times the process inventory workload in comparison to iron foundries. These high inventory levels inhibit the ability of the foundry to detect quality problems, leading to extended delivery times. The quality issue causes the foundry to use more energy as the amount of substandard product grows due to the slow reaction time of the process. Researchers at Iowa State University set out to gain an understanding of the reasons for these high inventory levels. Researchers determined that the largest problem that was leading to the high inventory levels has been the inability of operators to understand quality level requirements. Due to this lack of knowledge, the researchers realized that many cleaning rooms were only operating at a 20 percent efficiency level. This inefficiency forced many steel foundries to use heat treat castings or scrap castings for reworking, or to provide excess cleaning rooms, thus consuming more energy. Researchers at Iowa State University have developed recommendations that will reduce the inefficiencies. Researchers estimate that this research will save 1.78 trillion Btu. To learn more, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/ui_yield_def.pdf.

- ***A Model for the Mechanics of Foam Decomposition in Contact Mode*** – There are two problems with the traditional lost foam pattern decomposition model. First, the calculated filling speeds are slow by an order of magnitude, and second, there is a strong thickness dependence. A new model was developed that recognizes the formation of an undercut in the foam pattern while it is heated by the melt. This phenomenon is able to correctly predict the filling speed and a weak thickness dependence. GMC has used this understanding to make production decisions to improve the quality of its lost foam casting lines. This insight would not have been possible without the quantitative gas evolution measurements made at the University of Alabama-Birmingham through their lost foam research supported by ITP's Metal Casting portfolio. ITP estimates that this research will save 8.07 Trillion Btu and $48.5 million in energy cost savings in 2020. To learn more, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/uab_lostfoam.pdf.

- ***Predicting Wax Pattern Distortion for Investment Casting*** – In the investment casting industry, tooling dimensioning is based on proprietary and plant experience, with very few industry guidelines. The work on wax and shell systems is an important step toward predicting the tooling dimensions for geometric features in a new casting during the first casting run. For the first time, researchers from Oak Ridge National Laboratory, with ITP Metal Casting portfolio funding, have developed a computational tool that can be used to predict the tooling dimensions, as well as the casting dimensions. The computer tools enable the designers to develop castings with high structural efficiency and avoid energy-intensive processes such as using mechanical fasteners, welding, and brazing. ITP estimates that this research will save 3.62 Trillion Btu and $14.1 million in energy cost-savings in 2020. To learn more, please visit: http://www.eere.energy.gov/industry/metalcasting/pdfs/ornl_predict_patrn_tool.pdf.

- ***Machinable Thin-Wall Ductile Iron Research Incorporated by Dura-Bar*** – There is a growing demand for ductile iron castings with a consistent machinability at high speed. Foundries that produce machinable castings occasionally encounter batches that are extremely "hard-to-machine" or cause rapid tool wear. Under ITP Metal Casting portfolio funding, a technique was developed by researchers at the University of Alabama-Birmingham to accurately measure tool wear as a function of metallurgical variables and machining conditions. The improved technique provides a rate of tool wear and volume of metal removed as a function of casting variables. This technique consistently ranked different iron grades regardless of the machining operations. Dura-Bar has incorporated these findings into their manufacturing process. By doing this, Dura-Bar has been able to give their customers confidence that they are controlling variables that affect machinability, but can also directly benefit their customers' profits by reducing their machining operations. ITP estimates that this research will save 1.37 Trillion Btu and $18.4 million in energy cost-savings in 2020.

New Project Awards

The Industrial Technologies Program, Metal Casting portfolio solicitation for competitive cost-shared research proposals resulted in four awards. The ensuing research projects will make important contributions to ongoing efforts to address both Vision targets and national energy efficiency goals. These projects will make advances in the melting systems and innovative casting processes for the metal casting industry. The four selected projects are:

- ***Energy-Saving Melting and Revert Reduction Technology (Energy SMARRT)*** – The Advanced Technology Institute of Charleston, South Carolina is leading a research team that includes University of Alabama, University of Iowa, University of Missouri - Rolla, CANMET, Case Western Reserve University, Eck Industries, Worcester Polytechnic Institute, Idaho National Energy and Environmental Laboratory, Ohio State University, Colorado School of Mines, Iowa Sate University, Lehigh University, International Lead Zinc Research Organization, and Edison Materials Technology Center. The project, known as Energy SMARRT, is a balanced portfolio of tasks to reduce energy consumption in the metal casting industry by 49 trillion Btu per year over ten years. The portfolio will improve existing technologies, as well as develop breakthroughs to revolutionize casting production. Maximum energy savings from the "as is" environment are realized in these tasks, while the theoretical minimum energy inputs are researched for existing and new melting technologies.

- ***In-Situ, Real-Time Monitoring and Control of Mold Making and Filling Processes*** – Tennessee Technological University will lead a research team from Oak Ridge National Laboratory, Walford Technologies, and nine other partners in developing an innovative approach to introduce technologies for real-time characterization of sand molds, lost foam patterns, and monitoring of the mold filling process. The proposed technology will enable better control over the casting process and reduce scrap and variances in casting quality.

- ***Development of Computational Tools for the Assurance of High-Strength and Fatigue-Resistant Aluminum Castings*** – General Motors Powertrain will lead a team of researchers from Oak Ridge National Laboratory, the University of Wisconsin, ComuTherm, EKK, and Worcester Polytechnic Institute on a project to develop computational techniques for alloy design, melt treatment, microstructure control, and heat treatment optimization of aluminum castings. With computational tools, designers of aluminum cast components and casting engineers will be able to optimize the alloy, as well as the casting and heat treatment processes to achieve strength and fatigue life requirements with minimal lead-time and cost.

- ***Advanced, Scalable Clean Aluminum Melting Systems*** – SECAT, Inc., will lead a team of researchers from Oak Ridge National Laboratory, the DOE Albany Research Center, University of Kentucky, E3M, and nine other partners on a project to develop and integrate the technologies necessary to substitute immersion heating for the conventional radiant burner methods used in reverberatory furnaces. Specifically, the project will couple heater improvement with furnace modeling to enable cost-effective retrofits to a range of existing furnaces, thus reducing the economic barriers to the application and reducing the energy and environmental impact of aluminum melting.

Improving Energy Efficiency Today

Within ITP, there are other services that help the metal casting industry save energy. These include software tools, training, and energy-saving resources from EERE BestPractices and Industrial Assessment Centers. Recommendations by these groups have the potential to save metal casters millions of dollars annually. For example, a plant-wide assessment performed by the BestPractices program for Sawbrook, Ohio identified 15 plant and process modifications that would result in an annual savings of $169,000 per year in costs and energy savings. Another plant-wide assessment conducted at Techni-Cast, California, identified improvements in the compressed air systems that allowed the foundry to reduce its compressor capacity by 50 percent, thus saving annual energy of 242,000 kWh and costs of $24,000. To learn more about plant-wide assessments, please visit: http://www.oit.doe.gov/bestpractices.

Energy Analysis – Targeting Energy Efficiency

In FY 2004, ITP published two reports, *Energy Use in Selected Metal Casting Facilities – 2003* and *Theoretical/Best Practice Energy Use In Metalcasting Operations*. The *Energy Use in Selected Metal Casting Facilities – 2003* provides an energy benchmark for various metalcasting processes. It describes process flows and energy use by fuel type and processes for selected casting operations. It also provides recommendations for improving energy efficiency in casting. The *Theoretical/Best Practice Energy Use In Metalcasting Operations* report evaluates the potential for reducing the energy needed to produce molten metal (cast iron, steel, aluminum, magnesium, zinc and copper). It also includes energy-saving opportunities beyond melting, as well as an analysis of the potential for combined heat and power in metal. These reports will assist the Metal Casting IOF and the CMC to direct efforts to high-impact, revolutionary processes research. These reports are available at: http://www.eere.energy.gov/industry/metalcasting/analysis.html.

University-Based Research

The availability of a well-trained workforce in the U.S. metal casting industry has been one of the industry's top priorities. Addressing this concern, the Metal Casting IOF places a strong emphasis on university-based research. Metal Casting IOF-funded research is performed at nearly 18 universities across the United States. U.S. students are being exposed to cutting-edge technology and material research critical to the future health of the U.S. economy. In addition, well-trained students are moving toward productive careers in the metal casting industry. In October 2003, ITP conducted a survey of all university participants in the portfolio since the inception of the Metal Casting portfolio. The survey was used to determine the number of students that participated in ITP Metal Casting portfolio-funded research, and of those that participated, how many now work in the metal casting industry. The results concluded that over 325 students participated in Metal Casting portfolio-funded research; 150 are now working in the metal casting industry. These students have been able to translate their education in the advanced technologies, materials, and processes into improved energy efficiency and productivity for the metal casting industry.

Disseminating Research Results to Industry

The ITP Metal Casting portfolio performs various outreach activities to disseminate R&D results and enable the U.S. metal casting industry to implement energy-saving practices and technologies. This includes participating in trade shows and maintaining an up-to-date Web site that highlights Metal Casting portfolio activities. In addition, through trade publications such as *Die Casting Engineer* and *Modern Casting,* research funded by the ITP Metal Casting portfolio is often highlighted, exposing metal casters to research that can save them energy and reduce their costs. Examples of trade shows in which the ITP participates include:

- CastExpo hosted by AFS (http://www.afsinc.org)
- Die Casting Congress & Exposition hosted by NADCA (http://www.diecasting.org)
- Technical and Operating Conference hosted by SFSA (http://www.sfsa.org)

TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

The Metal Casting Industry of the Future offers a wide array of tools and publications to help metal casters improve productivity and energy efficiency. These resources are available online at the Metal Casting Web site at: http://www.eere.energy.gov/industry/metalcasting/analysis.html.

Tools and Publications

The tools and publications available from the ITP Metal Casting portfolio include:

- ***A Vision for the U.S. Metal Casting Industry: 2002 and Beyond***: This document outlines the broad goals and challenges identified by industry leaders that must be addressed over the next 20 years. Achieving the goals set forth in the vision will improve productivity and energy efficiency in the industry and quicken the development and application of advanced, clean technologies in metal casting processes.

- ***Metal Casting Industry Technology Roadmap: Pathway for 2002 and Beyond (2003)***: The Metal Casting Industry Technology Roadmap establishes the industry's R&D priorities, performance targets, and milestones for attaining the goals set forth in the vision. This roadmap identifies specific research challenges and needs in the areas of *Improved Metalcasting Design Capabilities* and *Improved Metalcasting Processes*.

- ***Gateway to Metal Casting Resources***: This application is available both online and in CD-ROM form. It provides abstracts of Metal Casting portfolio projects along with links to both fact sheets and technical reports of these projects. Projects are categorized by alloy, casting method, and step in the casting process. This application provides both links to the technical societies and other resources available from DOE.

- ***Energy Use in Selected Metalcasting Facilities – 2003:*** This report represents an energy benchmark for various metal casting processes. It describes process flows and energy use by fuel type and processes for selected casting operations. It also provides recommendations for improving energy efficiency in casting.

- ***Energy and Environmental Profile of the Metal Casting Industry***: This detailed report benchmarks the energy and environmental characteristics of the key technologies used in the major processes of the metal casting industry.

- ***Theoretical/Best Practice Energy Use In Metalcasting Operations:*** With U.S. energy costs increasing, this timely report evaluates the potential for reducing the energy needed to produce molten metal (cast iron, steel, aluminum, magnesium, zinc and copper). It also includes energy-saving opportunities beyond melting, as well as an analysis of the potential for combined heat and power in metal casting.

To view these documents and application, please visit: http://www.eere.energy.gov/industry/metalcasting/analysis.html

Fact Sheets

The Metal Casting IOF disseminates information on current and past projects through project fact sheets. The information provided in each fact sheet includes the objective, accomplishments, benefits, principal investigator, and project partners. All metal casting fact sheets are available online at: http://www.eere.energy.gov/industry/metalcasting/portfolio.html and on the *Gateway to Metal Casting Resources*.

HOW TO GET INVOLVED AND CONTACT INFORMATION

Partnership Information

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

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

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

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

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

- EERE's technical programs (ITP is one of 11) give manufacturers access to a diverse portfolio of energy efficiency and renewable energy technologies and bring advanced manufacturing technology to the renewable energy community. For more information, access the EERE home page at http://www.eere.energy.gov.

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

Access to Resources and Expertise

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

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

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

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

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

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

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

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

Where to Go to Get More Information

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

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

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

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

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A Strong Energy Portfolio for a Strong America

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

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

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

The Opportunities

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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