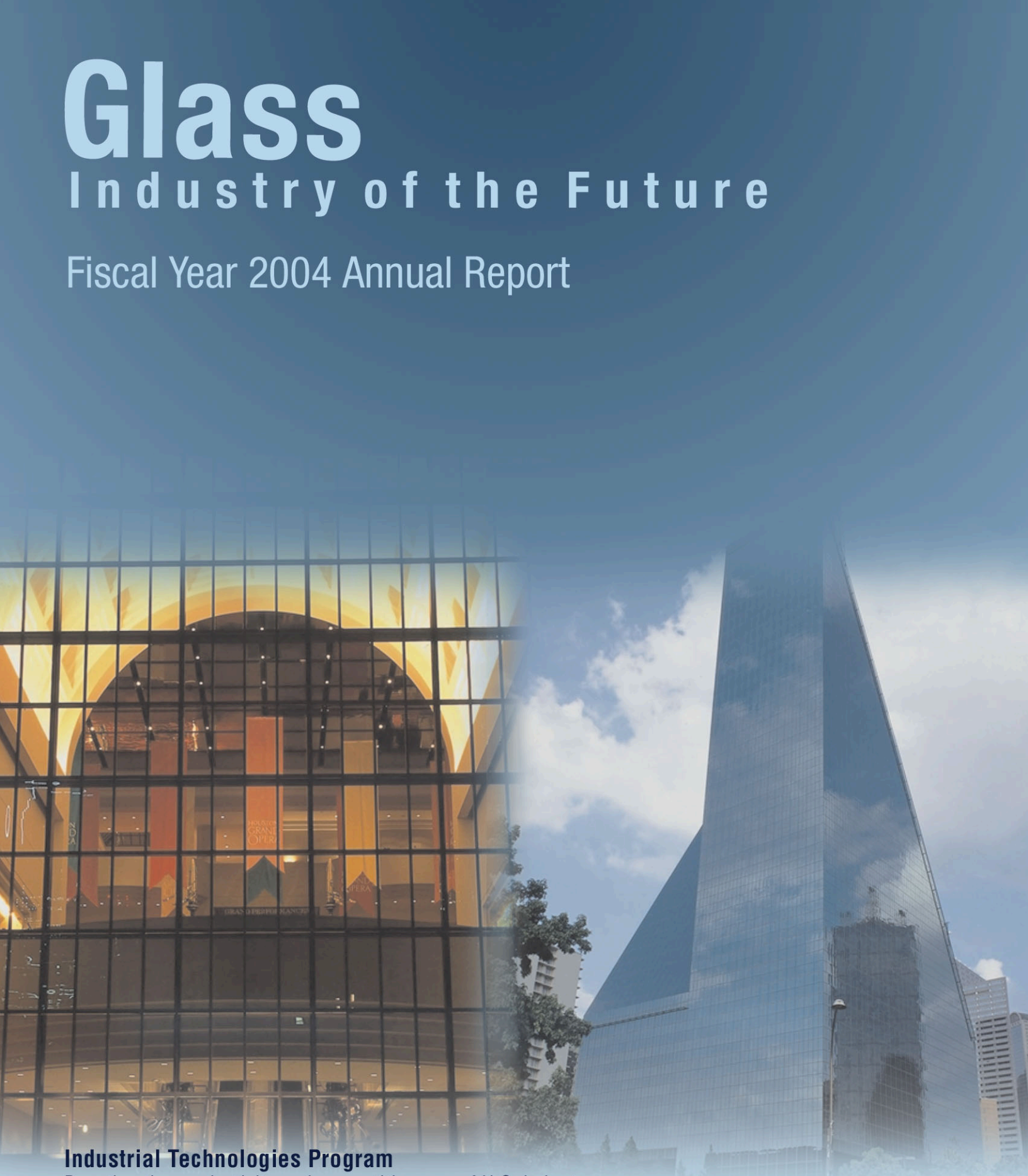
Glass
Industry of the Future

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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The glass industry continues to face significant challenges in maintaining its competitive standing in global markets. Competition from developing countries where energy and labor are cheaper is putting pressure on U.S. producers. These difficult conditions are exacerbated by the increasing volatility of domestic energy prices. Growing societal demands for environmental stewardship, and demand for short-term returns on investment continue to impact the availability of R&D funds, especially for basic and applied research. Productivity improvements and economic weakness have led to workforce reductions in the industry. These challenges have led to a major change in this highly competitive industry. Companies are now more willing to collaborate in strategic, pre-competitive areas to reduce costs, environmental impacts, and energy use.

The U.S. glass industry is a significant consumer of energy in the manufacturing sector, using an estimated 254 trillion Btu of energy in 1998. More importantly, the high proportion of energy costs (between 15 and 20 percent, depending on segment) as a percent of direct production costs in the industry makes the glass industry a prime target for energy efficiency R&D. Increasingly stringent environmental regulations associated with the combustion of fuels, used primarily for process heating in the glass industry, and the growing volatility of energy markets are making investments in energy efficiency R&D more attractive. Wellhead prices for natural gas, the glass industry's fuel of choice, have roughly tripled since the beginning of the decade. Furthermore, our growing dependence on imported energy threatens our national energy security and makes a strong case for reducing energy use.

Significant advancements in melting technology are needed to revolutionize the way energy is used in glass manufacturing. Energy consumed in manufacturing glass products is generally two to three times the theoretical minimum. More efficient process heating technology can significantly reduce the use of fuels and electricity required for glass processing.

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. glass industry. Studies sponsored by EERE have quantified the opportunity for saving energy in glassmaking (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 help the glass industry achieve a 50 percent reduction in the gap between 1995 melting energy use and the theoretical minimum by 2020.

The Glass portfolio will help the glass industry achieve a 50 percent reduction in the gap between 1995 melting energy use and the theoretical minimum by 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. Glass 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 *Glass Industry Technology Roadmap*, published in April 2002, has provided the basis for focusing R&D by identifying industry research interests. The *Glass Energy and Environmental Profile*, 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. A bandwidth analysis is currently underway to add to this analysis and provide support for the prioritization of 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 glass 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 the glass industry. Improving energy efficiency in glass manufacturing as well as improving glass products, will reduce the energy intensity of industry and could directly reduce the amount of petroleum imported into the United States, two of EERE's top priorities.

The EERE Industrial Technologies Program implements the Glass portfolio effort, which seeks to boost efficiency and productivity of the energy- and resource-intensive glass industry by investing in a balanced R&D portfolio with broad applicability in furnace operations. ITP works in partnership with the Glass Manufacturing Industry Council, an organization representing the technology needs of the U.S. glass industry. The groups involved in this partnership work with industry, academia, national laboratories, and others to promote technology development of more environmentally sound energy efficiency technologies. This partnership allows the Glass portfolio to leverage public and private resources and ensure the application of research results.

Achieving Energy Savings: Portfolio Strategy

ITP supports a Glass portfolio of cost-shared, pre-competitive research addressing key technological needs that have broad applicability throughout the glass industry. The strategy fosters both revolutionary technologies and incremental improvement to existing processes, thereby addressing long-term goals without neglecting short-term opportunities to improve energy efficiency. As the Glass portfolio shifts toward supporting a smaller number of riskier and more costly high-impact projects, research activities are being organized into the following categories: next generation melting systems, energy efficiency performance improvements, advanced processing and environmental R&D, and technology deployment. The FY 2004 ITP Glass Portfolio included seven R&D projects. Many other projects funded by EERE are applicable to the glass industry. More information about the Glass portfolio is available on the Industrial Technologies Program Web site at http://www.eere.energy.gov/industry/glass.

FY 2004 Highlights

- **Advanced Glass Furnace Model Commercialized and Receives *R&D 100* Award** –An advanced glass furnace model, developed by Argonne National Laboratory, has been commercialized successfully. Accessible from Argonne's software shop, the software has established licensure procedures. The model received one of the prestigious *R&D 100* Awards and 17 licenses were signed in 2004. To maximize effectiveness and adoption, validation studies are continuing and an industry user group is being formed.

- **Furnace Energy Assessment Best Practice Now Available** –This protocol for oxy-fuel furnaces, developed by the Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University, identifies opportunities for optimizing furnace operations and reducing energy consumption. Recommendations from the initial assessment of a PPG Industries furnace would improve energy efficiency by at least 6 percent. DIAL has already received interest from two other glass manufacturers about utilizing the protocol; a case study is also available.

- **Oxy-Fuel-Fired Front-End System Readied for In-Plant Testing at Fiberglass Facility** – Owens Corning and project partners have conducted preliminary work and prepared the demonstration host site in Jackson, Tennessee for installation of the technology. Analysis indicates that the technology will reduce fuel use in the front-end system by over 60 percent and NO_x emissions by over 90 percent, and will provide attractive financial returns, with payback time of less than two years.

- **Pilot-Scale Testing Underway for High-Intensity Plasma Glass Melter** – Plasmelt has designed and constructed the pilot-scale plasma melter and has operated the unit at 200 pounds of glass per hour with stable operating conditions for over two hours. Researchers continue to test and improve plasma torches toward their goal of 500 pounds/hour. In FY 2005, Plasmelt will validate energy efficiency targets and test glass quality.

- **Design of Pilot-Scale Submerged Combustion Melter Underway** – In the first full year of this project, the Gas Technology Institute has worked with project partners to design the pilot-plant unit, purchase necessary equipment, determine modeling parameters, conduct laboratory-scale testing, and finalize the consortium agreement. The pilot-scale unit will be constructed and testing will be initiated in FY 2005.

- **Technical and Economic Assessment for Next Generation Melting Systems Completed** – This document highlights technical and economic barriers that have stifled innovation and change in glass processes, including a detailed review of previous research efforts to improve glass melting and refining.

- **Strong Collaborative Partnership Continues with Glass Research Community** – The ITP Glass portfolio continues to work closely with industry, university, and national laboratory partners to maximize potential improvement in energy efficiency. ITP coordinates activities with the Glass Manufacturing Industry Council (GMIC), which sponsored several workshops to support the Glass portfolio efforts.

Additional research and partnership highlights can be found in the FY 2004 Highlights and Accomplishments section (see pages 9-14).

INDUSTRY OVERVIEW

Glass is an integral part of the American life style and a staple of the nation's economic success. Its popularity as a material stems from its transparent, durable, recyclable, and non-permeable qualities. The U.S. glass industry is comprised of four major segments based on end products:

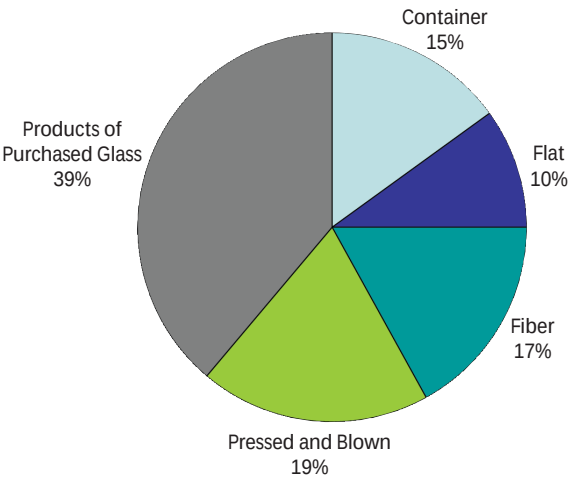
- Container glass (bottles, jars, packaging)
- Flat glass (windows, automobile windshields, picture glass)
- Fiberglass (insulation fiberglass, optical fibers, textile fibers)
- Pressed and blown glass (television tubes, light bulbs, table and ovenware, scientific and medical glassware)

The U.S. glass industry employs over 140,000 workers at approximately 2,500 facilities throughout the nation, including workers from a fifth glass industry segment, products of purchased glass. This segment includes items such as mirrors, ornaments, art glass, and aquariums.

Competitive global markets and technological change have led to accelerated restructuring, joint ventures, mergers, and acquisition activities throughout the industry. Glass companies today are often diversified into other related products, such as ceramics, packaging, building materials, and other higher margin products. Glass companies rely on technology, science, and innovation to create value-added products and gain ground in new markets. However, large capital investments are required to keep glass manufacturing plants operating at a competitive level. U.S. glass companies' products compete both with foreign sources and, in many segments, with other materials such as plastics and metals.

While all glass product segments have melting in common, there are both real and perceived differences in which types of melting satisfy their individual business needs, such as production rate and compositional flexibility. Another key attribute is glass quality, and requirements vary from sector to sector. The most significant quality parameter between sectors is the amount of small gaseous inclusions, called seeds, which are allowed to remain in the molten glass. Seeds influence the aesthetics and service performance of glass products. For example, customers would not tolerate bubbles in auto windshields, but would not care about imperfections in residential insulation fiberglass.

Exhibit 1
Industry Shipments by Segment, 2001



Source: Annual Survey of Manufactures, DOC.

Glass Industry Shipments and Trade

In 2001, U.S. glass industry shipments totaled nearly $28 billion. Exhibit 1 shows the value of shipments for the major sub-sectors. Products of purchased glass lead the industry in shipments with 39 percent, followed by pressed and blown glass (19 percent), mineral wool/fiber (17 percent), container glass (15 percent), and flat glass (10 percent). Over the last decade, the industry has grown at an average rate of about 1 to 2 percent per year, with highest growth rates in the flat and fiberglass segments. During the 1990s, industry consolidation continued and high-value niche industries such as fiber optics and glass for electronics began to gain market share. Along with consolidation has come an increase in foreign ownership. Today, the U.S. industry has fewer major players in most industry segments. While commodity glass products continue to form the core of the industry, the highest future growth is predicted to occur in specialty applications. The U.S. glass industry has generally maintained a small trade deficit (around 1 to 2 percent of net shipments). Annual production of the U.S. glass industry is approximately 20 million tons. Production of container and flat glass is estimated to be about 9 million tons and 5 million tons respectively.

Energy Use

In 1998, energy consumption in the glass industry was estimated at approximately 254 trillion Btu. Energy in the glass industry is used primarily for process heating. During the last decade, significant improvements have been made in energy efficiency, reducing energy use per unit of output substantially from the early 1970s. Technologies such as advanced burners, improved refractories, and oxy-fuel firing have played a major role in efficiency improvements.

Exhibit 2 (page 3) shows the glass industry's energy inputs by source. Natural gas provides the largest share of energy for process heat and power. Electricity is primarily used for machine-driven equipment, such as motors, fans, pumps, and furnace heating.

The industry spent $1.8 billion in energy purchases for fuel and power in 2001, a nearly 30 percent increase from energy costs in 1997. The dramatic increases in natural gas prices since 2000 have had a substantial negative impact on the industry as the existing plant infrastructure has a limited ability for near-term substitution of fuels.

Energy end-use patterns can be illustrated through the use of an energy footprint, shown in Exhibit 3 (see page 4), which identifies both energy use and losses due to equipment and system inefficiencies. The total primary energy associated with the glass industry is 372 trillion Btu, which includes energy losses associated with the generation of power at off-site utilities, and the transport of fuels to the plant site. As shown in Exhibit 3, these off-site losses are considerable, amounting to about 118 trillion Btu. Furthermore, within the plant, about 18 percent of the energy delivered to the plant is lost prior to being used in specific processes.

Process heating, mostly from glass melting and refining, represents the largest use of fuels in the glass industry (91 percent). Electricity use is primarily split between process heating (43 percent) and motor-driven equipment (41 percent). While not estimated by the energy footprint, process operations represent substantial energy sinks where new technology, as well as incremental improvements, can have an impact.

In theory, 2.2 to 2.7 million Btu/ton are required to melt a ton of glass, depending on the composition of the glass. Energy is required for the heat of reaction, and enthalpy of glass and gases emitted. However, inefficiencies cause the process to consume considerably more energy than is theoretically required. Glass furnaces, for example, the mainstay of the industry, often operate with less than the optimal thermal efficiencies. Much of the heat is lost through furnace walls and exhaust gases. In practice, two or three times the theoretical minimum energy is consumed during the melting and refining of glass.

Glass Segment Average Melting/Refining Energy Consumption, 1998
(million Btu/ton)

Flat Glass	8.6
Fiber Glass	8.4
Pressed and Blown Glass	7.3
Container Glass	5.5

Exhibit 2
Energy Use in the Glass Industry

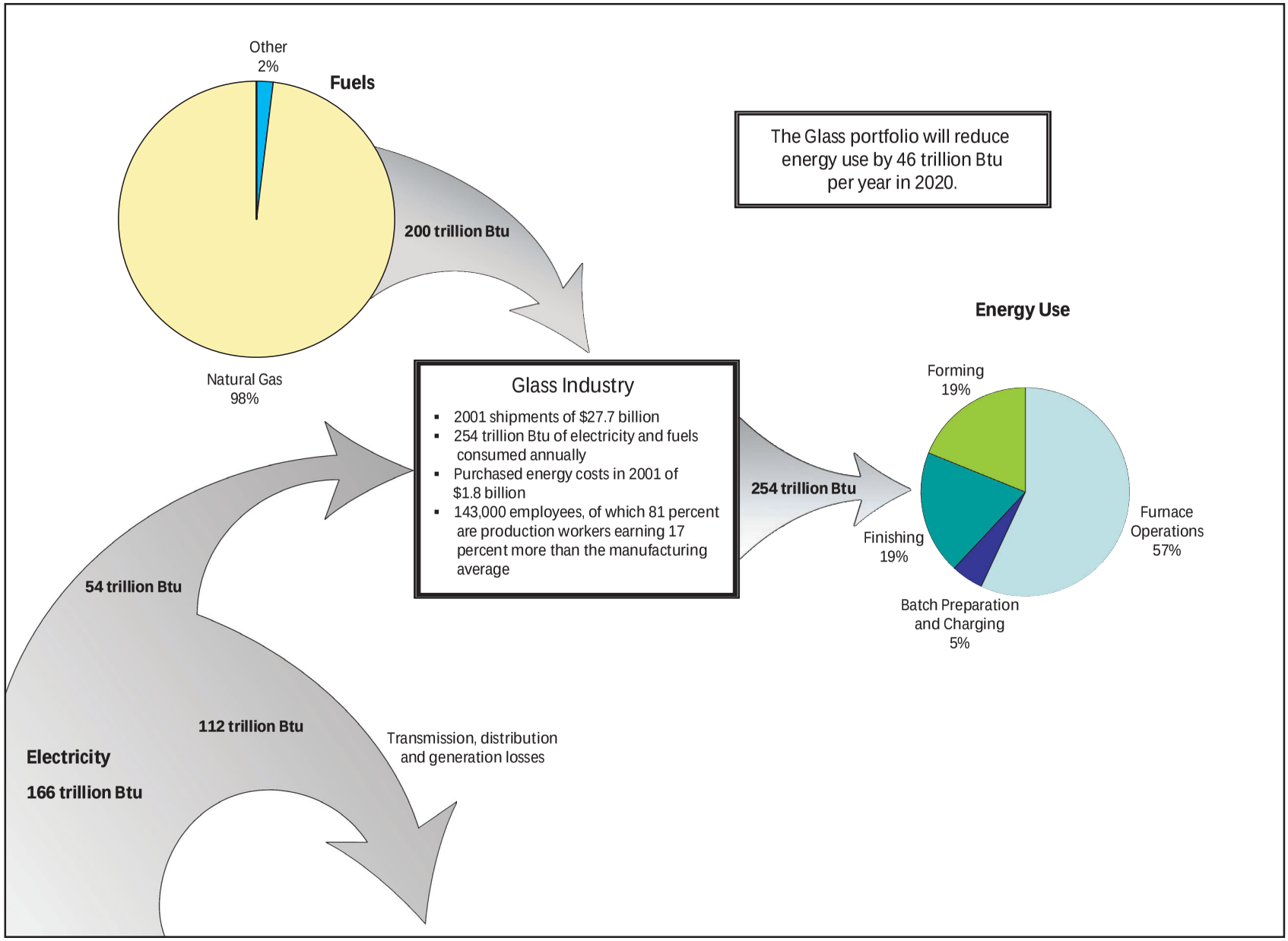
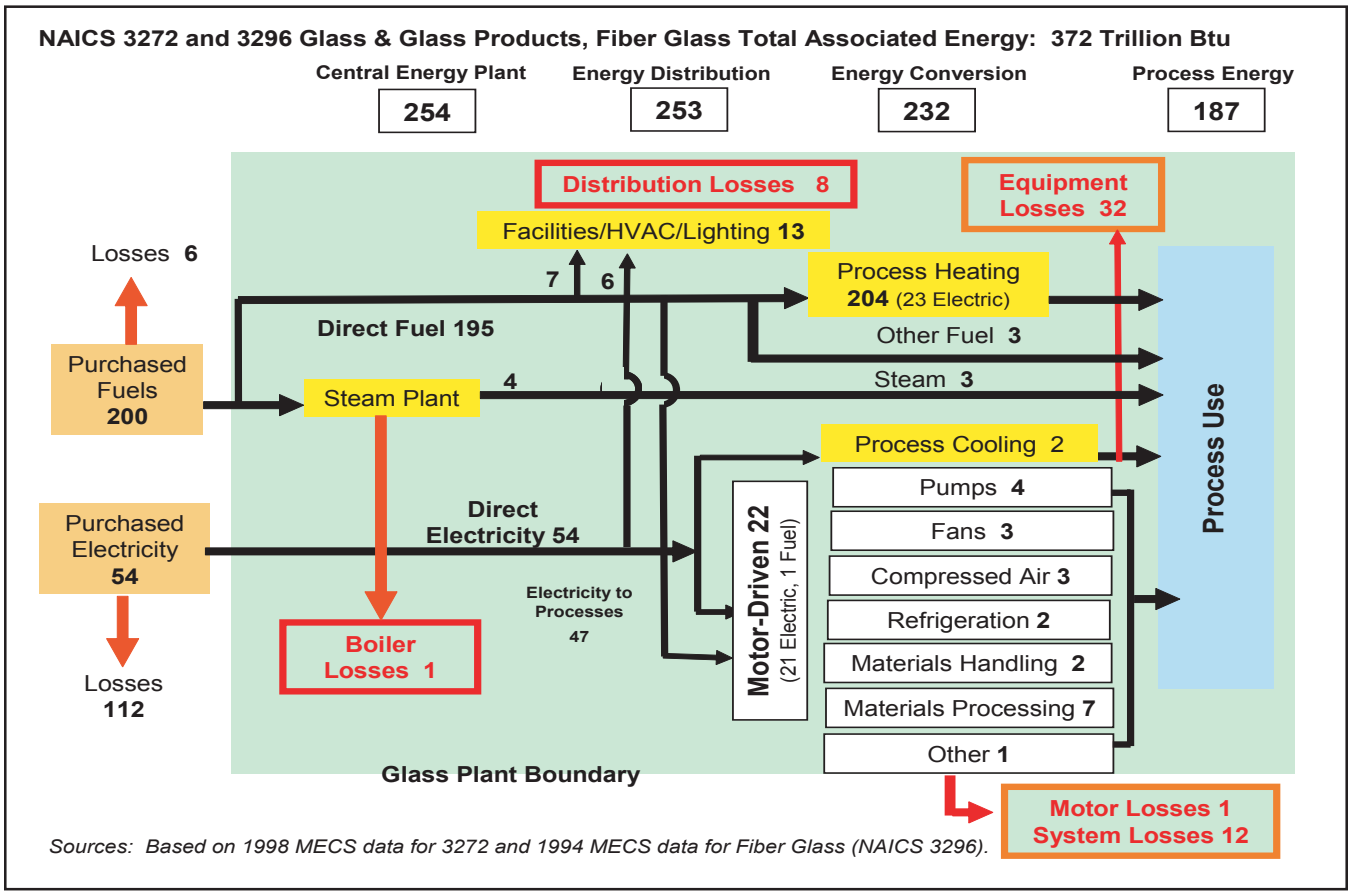


Exhibit 3
Energy Footprint for the U.S. Glass Industry



Sources: Based on 1998 MECS data for 3272 and 1994 MECS data for Fiber Glass (NAICS 3296).

THE CHALLENGE

Glass products are an integral part of the American economy and everyday life. These products are used in food and beverage packaging, lighting, communications, transportation, and building construction.

Today, the U.S. glass industry faces significant challenges in maintaining its leadership position in the global market. Competition from developing countries is putting increasing pressure on U.S. producers, particularly countries where energy and labor are cheaper and government subsidies help to fuel new industry with less stringent regulations. Growing societal demands for cleaner production and environmental stewardship continue to place increasing pressure on limited R&D funds. Demand for short-term returns on investment in recent years has also limited the amount of capital available for research activities, especially basic and applied research. The workforce in the glass industry has dropped in recent years by more than 5 percent, from 150,000 in 1997 to 143,000 in 2001.

The competitive demands facing glass companies have led to a major change within this highly competitive industry. For the first time in several decades, glass companies are now willing to collaborate in strategic, pre-competitive areas to reduce costs, environmental impacts and energy use. The industry has emphasized in the *Glass Industry Technology Roadmap* that collaborative partnerships involving government, industry and academia will be critical to meeting the technology challenges of the future and accelerating the pace of technological innovation. Recognizing that R&D consortia could benefit both industry and the nation, the industry organized the Glass Manufacturing Industry Council, an association of major U.S. glass companies and supporting organizations. This group works with government and academia to promote the development of more environmentally sound energy efficiency glass technologies.

An Energy-Intensive Industry

Energy is a major factor in the technology equation for the glass industry. The U.S. glass industry consumed an estimated 254 trillion Btu of energy in 1998. The magnitude of energy consumed by the industry makes it a prime target for energy efficiency R&D, with potentially large energy savings opportunities. In 2001, energy costs accounted on average for about 19 percent of direct glassmaking production costs. The industry relies primarily on natural gas to provide heating for the manufacture of glass products.

While tremendous advances have been made in energy efficiency since the oil crisis of the 1970s, the industry still relies on many processes that are relatively inefficient and energy intensive. When energy costs are low relative to the costs of processing and other inputs to production, investments in energy efficiency often take a backseat to investments in environmental compliance or product development. However, increasingly stringent environmental regulations associated with the combustion of fuels and the growing volatility of energy markets are moving energy efficiency to the forefront. The record high prices for natural gas over the last two years, for example, have forced plants to close and to move production out of North America to locations where natural gas is cheap and plentiful.

The government and the glass industry have overlapping interests for improving energy efficiency. By improving the efficiency of glassmaking, the glass industry benefits by reducing production costs and by becoming more competitive. The government also desires both near- and long-term solutions for reducing domestic energy consumption. Innovative glass products, such as advanced windows and lighting products, which allow consumers to use less energy, will also help the United States reduce energy demand. However, permanent technology changes, rather than short-term fixes, are needed to revolutionize the way energy is used in glass manufacturing. Efforts have been initiated to develop a next-generation melting system to significantly reduce energy requirements for glassmaking.

Glass industry R&D is a component of the overall EERE strategy to improve energy efficiency and contributes to the goals outlined in the National Energy Policy. Specifically, improving energy efficiency in glass manufacturing will reduce the energy intensity of industry and indirectly reduce the amount of petroleum imported into the United States, two of EERE's top priorities.

Strategy for Improving Glass Industry Energy Efficiency

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) leads the federal role in developing advanced energy efficiency and environmentally friendly industrial technologies. The EERE Industrial Technologies Program (ITP) implements the Glass portfolio effort, to boost efficiency and productivity of the energy-intensive glass industry.

ITP's Glass portfolio responds to the unique challenges in the glass industry by supporting collaborative, innovative R&D improvements in process technologies, design tools and methodologies; promoting demonstrations of promising technologies; and promoting the implementation of best practices and emerging technologies that will contribute to the ITP goal of helping industry achieve a 30 percent reduction in energy consumption per unit of output by 2020. The objective of the Glass portfolio is to reduce energy use in the glass industry by 46 trillion Btu per year by 2020.

Fact sheets describing projects in the ITP Glass portfolio are located at http://www.eere.energy.gov/industry/glass/portfolio.html.

ITP's Glass portfolio works in partnership with the Glass Manufacturing Industry Council (GMIC) on an ongoing basis to identify research priorities with broad applicability in the glass industry. The GMIC was established to represent the needs of the entire glass industry, bridging diverse interests and creating a unified voice. By partnering with GMIC and fostering broad collaboration with glass industry partners, ITP's Glass portfolio leverages public and private resources and ensures the application of research results.

ITP's Glass portfolio created the impetus for the industry to develop a long-term vision and roadmap. Glass portfolio solicitations reflect the priorities in the vision and roadmaps, as well as ITP's analysis of opportunities for energy savings, national priorities and the appropriate federal role. To assure broad participation among glass companies, Glass portfolio solicitations are announced via email to the GMIC listserv, in trade society publications, Web sites, meetings, the *Commerce Business Daily*, *FedBizOpps*, and the ITP Glass portfolio Web site. Selection of projects follows merit-based criteria that emphasize projected energy, environmental, and economic benefits based on sound analysis using a standardized procedure available through the On-line Glass Project Evaluation Tool (http://www.energetics.com/glasstool). This rigorous solicitation development and implementation process ensures targeted, competitive solicitations for pre-competitive R&D.

ITP's Glass portfolio strategy is

GMIC

The Glass Manufacturing Industry Council (GMIC) is a trade association of the U.S. glass industry that includes among its members representatives of all four sectors: Flat, Container, Fiber and Specialty. GMIC, incorporated in September 1998, is moving forward on a broad front to promote the interests and growth of the U.S. glass industry as a whole. Its formation represents a milestone development for the industry. Other industries (steel, aluminum, forest and paper products, etc.) have had organizations that operated on behalf of the entire industry and that were effective in consolidating benefits for the industry as a whole. Until the formation of the GMIC, the U.S. glass industry has had no "umbrella" body to represent its interests.

The mission of the Glass Manufacturing Industry Council is:

"To facilitate, organize, and promote the interests and growth of the U.S. glass industry through cooperation in the areas of technology, productivity and the environment."

GMIC Members

Core

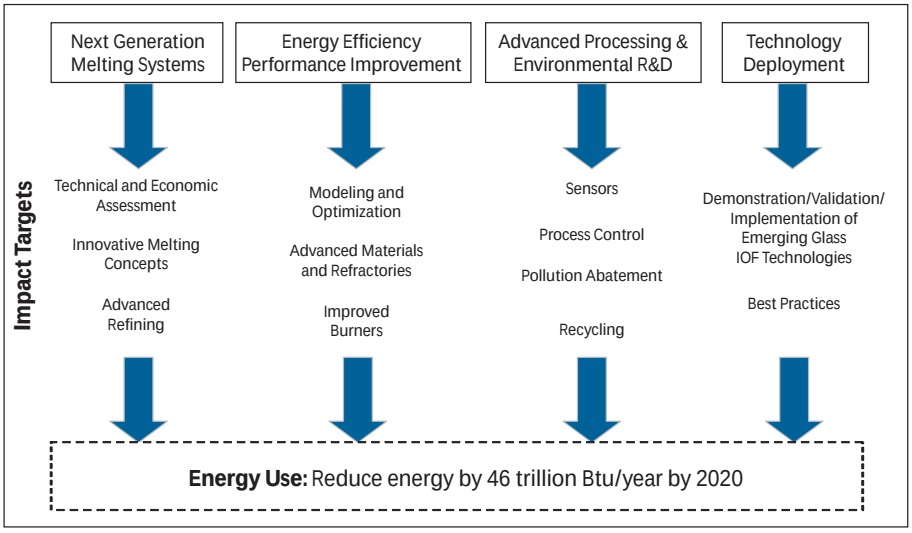
CertainTeed Corporation
Corning Incorporated
Johns Mansville
Leone Industries
Longhorn Glass Corporation
Owens Corning
PPG Industries - Fiberglass
Society for Glass Science and Practices
Techneglas
Visteon - An Enterprise of Ford Motor Company

Associate

Advanced Manufacturing Center
Air Liquide America
BOC Gases
Center for Glass Research
Eclipse Inc. /Combustion Tec
Gas Technology Institute
Glass Service, Inc.
Mississippi State University (Diagnostic Instrumentation & Analysis Laboratory)
Praxair, Inc.
Siemens Energy & Automation
Unimin
U.S. Borax
U.S. Silica
Westinghouse Savannah River Company

designed to have the greatest impact on reducing glass industry energy intensity. The strategy evolves over time as R&D projects are funded and completed, as new opportunities to have a significant impact on the industry are identified, and as national priorities change. The Glass portfolio organizes its activities into four categories: next generation melting systems, energy efficiency performance improvements, advanced processing and environmental R&D, and technology deployment. Exhibit 4 shows the target areas for each of these research categories.

Exhibit 4
Process and Technology Improvements Target Energy Efficiency



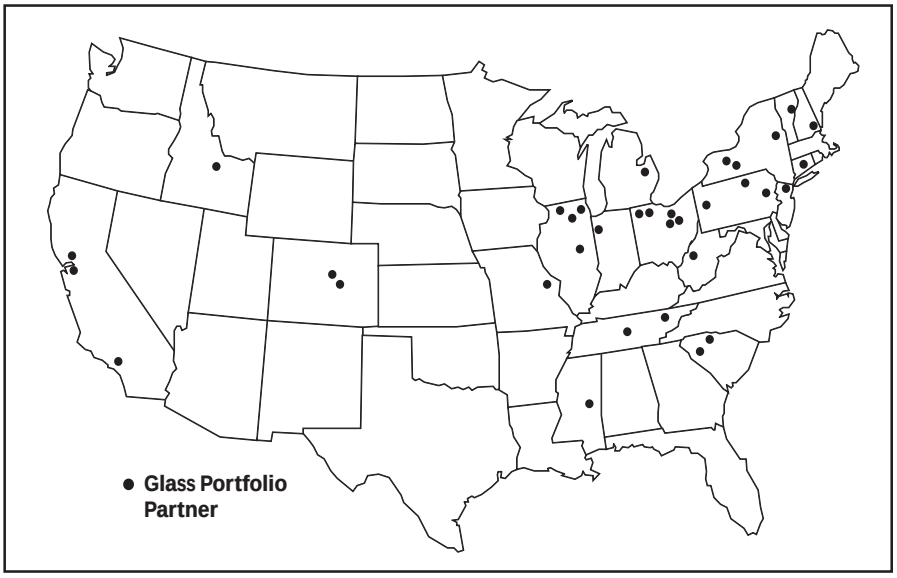
During FY 2004, the Glass portfolio participated in ITP Corporate and National Academy of Science Peer Reviews. The ITP Corporate Peer Review was held March 9-10, 2004. This Peer Review brought industry stakeholders and government partners together to review the mission, strategies and future direction of the Industrial Technologies program, including a strategic overview of the Glass R&D portfolio. Examples of some of the feedback the Glass portfolio received from the review included:

- Impressed with number of industry partners on projects.
- Fundamental understanding of glass melting process is still insufficient.
- Consider more work in cullet area to potentially reduce energy use.

Subsequently, the National Academy of Sciences was briefed with similar presentations about ITP efforts and is preparing a formal report of findings.

In FY 2004, the Glass portfolio continued to transition to fewer, yet higher-risk, higher-impact research projects that will have the opportunity to produce revolutionary improvements in glass processing efficiency. To leverage available funding, the Glass portfolio submits topics to the Small Business Innovation Research and Small Business Technology Transfer Program (SBIR/STTR), and tracks and manages SBIR/STTR glass projects. The Glass portfolio also encourages other ITP elements and other EERE programs to fund R&D priorities of the glass industry. For example, several sensors and automation and industrial materials projects are of great interest to the glass industry.

Exhibit 5
FY 2004 Glass Portfolio Partners



The Glass portfolio includes projects and activities ranging from high-risk, high-return R&D and applied research and development, to demonstrations and technology delivery activities. Most R&D projects in the portfolio address technical needs in multiple glass industry segments. The duration of projects is two to five years. Industry generally contributes between 30 and 50 percent of the funds for each R&D project. R&D is conducted by glass companies, national laboratories, research institutes, and universities. Industry involvement accelerates the dissemination of research results and technology transfer. The portfolio also includes activities to highlight available opportunities that can immediately reduce glass industry energy use.

Project participants and partners are distributed across the United States, with the majority in areas densely populated with glass industry manufacturing facilities, such as the Midwest and Mid-Atlantic states, and at national laboratories. The map in exhibit 5 shows the distribution of the 34 Glass portfolio partners (FY 2004).

FY 2004 HIGHLIGHTS AND ACCOMPLISHMENTS

The ITP Glass portfolio supports a diverse portfolio of cost-shared, pre-competitive research that address high-risk, high-impact needs and have a broad application throughout the glass industry. In FY 2004, the Glass portfolio included seven core R&D projects. Of these seven projects, two were completed in FY 2004. These projects, along with the current Glass Project Laboratory User Services projects, one project with states, and two SBIR projects are listed below. In addition, over 20 projects relevant to the glass industry that are funded by other EERE programs are included in the Glass portfolio.

R&D Highlights

Advanced Glass Furnace Model Commercialized and Receives *R&D 100* Award – An advanced glass furnace model, developed by Argonne National Laboratory, has been commercialized successfully. Accessible from Argonne's software shop, the software has established licensure procedures. The model received one of the prestigious *R&D 100* Awards and 17 licenses were signed in 2004. To maximize effectiveness and adoption, validation studies are continuing by industry partners and an industry user group is being formed.

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In-Plant Trials Successfully Conducted for On-line Coatings of Float Glass – Initial full-scale testing has been completed at PPG Industries. Results indicated an improvement in the efficiency of precursor material used in coating operations from 50 to 150 percent over current usage at standard conditions. Additional trials are continuing under differing conditions and parameters to gain further insights on optimizing the process.

LIBS Sensor Technique Successfully Tested in Plant Environment – Scientists from Energy Research Company successfully tested a laser-induced breakdown spectroscopy (LIBS) sensor technique at PPG Industries' Chester, South Carolina plant for a 20 day-equivalent period, and a long-term trial is now underway. Plant personnel were very satisfied with the method's accuracy, repeatability and ease of use in determining concentrations for their material of interest. Further development activities will expand the method's capabilities and applicable materials.

Glass Projects with Completed Government Funding in FY 2004

Energy Efficiency Performance Improvements

- *Process Optimization Strategies, Models, and Chemical Databases for On-line Coating of Float Glass* (PPG Industries, Sandia National Laboratories)
  Sandia National Laboratories and PPG Industries have developed modifications to atmospheric pressure chemical vapor deposition to increase the efficiency of reactant utilization. Researchers are conducting detailed theoretical and experimental studies of the underlying deposition process. Computational models are being developed that can predict defects in coatings.

Advanced Processing and Environmental R&D

- *Monitoring and Control of Alkali Volatilization and Batch Carryover for Minimization of Particulates and Crown Corrosion* (Sandia National Laboratories, Gallo Glass)
  Researchers at Gallo Glass and Sandia National Laboratories are collecting data to determine the conditions having the greatest influence on volatilization, batch carryover, combustion efficiency and furnace efficiency. A prototype measurement instrument using laser-induced breakdown spectroscopy has been designed and built. A control strategy and system for minimizing alkali volatilization and batch carryover is being developed.

Active Glass Projects in FY 2004

Glass R&D Projects

Next Generation Melting Systems

- *Energy-Efficient Glass Melting: The Next Generation Melter* (Gas Technology Institute, Corning Incorporated, PPG Industries, Owens Corning, Johns Manville, Schott Glass Technologies, CertainTeed Corporation, Fluent, Praxair, Eclipse/Combustion Tec, A.C. Leadbetter and Son)
  Researchers at the Gas Technology Institute are designing and fabricating a pilot-scale submerged combustion glass melter. Two series of tests will be performed and product glass properties will be analyzed.
- *High-Intensity Plasma Glass Melter* (Plasmelt Glass Technologies, LLC, Johns Manville, Advanced Glassfiber Yarns)
  Plasmelt is developing a plasma-melting system that is generically suited to melting a large variety of glass compositions. A prototype system is being constructed and tested and product quality will be evaluated.

Energy Efficiency Performance Improvements

- *Development/Demonstration of an Advanced Oxy-Fuel-Fired Front-End System (*Owens Corning, Osram Sylvania, BOC Gases, Eclipse/Combustion Tec)
  Scientists at Owens Corning are developing a novel, oxy-fuel fired front-end system. After laboratory design testing of burners and system control, the system will be demonstrated in a commercial fiberglass production plant.
- *Development and Validation of a Coupled Combustion Space/Glass Bath Furnace Simulation* (Argonne National Laboratory, Techneglas, Owens Corning, Osram Sylvania, Libbey, Visteon, Mississippi State University, Purdue University)
  Researchers have developed a validated glass melting furnace simulation model that incorporates innovative features. The combustion space and glass bath models are coupled at their interface through the use of appropriate heat flux and temperature continuity conditions. The combustion space model incorporates a rigorous treatment of the radiative heat transfer to the glass bath.

Advanced Processing and Environmental R&D

- *Measurement and Control of Glass Feedstocks* (Energy Research Company, PPG Industries, Oak Ridge National Laboratory, Fenton Art Glass Company)
  Researchers at Energy Research Company are developing a probe based on laser-induced breakdown spectroscopy to measure the chemical makeup of glass feedstocks in real time. The probe will quickly detect contaminants and batch nonuniformity in the raw materials and cullet. Artificial neural network software will be tested to provide high-speed analysis of data obtained by the probe.

GPLUS Projects

The **Glass Project Laboratory User Services (GPLUS)** program enables glass manufacturers to conduct small-scale scoping studies in collaboration with any of the DOE national laboratories. The program is cost-shared by DOE and the glass manufacturer, and results are provided to the GMIC to enable technology transfer.

- *Foaming of Glass* (PPG Industries, Pacific Northwest National Laboratory)
- *Study of Sulfate Fining Chemistry in Oxidized and Reduced Soda-Lime Silica Glasses* (Visteon, Pacific Northwest National Laboratory)
- *Spectral Analysis and Imaging of Colored Glasses* (Society for Glass Science and Practices, Judel Products, Oak Ridge National Laboratory)
- *Application of Furnace Model to an Oxy-Fuel Furnace for the Production of Amber Glass* (Longhorn Glass, Argonne National Laboratory, Metal Container Corp.)
- *High-Temperature Thermocouple Study* (Schott Glass Technologies, Idaho National Laboratory)
- *Improvement of Oxy-Fuel Burner Design/Operations* (Owens Corning, Sandia National Laboratories)
- *Laser-Induced Laser Breakdown Spectroscopy (LIBS) as a Glass Melt Monitor* (Corning, Sandia National Laboratories)
- *Strength Data and Design Method for Tempered Automotive Glazing Which is Subject to Stress Corrosion Cracking* (Visteon, Pacific Northwest National Laboratory)
- *TV Glass Surface Problems* (Techneglas, Oak Ridge National Laboratory)

Projects with States

- *Improvement of Performance and Yield of Continuous Glass Fiber Drawing Technology* (Cleveland State University, PPG Industries, Johns Manville, Schott Glass, U.S. Borax)
  This project is applying six sigma quality methodology and fundamental glass science to reduce fiber breakage and resultant waste. During the project, instrumentation will be developed, simulation models will be employed, and the process will be investigated and optimized.

SBIR Projects

- *An Optical Fiber Probe for the Measurement of High-Temperatures* (Hope Technologies, Inc.)
- *Universal Photo-Acoustic Sensor System* (Physical Optics Corporation)

Other ITP and EERE Projects Relevant to the Glass Industry

Advanced Industrial Materials Projects Relevant to Glass

- *Advanced Thermoelectric Materials for Efficient Waste Heat Recovery in Process Industries*
- *Thermochemical Models and Databases for High-Temperature Materials*
- *Alkaline-Resistant Fe-Phosphate Glass Fibers as Concrete Reinforcement*
- *Development of Functionally Graded Materials for Manufacturing Tools and Dies and Industrial Processing Equipment*
- *Advanced Nanoporous Composite Materials for Industrial Heat Applications*
- *Crosscutting Industrial Applications of a New Class of Ultra-Hard Borides*
- *Development and Demonstration of Advanced Tooling Alloys for Molds and Dies*

Combustion Project Relevant to Glass

- *Development of an Innovative Energy-Efficient, High-Temperature Natural Gas-Fired Furnace*

Sensors and Automation Projects Relevant to Glass

- *Boiler and Furnace Efficiency Improvement with Low-Cost CO Sensor and Burner Control System*
- *Diagnostics and Control of Natural Gas-Fired Furnaces via Flame Image Analysis Using Machine Vision and Artificial Intelligence Techniques*
- *Fiber-Optic Sensor for Industrial Process Measurement and Control*
- *Thermal Imaging Control of Furnaces and Combustors*
- *Tunable Diode Lasers Sensors for Monitoring and Control of Harsh Combustion Environments*
- *Advanced Wireless Sensors for the Industries of the Future*

Inventions and Innovations Projects Relevant to Glass

- *Monitoring of Refractory Wall Recession Using High-Temperature Impact-Echo Instrumentation*
- *Monitoring of Refractory Wall Recession Using Radar Techniques*
- *Fiber-Sizing Sensor/Controller for Optimizing Glass and Polymer Fiber Manufacturing Processes*
- *Development of a Novel Frequency-Selective Solar Glazing System*
- *Enabling Tool for Innovative Glass Applications*
- *Energy-Saving Method of Manufacturing Ceramic Products from Waste Glass*
- *High-Throughput Vacuum Processing for Innovative Uses of Glass*
- *Low-Energy Alternative to Commercial Silica-Based Glass Fibers*
- *Thermophotovoltaic Electric Power Generation Using Exhaust Heat*

Partnership Highlights

In addition to sponsoring R&D, the Glass portfolio achieved a number of noteworthy accomplishments in FY 2004. These accomplishments are described below:

Allied Partnership Agreement Continues with GMIC – An Allied Partnership with the Glass Manufacturing Industry Council (GMIC) was established in June 2003 and continued throughout FY 2004. Key activities during FY 2004 included: conducting three Best Practices workshops (Process Heating, Compressed Air, and 20 Major Energy Savings Tips) in conjunction with Glassman America in Pittsburgh, promoting the commercialization and adoption of ITP and EERE glass technologies, and distributing ITP and EERE literature at numerous industry events.

Technical and Economic Assessment for Next-Generation Melting Systems Completed – This document highlights technical and economic barriers that have stifled innovation and change in glass processes, including a detailed review of previous research efforts to improve glass melting and refining.

Alternative Refining/Conditioning Technology Pathways Examined – As part of broader efforts to develop next generation melting systems, two workshops were conducted to examine the potential for alternative refining/conditioning technologies. The GMIC focused workshop discussions and analysis on four potential technologies: vacuum refining, helium gas refining, sonic refining and centrifugal refining. Development of advanced refining concepts may be necessary for broad adoption of next generation melting technology.

Glass Project Review Conducted – As part of its effort to ensure stewardship of public funds, the Glass portfolio conducts a yearly evaluation of research projects to assess performance, including progress toward technical, economic and market goals. The FY 2004 review was held in June 2004 near Washington, DC in conjunction with the ITP Industrial Materials, and Sensors and Automation subprograms. Over 150 attendees heard presentations on ongoing research projects being conducted by industry, university, and national laboratory researchers in order to evaluate each project's progress, significance and relevance to the industry's needs.

Glass Resources CD-ROM Wins Communications Awards – The glass resources CD-ROM, released in FY 2003, provides tips and tools for spotting energy-saving opportunities in glass plants, as well as details on energy efficiency technologies. This CD-ROM won two awards in 2004. First, the CD won an Award of Merit from the Colorado Chapter of the International Association of Business Communicators. The CD was one of only three award winners in the Electronic and Digital Communications, Multimedia CD category. Second, the CD won an APEX Award of Excellence from Communications Concepts, Inc. Out of nearly 200 entries, the CD was one of five award winners in the Multimedia and Interactive Publications category. The APEX awards are based on excellence in graphic design, editorial content, and the ability to achieve overall communication excellence.

Guidebook on Commercialized Energy Efficiency and Supply Technologies for the Glass Manufacturing Industry Completed – This document describes a variety of technologies that energy managers in the glass industry can use to make their plants more efficient, self-reliant and profitable, creating less pollution.

Improving Energy Efficiency Today

Plant-wide assessments (PWAs) are cost-shared assessments of plant utility and process-related energy efficiency opportunities across a plant. Plants are eligible through a competitive solicitation. In FY 2004, a PWA was awarded for Owens Corning's Santa Clara, California plant to evaluate all major energy-consuming systems required for the glass-melting and fiber-forming processes. The assessment team will focus on efficiency and identify opportunities for state-of-the-art and emerging technologies. The assessment includes the adoption of best practices in the design, management, operation, and procurement of systems that support production.

Additionally, the case study from an earlier Corning, Incorporated PWA assessment was published. The assessment team developed 17 recommendations with the potential to save 123 billion Btu of natural gas and 72 million kWh of electricity annually. The average payback period for each recommendation was less than one year.

Disseminating Research Results to Industry

ITP's Glass portfolio conducts numerous outreach activities to disseminate R&D results and encourage companies to reduce energy intensity of glass processing. Project reports submitted to DOE are available on the ITP Glass portfolio Web site (http://www.eere.energy.gov/industry/glass) and on DOE's Information Bridge Web site (http://www.osti.gov/bridge). In addition, the Glass portfolio attended and participated in several meetings and workshops in FY 2004, including:

- Glass Problems Conference
- Future Refining/Conditioning Needs Workshop
- Next Generation Refining/Conditioning Workshop

The Glass portfolio is also supporting focus group interactions for establishing distance learning from the preeminent glass science degree-granting university, the Center for Glass Research at Alfred University. The focus groups will determine industry interests relating to emerging energy efficiency technologies and practices and glass science and engineering.

Two commercial technologies supported by the Glass portfolio continued to have great success in the U.S. glass industry. Oxy-fuel firing, commercialized in the early 1990s, now represents over 30 percent of U.S. glass industry capacity. The technology, while no longer tracked by ITP, was saving over 4 trillion Btu annually industry-wide when last reported. Oxygen-Enriched Air Staging (OEAS), which provides a low-cost method for glass manufacturers to reduce NO_x emissions, is being utilized in 16 glass furnaces. Another technology, the High-Luminosity Low-NO_x Burner, has just entered the commercial marketplace. More information about these and other ITP commercialized and emerging technologies of interest to the glass industry can be found in ITP's "Impacts" document (http://www.pnl.gov/impacts).

ITP's Glass portfolio Web site underwent a significant improvement during FY 2004. It is now easier to navigate and is more consistent with the other EERE Web sites. Other improvements include additional information, highlights of activities and opportunities, and increased accessibility of final reports from R&D projects.

In addition, an on-line stakeholder engagement tool was developed to allow better two-way interaction with the glass research community. The tool allows stakeholders to share feedback on current activities and research, suggestions for future collaborative activities, and sharing of best practices (http://www.govforums.org/glass).

Energy Analysis – Targeting Energy Efficiency

The **Energy Bandwidth Study** continued in FY 2004 to show the magnitude of energy savings possible for glass manufacture. The energy "bandwidth" will be used to provide a rationale for supporting R&D on new technologies with the highest potential impact on glass industry energy consumption.

The **Energy Footprint Study** of the Glass Industry shows the flow of energy throughout the industry. The energy flow and losses are shown for energy supply, central energy generation/utilities, energy distribution, energy conversion, and process energy (see Exhibit 3, page 4).

A **Project Evaluation Tool** has been created to analyze energy and environmental benefits of glass research projects. Applicants to ITP Glass portfolio solicitations are now required to use the project evaluation tool.

The **Government Performance and Results Act (GPRA) Analysis** was completed for projects considered in the FY 2006 budget. The GPRA analysis estimates future benefits of emerging technologies in the Glass portfolio based on market penetration, energy savings, and environmental emission reductions.

TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

EERE offers valuable tools and publications to help glass companies improve productivity and energy efficiency. Some of these resources are described below. See the Web site at http://www.eere.energy.gov/industry/glass for a complete listing.

Glass: A Clear Vision for a Bright Future – This landmark document released in 1996 outlines a vision for the glass industry in 2020 and identifies industry-wide goals for production efficiency, energy efficiency, environmental performance, and innovative uses.

Glass Industry Technology Roadmap – The GMIC published the Glass Industry Technology Roadmap in April 2002. The document describes technology challenges, research needs and priorities, and implementation roles.

Fact Sheets and Success Stories – These brief publications describe the objectives, benefits, partners, and accomplishments of RD&D projects in the Glass portfolio.

Resource CD-ROM – This award-winning CD-ROM provides tips and tools for spotting energy-saving opportunities in glass plants today, as well as details on energy efficiency technologies. The CD-ROM contains over 200 documents relevant to glass manufacturers.

Energy and Environmental Profile of the Glass Industry – This detailed report benchmarks the energy and environmental characteristics of key technologies used in major processes of the glass industry.

Technical and Economic Assessment for Next Generation Melting Systems – This document highlights technical and economic barriers that have stifled innovation and change in glass processes, including a detailed review of previous research efforts to improve glass melting and refining.

***Guidebook on Commercialized Energy Efficiency and Supply Technologies for the Glass Manufacturing* Industry** – This document describes a variety of technologies that energy managers in the glass industry can use to make their plants more efficient, self-reliant and profitable, creating less pollution.

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 IOF 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 http://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 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 nationwide network of capabilities for implementing ITP's technology delivery strategy. Regional Offices are located in Atlanta, Boston, Chicago, Denver, Philadelphia, and Seattle. 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/glass

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
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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

Glass Industry of the Future

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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