Glass is an integral part of the American economy and everyday life. It is essential for food and beverage packaging, for lighting homes and businesses, for communicating sounds and visual signals, and for commercial and residential construction. The four sectors of the glass industry – container, flat, specialty, and fiberglass – produce over 20 million tons of glass annually, which is used for myriad consumer products ranging from ordinary tableware to televisions to automotive glass.

The unique attributes of glass – transparency, chemical durability, optical properties, low cost, recyclability – and the abundance of the raw materials from which it is made account for the ubiquity of glass products in our society and ensure its continued success. But while opportunities are expanding, in many markets glass must increasingly compete with other materials such as plastics and aluminum that may offer lighter weight, higher strength, lower cost, or other competitive advantages.

The 1970s and 1980s brought significant restructuring to the glass industry in response to changes in the global business climate. During this period, sectors such as container and flat glass pared excess capacity to maximize productivity, while others, such as specialty glass, expanded to keep pace with increased demand for new products that were the result of pioneering research. Indeed, many glass products that now are considered commonplace, such as fiber optics, were only developed within the last two decades.

Today, the glass industry ships nearly $30 billion of products annually, and employs over 150,000 employees (Exhibit 2-1). The U.S. glass industry is now more streamlined, efficient, and closely aligned to its customers’ needs. It is also an industry increasingly dependent on new or improved products, and as the industry enters the 21st century international and intermaterial competition for many market segments continues to increase. Manufacturers are confronted with ever increasing environmental regulations and pollution control expenditures. And each sector faces its own challenges in addition to those of the collective industry.

### Exhibit 2-1. Glass Industry statistics

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>150,500</td>
</tr>
<tr>
<td>Shipments</td>
<td>$28.4 billion</td>
</tr>
<tr>
<td>Capital Expenditures</td>
<td>$2.0 billion</td>
</tr>
<tr>
<td>Average Hourly Wages</td>
<td>$15.79</td>
</tr>
<tr>
<td>Energy Use (estimated)</td>
<td>250 trillion Btu</td>
</tr>
<tr>
<td>Energy Expenditures</td>
<td>$1.4 billion</td>
</tr>
</tbody>
</table>

Sources: U.S. Department of Commerce
          U.S. Energy Information Administration
**Products and Markets**

**Container Glass**

The container glass sector is the industry’s largest producer, manufacturing roughly ten million tons of product per year. The sector uses a significant amount of energy to produce bottles, jars, and other containers that compete with alternative materials such as plastic, aluminum, steel, and paper.

Prior to 1970, many glass furnaces were fueled by oil, thus the oil crisis of the 1970s had a significant impact on the glass industry. Higher oil prices, combined with high capital costs necessary to convert plants to an alternative fuel -- natural gas -- resulted in the closure of 15 container glass plants between 1979 and 1983. Further economic pressures in the form of increased competition, environmental compliance, and labor costs contributed to the closing of an additional 33 plants from 1983 to 1992. Currently, there are about 55 plants operating in the United States producing around 36 billion glass containers per year.

As a result of past mergers and consolidation to maintain competitiveness, the make-up of the container glass sector has changed dramatically. Three manufacturers now account for about 95 percent of the domestic container glass market.

Although container glass sales have currently stabilized, the sector remains under intense pressure from other materials. Distribution also remains a limiting factor for container glass; the weight and volume of empty containers prohibits transportation over long distances thus limiting international trade. Often, plants are strategically located close to the facilities that process the products for which the containers will be used.

Competition for container glass comes primarily from alternative materials, particularly plastic and aluminum. Plastic and aluminum have made substantial inroads into the container market, especially for food and soft drinks, which once were stalwarts of the glass container industry. Beverage and food products account for the largest portion of U.S. glass container production.

In the future, the gains made by plastic in the past two decades may be offset somewhat by growing concerns about wastes and toxic emissions associated with plastics manufacturing and recycling. Glass manufacturing, on the whole, has fewer environmental hazards. In addition, recycling efforts within the container glass sector continue to increase. In 1998, 35% of all glass containers were recycled for the manufacture of new glass products.

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*Exhibit 2-2. Glass Container Products*

The majority of the industry’s container products are made of clear glass.
**Flat Glass**

The flat glass sector (also commonly referred to as the float glass sector, based on the name of the manufacturing process involved in making flat glass) produces about five million tons of glass per year, with residential and commercial construction and automotive industries comprising about 80 percent of the market. Other products from this sector include mirrors, instrumentation gauges, and architectural items such as table tops and cabinet doors.

There are currently six raw flat glass manufacturers in the United States operating around 30 plants. The industry has become increasingly global, with a rise in foreign ownership of U.S. facilities as well as increased U.S. participation in overseas plants.

Flat glass production is highly dependent on the fluctuating economic cycles of its primary market industries, as depicted in Exhibit 2-3. In addition, international trade has become an important component of the U.S. flat glass market. Exports accounted for about 23% of glass shipments in 1998 while imports accounted for about 12% of apparent consumption. Both import and export levels have risen over the past decade.

Few alternative materials currently exist for flat glass, securing its dominant position in its primary markets. However, because this sector is subject to the economic cycles of other industries its growth patterns are somewhat difficult to predict.

Flat glass manufacturers recycle 15 to 30 percent of their own cullet. Because of extremely high quality requirements, scrap glass from post-consumer sources such as building sites or household uses is currently incompatible with flat glass manufacturing.

The flat glass industry sector is facing several issues as it looks toward the future. Regulations affecting the construction and automotive industries will present additional challenges by imposing new energy efficiency and safety requirements on glass used in buildings and vehicles, as well the desire for improved product characteristics by customers. Consolidation in the global automotive industry will also affect this sector.

**Fiberglass**

Fiberglass is composed of two distinct subindustries: insulation, which is often referred to as glass wool, and textile fibers, which are continuous fiber strands used to reinforce plastics and other materials important to the transportation, marine, and construction industries. These two subindustries together manufacture about 3 million tons of product annually. Similar to flat glass, fiberglass production is greatly affected by the economic cycles of its primary markets: the construction, automotive, and marine industries. Currently, there are about ten major fiberglass producers in the United States operating around 40 plants.
Since the binders used to hold insulating fibers together can fail when greatly compressed, transporting fiberglass insulation is expensive and limits international trade. Fiberglass insulation is currently dominates the U.S. insulation market, however, alternative materials such as foam and cellulose are beginning to make market inroads. The development of new binders that allow more intense compression during packaging could reduce shipping costs and make exports more feasible.

Recycled glass plays a prominent role in fiberglass insulation production. The fiberglass sector is the largest secondary market for post-consumer and industrial waste glass, reusing around one billion pounds of post-consumer and waste glass annually. Although fiberglass insulation companies now utilize 10 to 40 percent recycled glass in their manufacturing process, research is needed to facilitate recycling of the fiberglass itself.

Textile, or composite, fiberglass faces little competition from alternative materials. This sector is expected to grow with the increased use of fiberglass-reinforced composites in automobiles and watercraft. Textile fiberglass is still an emerging market with strong domestic and international potential. Fiberglass-reinforced polymer composites are an alternative replacement material for many traditional wood and metal applications.

**Specialty Glass**

The specialty glass sector is very diverse, and consists of traditional products, such as lighting, cookware, and television screens along with newer products such as fiber optics, photonics, flat screen displays, and LCD panels. The sector produces roughly two million tons of glass products annually, and has traditionally relied on research to develop new products. New and highly successful products such as fiber optics and photonics now routinely outperform traditional specialty glass segments such as lighting and cookware. Specialty glass is evolving so rapidly that many of today’s most profitable products did not even exist a decade ago, particularly for glass used in electric and electronic applications.

Specialty glass is also unlike the other glass industry sectors in that it is comprised of many small, specialized manufacturers in addition to a few large, multinational corporations. This make-up is due to the diversity of the markets and the costs necessary to compete in high-tech markets. Finding capital to fund research into advanced technologies remains a concern; the best performing specialty glass products are also normally those with the highest capital investment costs. Another limitation is the diverse equipment required to produce different forms of specialty glass, such as the precision mirrors of the Hubble and Subaru space telescopes.

Specialty glass producers face varying degrees of competition. Although there are few alternative materials for such products as television tubes and LCD displays, the electronic glass segment faces strong challenges from foreign producers, particularly in Europe and Japan. The technological race among the United States, Europe, and Japan has become increasingly overt in this sector as key alliances between manufacturers and materials suppliers can determine the viability of key industrial segments. Lower environmental compliance, labor costs, and tax policies in the third world are
additional complications facing U.S. producers. Joint ventures between American and foreign-owned companies may partially compensate for this phenomenon, as well as help U.S. manufacturers enter some overseas markets. Although a low tonnage product in terms of production, the high-tech products have high market value and profit margins, in addition to their state-of-the-art appeal. This is particularly evident in the rapidly changing telecommunications industry where demand for data transmission is surging exponentially.

The traditional consumer specialty glass products such as kitchenware, tableware, and fine crystal are challenged by numerous alternative materials -- such as ceramics, stainless steel, and enamel -- and are impacted greatly by imports. The few remaining American manufacturers of these products are surviving in the global market, but the absence of long-term capital investment and research funding remains a concern.

Recycling is also an issue for this segment. By their very nature, certain specialty products do not justify recycling due to insufficient volume and glass being an inherently environmentally friendly material. However, waste reduction goals and mandates may make recycling justifiable when volume makes it practical. For example, the television glass industry is undertaking efforts to recycle glass from used television sets and computer monitors.

**TRENDS AND DRIVERS**

Given the challenges posed by international competition and alternative materials, the U.S. glass industry must be able to provide superior products with unique properties that make them more desirable than the products made from other materials and other countries. These new glass products and formulations will require the development of novel process technologies that reduce production costs and enhance desirable characteristics. Innovations in glass composition and glass properties will be needed to support the expansion of glass into completely new markets.

In general, glass company funds for researching improvement in mature glass processing technology such as the glass furnace are very limited, even as a significant portion of the industry is changing from an air atmosphere natural gas furnace to an oxygen atmosphere natural gas furnace which reduces emissions and energy use and increases productivity.

To help address these needs and challenges of the future, the glass industry vision identified four broad areas in which the industry must focus its technological efforts. Improvements in these areas will help address the critical energy, environmental, and economic concerns of all four sectors of the glass industry.

**PRODUCTION EFFICIENCY**

The industry will explore opportunities to improve the efficiency of glass production, including improved manufacturing processes and new techniques that maximize glass strength and quality. In particular, production efficiency gains are expected to result from improved melting and refining processes that will increase product yield while lowering energy and other production costs. A constant driver is the desire to increase the life of a furnace campaign, at the end of which the furnace is essentially rebuilt.
**Energy Efficiency**

Development of more energy-efficient manufacturing processes and technologies will help the industry achieve significant energy savings while strengthening the competitiveness of glass products. Since the majority of energy consumption in the glass industry occurs in the melting and refining process, it offers the largest opportunity for improvements. The availability and price of natural gas, oxygen, and electricity are also a constant concern.

**Environmental**

Efforts in the environmental area focus on challenges and opportunities to reduce emissions and waste in the glass industry through leaner and cleaner processing. Increased emphasis on wise use of natural resources and solid waste reductions will also help increase recycling within the industry as a whole. Emission regulations are expected to continually become more stringent, with increasing concern for greenhouse gas emissions, which will likely result in increasing pollution control costs for glass manufacturers.

**Innovative Uses of Glass**

To meet the challenges of the future, the U.S. glass industry must broaden the use of glass in existing markets and support research to create completely new and innovative uses for glass by investigating new glass compositions, developing a better understanding of glass properties and interactions, and modifying and improving essential glassmaking processes. The industry needs to be able to respond to rapidly changing market needs at volume. In many markets, customers demand for lighter, stronger glass products is increasing rapidly.