Industrial Sectors Market Characterization

Glass Industry

Prepared for Pacific Gas & Electric and Southern California Edison

Oakland, California, January 2012

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Acronyms and Abbreviations

AB32	Assembly Bill 32 the Global Warming Solutions Act
ACEEE	American Council for an Energy Efficiency Economy
AMO	Advanced Manufacturing Office
ARB	California Air Resources Board
Btu	British thermal unit
CAA	Clean Air Act
CWA	Clean Water Act
CO_2	carbon dioxide
CO_2e	carbon-dioxide equivalent
GHG	greenhouse gas
GWh	gigawatt-hour(s)
HMO	health-maintenance organization
ESA	Endangered Species Act
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
MBtu	million British thermal unit
NAICS	North American Industry Classification System
O&M	operations and maintenance
PG&E	Pacific Gas and Electric Company
R&D	research and development
RCRA	Resource Conservation and Recovery Act
SCE	Southern California Edison Company
TBtu	trillion British thermal unit
VSD	variable speed drive
U.S.	United States
USGS.	U.S. Geological Survey
U.S. EPA	U.S. Environmental Protection Agency
U.S. DOE	U.S. Department of Energy

Summary of Findings

Glass producers take raw inputs of high-quality sand (silica), limestone, soda ash, and/or cullet (crushed recycled glass), then blend, melt, refine, and form the product into glass. Glass manufacturing is classified using North American Industry Classification System (NAICS) code 3272, part of the non-metallic mineral product manufacturing. The glass industry is mainly divided into three sectors: flat glass manufacturing, container glass manufacturing and fiberglass manufacturing. Thirteen large glass-manufacturing plants operate in California: three flat glass manufacturing, five container glass manufacturing, four fiberglass manufacturing, and one specialty fiberglass facility.[1]

The glass industry has a concentrated market structure where a few key players control most of the market share. Energy is considered an integral component to the glass manufacturing process and typically ranks as the second or third highest operating cost. Based on primary research conducted with California glass customers, the results suggest that most customers employ low or no cost activities to decrease energy costs. Because the industry is concentrated, there are opportunities to reach out to the sophisticated customers by providing continual energy improvement programs. The utilities can create the largest impact in this sector by honing in on the major customers and creating customized energy efficiency programs.

Business Models and Cost Structure

The glass industry is dominated by set of large manufacturers active primarily in the flat-glass and glass-container sectors. Smaller specialty producers focus on niche products that require more complicated custom processes. The large flat-glass and glass-container manufacturers are multinational companies with steady to moderate competition. Due to high transportation cost of glass products, these companies operate locally or regionally and have long-term contracts. The operation practices in these sectors focus on keeping the production processes simple and uniform since the production volumes are usually large. Since the start-up cost in this industry is high, newcomers are at a disadvantage when competing for business with the already established players. The largest customers of flat glass and glass container manufacturers are the automotive, construction, and food and beverage industries. The glass manufacturers are subject to competition through the import market and face competition from

[1] California Air Resources Board. 2010. *2009 Glass Manufacturers Surveys, Summary of Selected Results*. October 2010.
http://www.arb.ca.gov/cc/glass/docs/glasssurveys.PDF

plastic and metal producers. Since these glass manufacturers usually serve clients that require products that meet government mandated safety requirements, price can be a differentiator; however, quality and reliability are also important. The specialty glass manufacturers occupy a narrow and very specialized segment of the market. Success in this sector depends on producing high quality custom products, as well as expertise and production capacity to meet customer's needs. While profit margins may be higher, production volume is much lower than the large manufacturers.

Technology and Energy Consumption

Technology can be a differentiator in the glass industry and could help drive down production costs. One of the areas of technological innovation may be in the transportation of glass products. Glass manufacturers bear heavy cost when transporting glass to clients. Innovation toward making durable and lighter glass drives down the transportation cost. More durable and lighter glass may also help glass manufacturers deal with the competition faced by plastic and metal manufacturers.

Manufacturers are looking to increase the amount of cullet used in their glass production. Using higher amounts of cullet lowers the melter temperature and energy usage during the glass melting process. This practice is also driven by a government mandated recycling law which requires manufactures to use certain amount of cullet in their glass production process.

The glass melting process which takes in the furnace is the most energy intensive process in the glass manufacturing process. Opportunities to use the waste heat from the furnaces as heat source reduce overall energy needs.

Market Barriers and Opportunities for Energy Efficiency

The glass industry has been hard hit due to the recession. The major clients of the flat glass and fiberglass manufacturers tend to be automotive and construction industries which have cyclical business models, and these industries have been going in a downward economic trend. The glass container industry, however, has managed to stay afloat through the economic downturns. The container manufacturers mostly serves the food and beverage industry, which has remained steady despite a down economy.

Glass manufacturers are risk averse when it comes to changing proven equipment or processes. From interviews and a customer forum, most respondents acknowledged that new *unproven* technologies face a strong barrier to adoption in this industry. This attitude does create barriers but it also provides opportunities for utility programs. The glass manufacturers are less willing to make major changes to key unit operations such as glass melters than to employ solutions that do not require intensive restructuring.

Overall Findings

The following findings regarding improving the adoption of energy efficiency measures in the glass industry are based on the primary and secondary research presented in this report.

- Energy costs, particular natural gas, are major component of glass manufacturing costs. Customers are receptive to energy efficiency although it is not their primary focus. The best time to implement energy efficiency is during the periodic furnace rebuilding, approximately every eight years. As utilities are aware of the customers long-term plans, they can encourage the addition of energy efficiency during scheduled production down time.
- Low-cost and no-cost improvements through operational, maintenance, behavior are considered preferable to expending scarce capital. Programs that identify and support these improvements can tap new opportunities.
- Regulatory requirements, particularly maintaining air emissions permits, must be considered when implementing any energy efficient project. Projects that minimize this risk are more acceptable, such as installing efficient burners that could be removed if regulatory needs were not met.
- Utility program awareness could be significantly improved. Most customers interviewed had little contact with utility representatives and limited knowledge of programs.
- Collaboration between the industry, technical experts and the utility on energy efficiency presents a key opportunity to expand practices. Customers expressed interest in continuing the conversation started by this study as an ongoing dialogue between utilities and this industry.

1. Introduction

The industrial sector consumes over 30 percent of the nation's energy,[2] presenting enormous opportunities for energy efficiency.[3] Many market forces beyond simple energy cost drive industrial customer decision making. Attaining a better understanding of the customer's world will assist Pacific Gas and Electric Company (PG&E) and Southern California Edison (SCE) in their design and implementation of industrial energy efficiency programs. Following upon a potential study developed in 2009 for PG&E, PG&E and SCE engaged energy-consulting firm KEMA, Inc. for the next phase to prepare market intelligence on seven key energy-intensive sub-segments.

The research objective is give PG&E and SCE staff study results to facilitate improved marketing of energy efficiency products and support face-to-face engagement of customers with those products. To address the objective of this study, the work was organized into key elements. These include:

- Perspectives about broad trends affecting California and the nation's industrial sectors (section 2)
- Detailed in-depth, industry-specific analysis of business and process drivers developed from secondary research (section 3)
- Energy usage, target technologies and process, and energy efficiency opportunities (section 4)
- Real-time perspectives and intelligence gained from key industry insiders through interviews and Webinar/Forum group discussions (section 5)
- Recommendations (section 6)
- Attachments with the interview and forum guides
- Utility-specific appendices containing proprietary data and customer information (Appendices).

In practice, these report elements are built stepwise—broad national trends inform industry-specific secondary research and industry-specific analysis informs the primary interviews and roundtable discussions. The outcome is a thorough research report intended to provide PG&E

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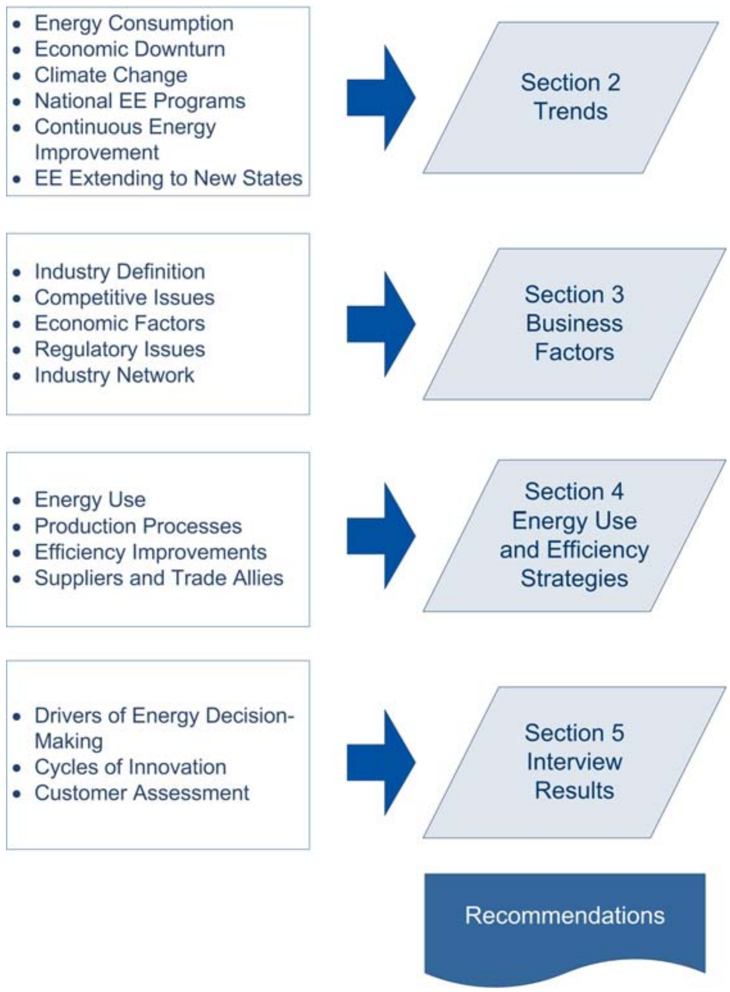
[2] Quinn, Jim. 2009. *Introduction to the Industrial Technologies Program*. Save Energy Now Series Webinar. January 15.
http://www1.eere.energy.gov/industry/pdfs/webcast_2009-0115_introtoitp.PDF

[3] U.S. Census Bureau, 2008.
http://www.census.gov/compendia/statab/2010/tables/10s0892.xls

and SCE staff members the breadth necessary to position their industrial energy efficiency products optimally and the depth necessary to knowledgeably engage their customers.

Figure 1: Graphic Overview of the Report



2. Trends in Industrial Energy Efficiency

The industrial sector consumes an immense amount of energy, nearly 32 percent of total U.S. consumption in 2008,[4] to produce goods and materials for wholesale and retail sales. In the past three decades, the overall energy efficiency of the industrial sector in the U.S. has increased dramatically. Energy efficiency potential savings have been estimated at 20 percent or more by 2020 nationally.[5] It has thus been an attractive target sector for utilities and government looking to reach new levels of energy savings through efficiency.

Changing energy markets and climate change policies are driving greater interest in energy efficiency technologies. Key trends discussed are energy consumption patterns; effect of the economic downturn on manufacturing; climate change and energy legislation; the rise of continuous energy improvement; energy efficiency adoption outside California and national energy efficiency programs; opportunities for combined heat and power. These trends are discussed in more detail below.

2.1 Energy Consumption Trends

California ranked first in the nation in gross domestic product, at $1891.4 billion in 2009. Table 1 shows the industrial energy consumption. California ranks only third in the nation for energy use, reflecting higher efficiency levels in the industrial sector.[6]

Figure 2 shows U.S. trends in industrial energy intensity over time. This figure shows that there has been a general trend since 1993 toward stable or slightly decreasing energy use, even while the economy prospered. More significantly, the energy intensity, or energy per unit of production, has been steadily increasing. Thus, the industrial sector has shown consistent improvement in reducing the amount of energy required to produce manufactured goods.

[4] U.S. Census Bureau, 2008. *Energy Consumption, by End-Use Sector*. http://www.census.gov/compendia/statab/2010/tables/10s0892.xls

[5] McKinsey & Co. 2009. *Unlocking Energy Efficiency in the U.S. Economy.* July. http://www.mckinsey.com/clientservice/electricpowernaturalgas/downloads/_energy_efficiency_exc_summary.PDF

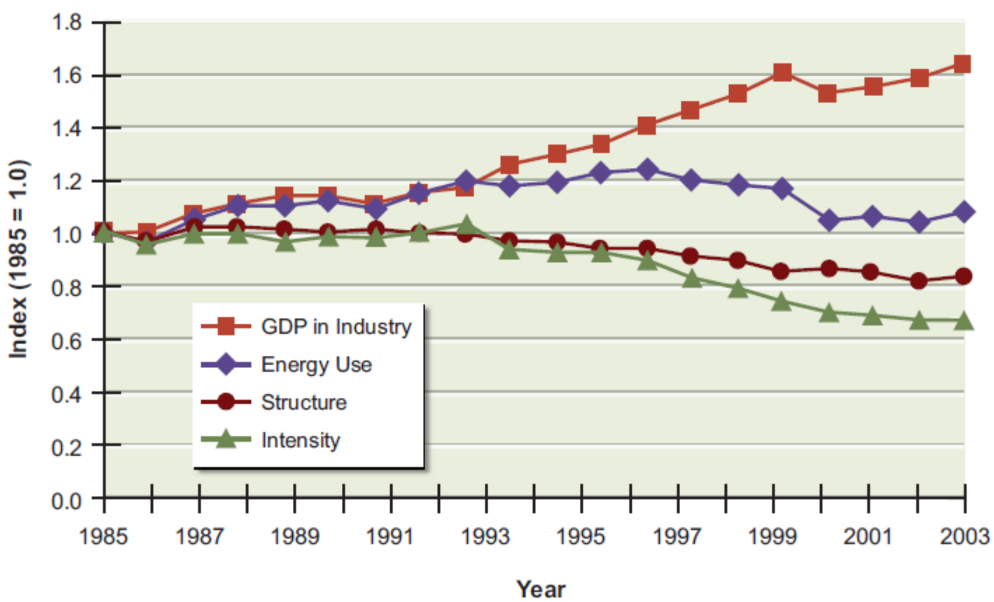
[6] U.S. Department of Energy, Energy Efficiency and Renewable Energy, State and Regional Partnerships. 2011. http://www1.eere.energy.gov/industry/states/state_activities/map_new.asp?stid=CA

Table 1: Industrial Energy Consumption, California

Year	California Industrial Energy Consumption (Trillion Btu)
2009	1,770
2008	1,955
2007	1,958
2006	1,979
2005	2,001
2004	2,053
2003	1,986
2002	1,999
2001	2,137
2000	2,132

Source: Energy Information Administration[7]

Figure 2: U.S. Trends in Industrial Energy Intensity Delivered Energy, 1985-2004



Source: National Academy of Sciences[8]

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[7] U.S.DOE. 2011. *State Energy Consumption Estimates 1960 through 2009*. DOE/EIA-0214(2009). June 2011. http://205.254.135.7/state/seds/sep_use/notes/use_print2009.PDF

2.2 Economic Downturn Effect on Industrial Production

Most U.S. industries experienced a sharp drop in production as demand for manufactured goods declined, starting in the last quarter of 2008. The glass industry experienced a reduction in demand for their products during the downturn. Domestic glassmaking began declining in the 1990s, and overall industry employment has declined 30 percent over the last nine years.[9]

A method of observing the economic downturn's effect in California is to consider trends in carbon emissions. Although multiple factors affect emissions, including energy efficiency and carbon reduction, dramatic short term changes do indicate likely reductions in production. According to analysis by research firm Thomson Reuters Point Carbon, an overall reduction of carbon emissions of 11 percent from 2008 to 2010 was observed among the 343 California facilities that must comply with California's cap-and-trade program. Table 2 displays the CO_2 emission changes by industrial sector. Facility closures was the major driver for cement, glass, pulp and paper industries' decline while chemicals sector emissions increased largely from a new hydrogen plant in SCE's territory.

Table 2: Percent Change in CO_2 Emissions among Largest Calif. Industrial Sectors, 2008-2010

CO2 Emissions 2008 vs. 2010	California Industrial Sector	Notes
+21%	Chemicals	Driven by new $80MM hydrogen facility in SCE territory
+5%	Metals	Increase in production
-34%	Cement, lime and glass	Driven by facility closures
-35%	Pulp, paper and wood	Driven by facility closures

Source: Thomson Reuters Point Carbon[10]

The economic recession is forcing businesses and governments to take a close look at initiatives that save money and do not require capital investments, such as the best practices

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[8] National Academy of Sciences. 2010. *Real Prospects for Energy Efficiency in the United States*. National Academies Press.

[9] Uchitelle, Louis. 2010. "Glassmaking Thrives Offshore, but is Declining in U.S." New York Times, January 18 http://www.nytimes.com/2010/01/19/business/19glass.html

[10] Thomson Reuters Point Carbon. 2011. *California Emissions in 2010 Down by 11%.* August http://www.pointcarbon.com/aboutus/pressroom/1.1564622

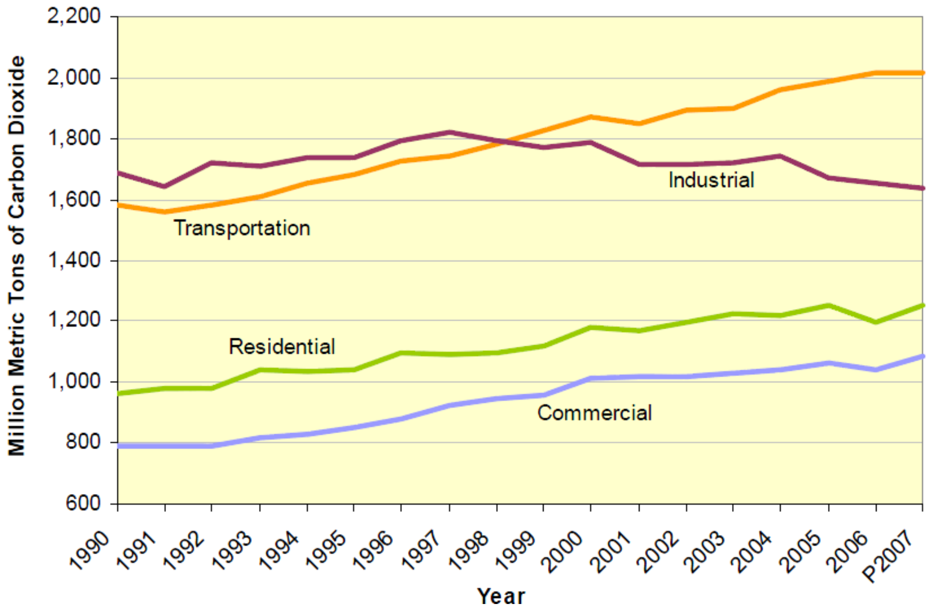
developed by the United States (U.S.) Department of Energy's (DOE) Advanced Manufacturing Office and through increased energy management systems, as discussed in the following sections.

2.3 Climate Change and Energy Legislation

Industry's energy-related carbon-dioxide emissions have decreased in the last decade, while rising more dramatically in other sectors, as shown in Figure 3. This reduction is largely attributable to U.S. industry's net decrease in energy consumption, according to the American Council for an Energy Efficient Economy[11] that resulted from a decrease in manufacturing activity as well as energy efficiency gains. Still, industry accounts for approximately 27.4 percent of total energy-related carbon dioxide emissions in the United States. Greater energy efficiency will almost certainly be an important component in comprehensive national—and global—strategies for managing energy resources and climate change in the future. Energy efficiency is generally acknowledged to be the lowest-cost and fastest-to-deploy resource to slow the growth of carbon dioxide emissions, and it also results in positive economic impacts. Congress is not expected to approve any policy mechanisms to reduce CO_2 emissions in the short-term although legislation encouraging greater energy efficiency in the U.S. manufacturing sector is possible.

[11]Chittum, A., R. Elliott, and N. Kaufman. 2009. *Trends in Industrial Energy Efficiency Programs: Today's Leaders and Directions for the Future*. American Council for an Energy Efficient Economy, Report IE091. September 2009.

Figure 3: U.S: Energy-Related CO_2 Emissions by End-Use Sector, 1990-2007



Source: ACEEE[12]

2.4 National Programs

Typical utility programs address only a subset of the energy efficiency improvement opportunities, focusing primarily on retrofits and capital improvements. Less attention is given to behavior or maintenance. Federal, regional, and state government agencies, utilities, and others have developed a range of programs to improve industrial energy efficiency.These include providing incentives, audits and technical assistance, and continuous improvement programs.

Many of PG&E and SCE's customers participate in these programs which can yield insights and best practices to inform utility programs, such as energy assessments offered by the U.S. DOE's Advanced Manufacturing Office (AMO), formerly the Industrial Technologies Program. In California, 49 assessments were completed for small and medium facilities in 2009 through 2011 and 38 assessments for large facilities between 2006 and 2011.[13] For example, facilities of Owens-Illinois in Los Angeles and Saint Gobain in Madera participated in large plant energy

[12] Chittum, A., R. Elliott, and N. Kaufman. 2009. *Trends in Industrial Energy Efficiency Programs: Today's Leaders and Directions for the Future*. American Council for an Energy Efficient Economy, Report IE091. September 2009.

[13] U.S. Department of Energy, Energy Efficiency and Renewable Energy, State and Regional Partnerships. 2011. http://www1.eere.energy.gov/industry/states/state_activities/map_new.asp?stid=CA

savings assessments. DOE lists as research and development successes a case study completed for Gallo Glass of monitoring and control of batch carryover and alkali volatilization.[14]

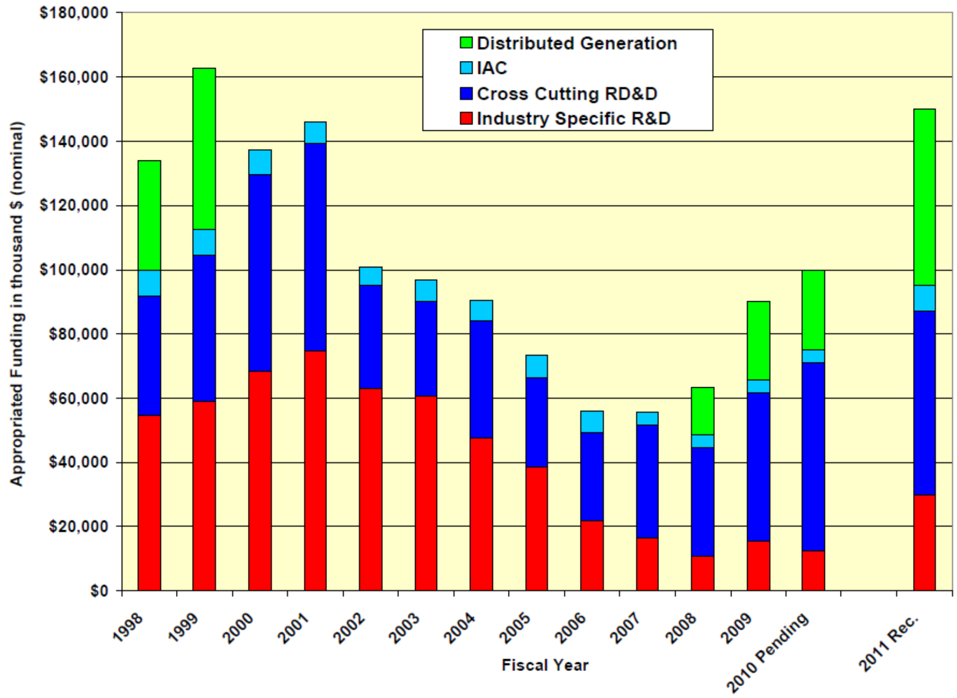
The U.S. DOE's AMO has been the primary federal entity supporting manufacturing R&D in partnership with industrial stakeholders. The AMO R&D program has been recognized as one of the most successful federal R&D efforts operating today. However, in recent years support for the program's R&D funding has faltered, particularly for the industry-specific R&D funding. This has been the most effectual initiative, considering its track record of commercializing products useful to industry. A U.S. DOE peer review report called the manufacturing R&D pipeline "largely empty."[15] This is challenging for the transformation of manufacturing because even though AMO's industry-specific R&D reaches commercialization faster than most other federal R&D, it can still take seven to ten years for results from R&D to reach a plant floor.

In addition to R&D activities (both the industry specific mentioned above and cross cutting), AMO has two technology and best practices programs: Better Plants (formerly Save Energy Now) and the Industrial Assessment Centers.

[14] U.S. DOE, Energy Efficiency and Renewable Energy, Industrial Technologies Program. 2003. "Neville Chemical Company: Management Pursues Five Projects Following Plant-Wide Energy-Efficiency Assessment." *Chemicals: Best Practices Plant-Wide Assessment Case Study.* DOE/GO-102003-1666. July 2003. http://www1.eere.energy.gov/industry/bestpractices/pdfs/ch_cs_neville_chemical_company.PDF

[15] ACEEE 2009. Barriers to energy efficiency investments and energy management in the U.S. industrial sector. http://www.aceee.org/files/pdf/fact-sheet/ACEEE-Barriers_to_industrial_EE_10-20-09.pdf

Figure 4: Industrial Technologies Program Funding, 1998-2010



Source: ACEEE[16]

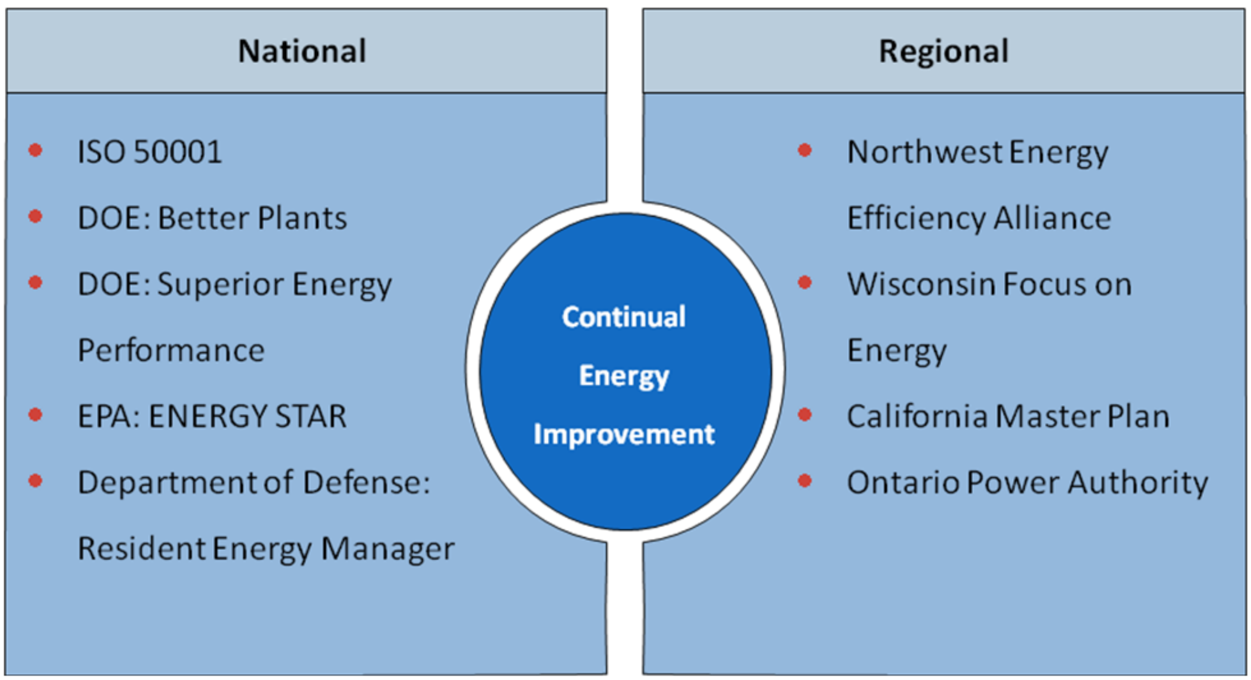
Better Plants works with large industrial energy consumers to help reduce their energy intensity using audits, software tools, and best practices. The other program, Industrial Assessment Center (IAC), serves a similar function for small and mid-sized industrial facilities, and also trains the next generation of industrial energy engineers. Twenty-six centers at U.S. engineering universities train students to identify energy savings opportunities and perform no-cost assessments for small and medium industrial customers. In California, San Francisco State University and San Diego State University run IAC programs. The IAC program has a public database of recommendations dating back to 1981, a resource for customers on industrial energy efficiency improvements.

[16] American Council for an Energy Efficient Economy. 2009. *Barriers to energy efficiency investments and energy management in the U.S. industrial sector*. October 20, 2009.

2.5 Rise of Continual Energy Improvement

Utilities, and private organizations, and governments around the world have developed programs in the last few years that focus on setting goals and targets to achieve continual energy improvement (CEI) in industry. National programs in the United States have been developed by the DOE (Better Plants and Superior Energy Performance) and EPA (ENERGY STAR). Figure 5 displays some examples of national and regional continual energy programs. From a business perspective, interest in energy management is increasing, as shown by the increasing number of participants in these programs.

Figure 5: Examples of National and Regional Continual Energy Improvement Programs



This year, two important developments are expected to heighten interest and activity around energy management: the release of ISO 50001, a global energy management standard, and the launch of Superior Energy Performance, a national program to support energy intensity reductions for industrial plants and commercial buildings.[17]

[17] McKane, Aimee, Lawrence Berkeley Laboratory, 2011. Presentation at the ACEEE Market Transformation Conference, Piloting Energy Management Standards for the U.S and the Globe.http://www.aceee.org/conferences/2011/mt/program

The recent work on U.S. and international energy management standards can have a significant impact on how energy is used in the industrial sector. The International Standards Organization (ISO) released an international energy management standard, ISO-50001 in June 2011.

The U.S. DOE is in the process of launching the Superior Energy Performance (SEP) program to promote industrial energy management and increased energy efficiency. This voluntary program will focus on fostering an organizational culture of energy efficiency improvement in U.S. manufacturing facilities, targeting mid to larger sized plants.

Participants establish an energy management system that complies with ISO 50001 and meets other SEP program requirements, including robust measurement and verification of energy savings. Pilot programs have been launched in Texas and the Pacific Northwest, and the full SEP program is expected to begin in 2013. A California pilot is also planned within the next two years. The American National Standards Institute (ANSI) is developing companion standards to support SEP. ANSI MSE 50021 will provide the additional energy performance and management system requirements for SEP certification that goes beyond basic conformance with ISO 5000; and ANSI 50028 will provide the requirements for verification bodies for use in accreditation or other forms of recognition.[18]

Regional CEI programs have been developed under the Northwest Energy Efficiency Alliance,[19] working with the Bonneville Power Administration and the Energy Trust of Oregon. California has identified CEI as an important aspect of its strategic plan.[20] Similarly, Wisconsin's Focus on Energy employs an internally developed tool called Practical Energy Management©.[21] CEI is still in its infancy, with few CEI programs beyond the pilot stage.

2.6 Additional States Adopt Industrial Energy Efficiency

California has long been perceived as a leader in energy efficiency programs. Historically, energy efficiency trends and best practices tended to spread from California to other states

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[18] U. S. Council for Energy-Efficient Manufacturing. 2010. Superior Energy Performance*.*
http://www.superiorenergyperformance.net/pdfs/SEP_Cert_Framework.PDF

[19] Northwest Energy Efficiency Alliance. Continuous Improvement for Industry website.
http://www.energyimprovement.org/index.html

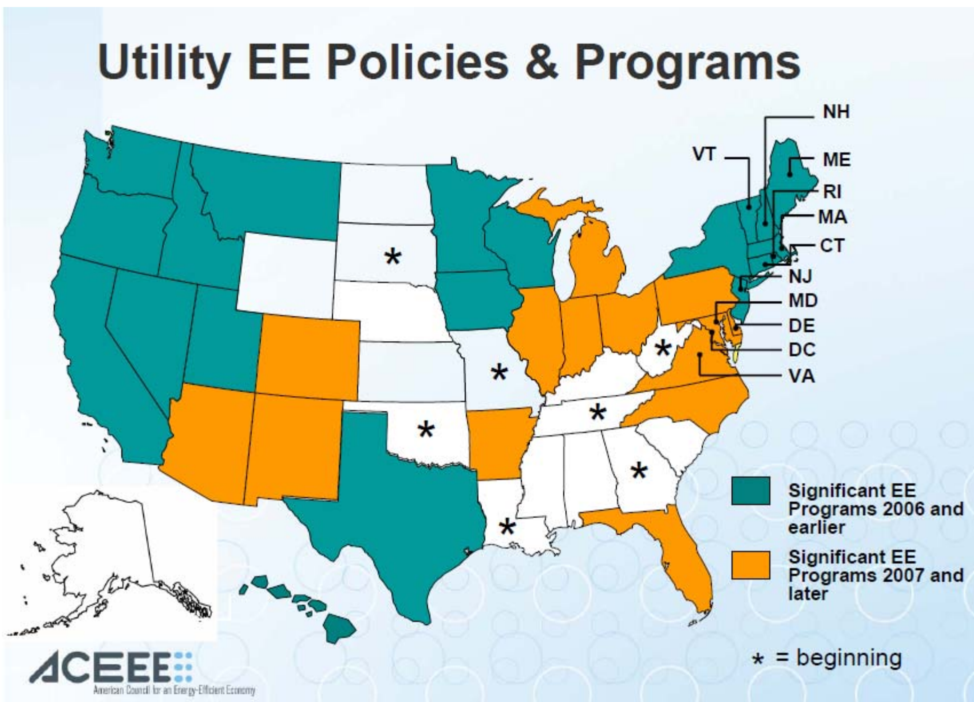
[20] California Public Utilities Commission. 2011. *CA Energy Efficiency Strategic Plan, January 2011 Update*.
http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.PDF

[21] Wisconsin Focus on Energy, Industrial Program. Practical Energy Management tool.
http://www.wifocusonenergy.com/page.jsp?pageId=368

involved in industrial energy efficiency. More recently, a sizable contingent of states have made significant commitments to energy efficiency programming as shown in Figure 6. The flow of information is changing as energy efficiency programs spread to locations in the Midwest and South that typically had provided modest or little ratepayer funding for energy efficiency. Program development efforts in many of the aforementioned states are in their early stages compared to California.

These states have signaled their commitment to energy efficiency by adopting aggressive Energy Efficiency Portfolio Standards[22] (EEPS) policies[23] that exceed those in California. As shown in Figure 6, California ranks number 14 for cumulative electricity savings targets by 2020, below states primarily in the Northeast and Midwest.

Figure 6: Utility Energy Efficiency Policies and Programs, 2006 vs. 2007+



Source: ACEEE[24]

[22] Covers all sectors including residential, commercial and industrial efficiency.

[23] These include: Illinois, Maryland, Michigan, New Mexico, Ohio, Pennsylvania, and Virginia (provisionally).

[24], Nadel, Steven. 2011. *Program Introduction*. (Presentation, ACEEE 2011 National Symposium on Market Transformation, Washington DC, April 10–12, 2011).
http://www.aceee.org/files/pdf/conferences/mt/2011/Introduction%20-%20Steve%20Nadel.PDF

The electric EEPS targets in most of these states rise from 1 to 2 percent of retail sales per year within the first 5–10 years of the standard, rivaling the annual savings levels currently being achieved in only a handful of leading states. For example, North Carolina has until recently been relatively inactive in energy efficiency, but has enacted a renewable portfolio standard (RPS). Under this RPS, energy efficiency can meet up to 40 percent of the total requirements of the state's investor-owned utilities (IOUs) and an unlimited amount of the publicly owned utilities' requirements.

The rise of energy efficiency policies and programs indicates that California utilities can increasingly draw on program experience in other states to inform their own experiences.

Table 3: 2020 Cumulative Electricity Savings Targets, by State[25]

State	2020 EE Target	State	2020 EE Target
Vermont	30%	Indiana	14%
New York	26%	Rhode Island	14%
Massachusetts	26%	Hawaii	14%
Maryland	25%	**California**	**13%**
Delaware	25%	Ohio	12%
Illinois	18%	Colorado	12%
Connecticut	18%	Utah	11%
Minnesota	17%	Michigan	11%
Iowa	16%	Pennsylvania	10%
Arizona	15%	Washington	10%

Source: ACEEE[26]

Fuel Switching and Cogeneration/Combined Heat and Power (CHP). Combined heat and power, or cogeneration, is a significant and growing share of U.S. generation (see Figure 7). CHP is the concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy. This technology is first and foremost an energy efficiency resource that allows users to produce needed electricity, heat, and mechanical energy while using as little fuel as possible.

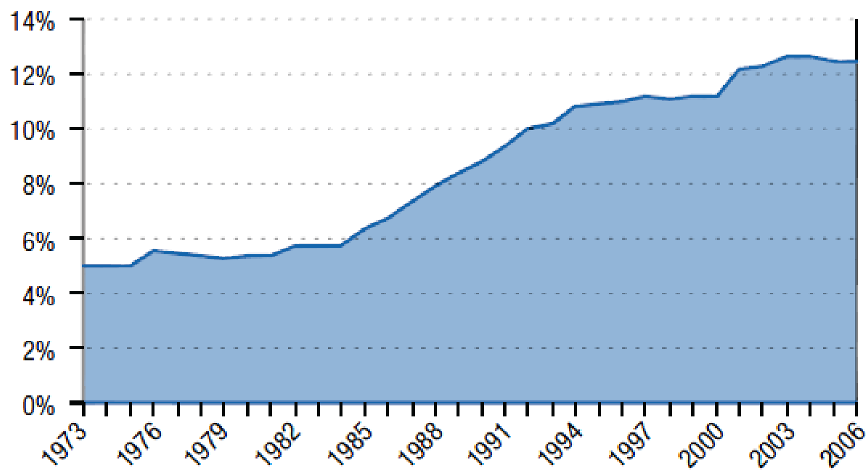
[25] Includes extensions to 2020 at savings rates that have been established.

[26] Nadel, Steven. 2011. *Program Introduction*. (Presentation, ACEEE 2011 National Symposium on Market Transformation, Washington DC, April 10–12, 2011). http://www.aceee.org/files/pdf/conferences/mt/2011/Introduction%20-%20Steve%20Nadel.PDF

Natural gas continues to be the preferred fuel for CHP systems, representing 50–80 percent of annual CHP capacity additions since 1990. This is primarily because natural gas is readily available at most industrial sites, is clean burning, and has historically been relatively plentiful and affordable. Since 2001, natural gas prices have been consistently volatile and relatively high. While natural gas remains an important CHP fuel, installers and technology developers are increasingly looking to "opportunity fuels" for CHP systems. Opportunity fuels are nontraditional fuels that are frequently considered waste or by-products and provide lower fuel costs.

CHP is particularly applicable to the glass industry because of its large process heat needs.[27] Nationwide, California ranked second in largest total available CHP capacity in 2006, at 9,220 MW compared to Texas at 17,240 MW. The capacity reflects large industrial demands, stringent air quality requirements, and effective policies that encourage adoption of CHP.

Figure 7: CHP as a Percentage of U.S. Annual Electricity Generation



Source: U.S. DOE[28]

[27] U.S. DOE, Energy Efficiency and Renewable Energy, Industrial Technologies Program. 2002. *Combined Heat & Power: Cost Reduction Strategies*. Factsheet, January 2002. http://www1.eere.energy.gov/industry/glass/pdfs/chp.PDF

[28] U.S. DOE. 2008. *Combined Heat and Power: Effective Solutions for a Sustainable Future*. Prepared by Oak Ridge National Laboratory, ORNL/TM-2008/224, December 2008.

3. Industry Characterization

3.1 Industry Definition

Glass is a commodity used in a wide range of products because it is relatively inexpensive and has properties—optical, chemical, and strength—that make it appealing to various applications. According to the U.S. Census 2006 Annual Survey of Manufacturers, glass manufacturing is a US$29B domestic industry classified using NAICS code 3272, part of the non-metallic mineral product manufacturing. Within glass manufacturing, the industry is further divided into flat glass for windows, automobile windshields and picture glass (327211); pressed and blown glass for specialty products like LCD screens or light bulbs (327212); container glass for bottles and jars (327213); products from purchased glass where glass is an intermediate like aquariums, mirrors, and lab apparatus (327215); and fiberglass manufacturing (327993). Manufacturers in all of these categories can be found within California, but only a few manufacture fiberglass. Some large vertically integrated firms in other industries (e.g., beer makers like Coors Brewing) may operate glass-manufacturing operations as well but are not covered here.

Table 4: Glass Manufacturing in NAICS Code 327 – Non-Metallic Mineral Manufacturing

327211	Flat Glass Manufacturing
327212	Other Pressed and Blown Glassware Manufacturing
327213	Glass Container Manufacturing
327215	Glass Product Manufacturing Made of Purchased Glass
327993	Mineral Wool Manufacturing

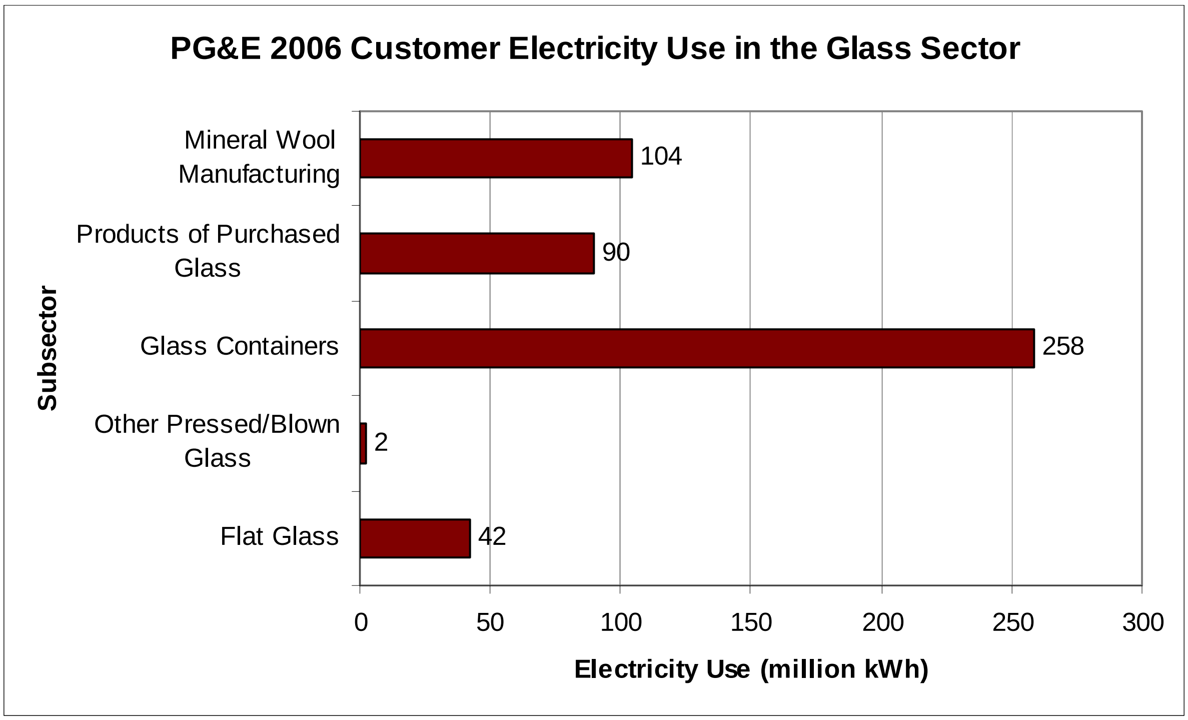
Glass producers take raw inputs of high-quality sand (silica), limestone, soda ash, and/or cullet (crushed recycled glass), then blend, melt, refine, and form the product into glass. Manufacturers of products made from purchased glass further take the manufactured glass output and put it into products with higher added value like windows, lighting, LCD screens, or specialty equipment. Flat glass and glass container manufacturers distribute their products directly to their major customers in the construction, automotive, and food and beverage industries. Specialty glassmakers also typically target small market segments and distribute directly. Manufacturers of products made from glass distribute in various ways, either directly or via a wholesale/retail chain.

Figure 8 shows the sub-sector breakdown of electricity use from within PG&E territory and

Figure 9 shows the breakdown of gas usage from within PG&E territory.

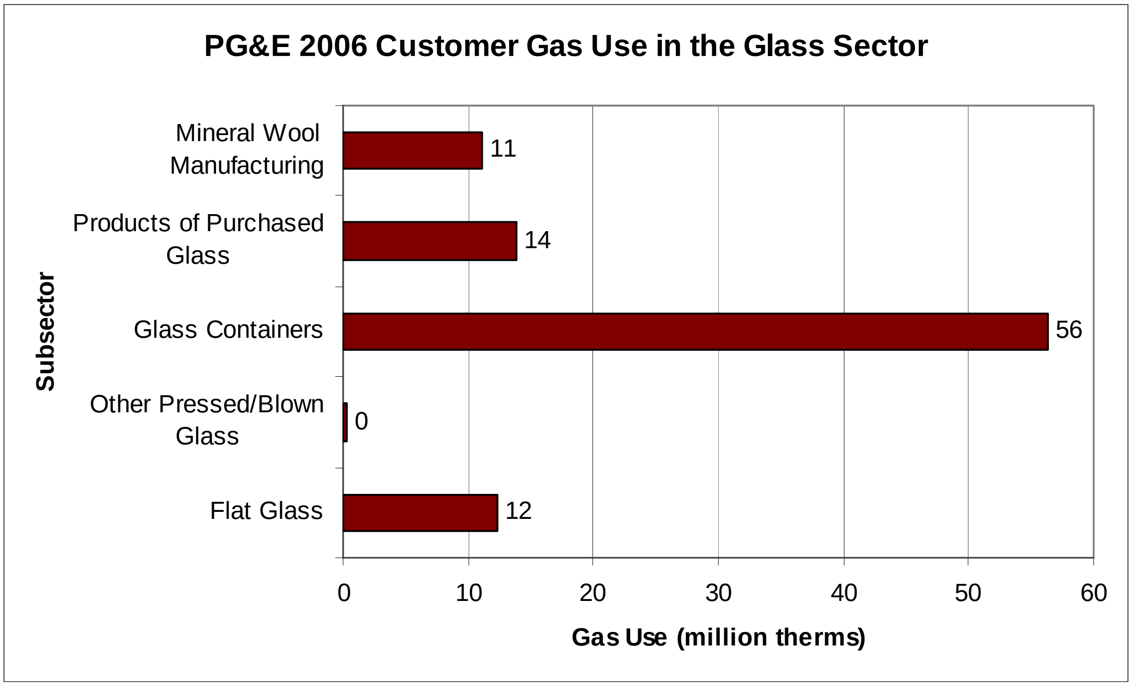
Figure 10 shows the subsector breakdown for electricity in SCE territory. Container glass manufacturers are major customers in PG&E territory, but not in SCE territory. Notable electricity sales also come from fiberglass, flat glass, and products made from processed glass, a very heterogeneous subsector. On the gas side, fiberglass, flat glass, and products from processed glass contribute in roughly equal amounts beyond container glass. However, sales are dominated by a small number of facilities.

Figure 8: Glass Subsector Electricity Purchases from PG&E



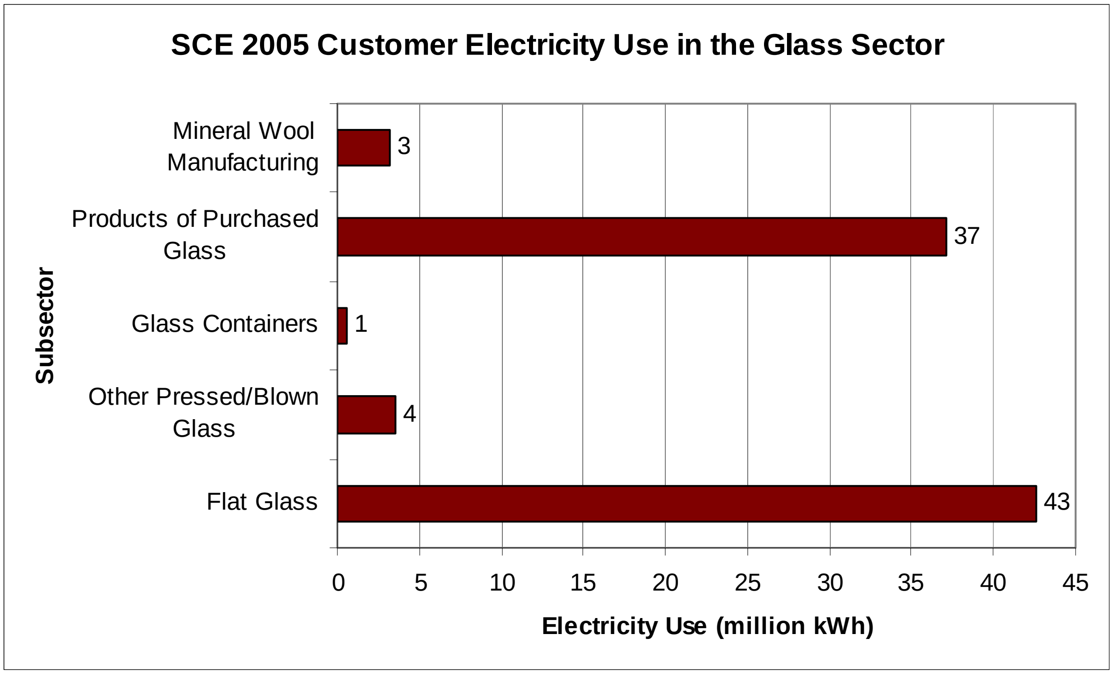
Source: KEMA, Inc. using PG&E data

Figure 9: Glass Subsector Gas Purchases from PG&E



Source: KEMA, Inc. using PG&E data

Figure 10: Glass Subsector Electricity Purchases from SCE in 2008



Source: KEMA, Inc. using SCE data

California mirrors the global trends—subsidiaries of the largest corporations dominate and the region has production from all subsectors. Because the fundamental processes of glass production are quite similar across the subsectors, they will be discussed together, with differences noted as needed.

3.2 Industry Leaders

Glass manufacturing has a moderate degree of concentration. According to the most recent U.S. Census Bureau statistics,[29] the domestic glass industry consists of 2,270 companies with paid employees and an additional 5,513 sole proprietorships without formal payroll. The five largest players, which account for over 40 percent of annual revenue for the industry, include Compagnie de Saint-Gobain, Owens-Illinois, Guardian Industries, Asahi Glass, and PPG industries. Aside from a few other reasonably large players, the industry is fragmented with

[29]U.S. Census Bureau, Industry Statistics Sampler, NAICS 327211: Flat glass manufacturing. http://www.census.gov/econ/census02/data/industry02/E327211.HTM

many smaller companies occupying specialty markets. Over 58 percent of U.S. glass manufacturing companies have fewer than ten employees. Sole proprietorships account for 0.5 percent of industry revenue.

The list of global leaders mirrors the list of U.S. leaders, echoing an ongoing trend towards consolidation and globalization which began in the early 1980s and has intensified over time. Compagnie de Saint Gobain in particular has grown through a continuous stream of acquisitions beginning in the mid-1990s. Foreign companies, especially those from Europe and Japan, have made inroads to the United States market through acquiring U.S. firms.

Glass suppliers typically have longstanding relationships with their customers and the manufacturing process is relatively capital intensive; therefore, it is difficult for new firms to achieve growth organically, especially since overall market demand is declining. However, recent innovations have substantially lowered the costs associated with transporting glass, which has traditionally been relatively expensive because glass is fragile. Such innovations include improved designs for specialty trucks transporting container and flat glass, improved dollies, extra lightweight packing boxes, and vacuum loading devices. Innovation is lowering entry barriers and allowing the market to expand. New specialty niche markets are now opening in the biomedical, communications, laser manufacturing, aerospace, semiconductor, fiber optics and electronics industries with regularity. However, while opportunities exist to enter the field, the large vertically-integrated market leaders are well-established and maintain long term contracts with their customers to exercise control over most of the market. The biggest players enjoy the structural advantage of being able to reliably supply demand for a wide variety of industries.

California joins New York, Pennsylvania, Ohio, and Texas as a leading geographic center of glass production in the United States. According to the California Air Resources Board, in California in 2009, there were five container glass manufacturing plants, four fiberglass manufacturing plants, three flat glass manufacturing plants, and one large specialty glass plant.[30] The top glass customers in California are corporate subsidiaries of the global leaders: Owens Illinois, Saint-Gobain Container, Guardian Industries, PPG Corporation., GKN plc, Cardinal Glass, and CRH plc. The source of the following information is the company websites of these organizations.

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[30]California Air Resources Board. 2010. *2009 Glass Manufacturers Surveys: Summary of Selected Results*. October 2010.
http://www.arb.ca.gov/cc/glass/docs/glasssurveys.PDF

- Compagnie de Saint Gobain is a French corporation with 12.5 percent of the overall U.S. glass market, which has grown steadily over the last 15 years by acquisition and now has more than 1,000 subsidiaries in 50 countries worldwide. It offers flat glass, construction products, and specialty glass, in addition to high performance abrasives. Saint-Gobain Containers is a Muncie, Indiana based U.S. subsidiary making containers for the food and beverage industry with $1.44B in sales from 2005-2007, over 4000 employees, and 14 manufacturing plants. The company previously had a division, Saint-Gobain Calmar, with facilities in City of Industry, but the unit was sold in 2006.

- Guardian Industries based in Michigan, $2.0B in U.S. sales (8 percent of the total U.S. market) and operates in 20 countries. With a focus on float glass, fabricated glass products, architectural glass products, fiberglass products, Guardian gets key demand from the automotive segment—windshields, flat glass, and fiberglass moldings. Guardian has grown 33 percent in the last eight years and recently expanded facilities in Iowa and California.

- Owens-Illinois Inc. (O-I) is the world's largest manufacturer of glass containers, primarily focusing on beverage containers, a market dominated by beer bottles. O-I has reduced its manufacturing capacity, closing four of its manufacturing plants worldwide, and bringing the number of U.S. facilities down to 20. Owens-Illinois has $7.8B in worldwide sales, 28 percent of which is in the United States, accounting for 10 percent of the total U.S. market. Although it operates facilities in Northern California, these do not fall into SCE's service territory.

- GKN plc is a global engineered products business serving the automotive, off-highway and aerospace markets. Subsidiary GKN Aerospace concentrates on the production of airframe and engine structures, components and assemblies for both military and civil aerospace markets. In 2003, GKN Aerospace created a new Transparency Systems operation by acquiring Pilkington Aerospace with its existing transparency activities. Employing 42,000 people worldwide, GKN plc had revenue of $7.75 billion in 2007 and profit of $445 million. GKN Aerospace employs 7,500 and GKN Aerospace Transparency Systems employs 1,150. A worldwide leader in military aircraft glass, GKN Aerospace Transparency Systems sells cockpit windshields, side windows and passenger windows commercial aircraft. The company has a manufacturing facility in Garden Grove, California.

- Cardinal Glass manufactures residential glass for windows and doors, and caters to domestic and international markets through five subsidiaries. Specialty glass products include self-cleaning coated panels and panels designed to cut solar heat gain. Employing over 5,500 people, Cardinal Glass operates 27 manufacturing facilities and two R&D centers around the United States. A facility in Moreno Valley, California produces coated glass. Cardinal Glass was founded in 1962 and is headquartered in Eden Prairie, Minnesota, a suburb of Minneapolis.

- PPG Industries accounts for 5 percent of the total U.S. market, despite a recent turn away from glass manufacturing. Glass accounted for only 6 percent of revenue in 2008, down from 20 percent prior to 2007. As U.S. auto sales began to fall, PPG reduced exposure and diversified operations. Despite the strategic move toward paints and coatings which has fueled growth to $15.8B in worldwide revenue, PPG maintains eight U.S. facilities producing flat glass and fiberglass among its worldwide portfolio of 150 manufacturing facilities spread across 60 countries. PPG is headquartered in Pittsburgh, Pennsylvania.

- Oldcastle Glass is a subsidiary of Old Castle Inc., the North American arm of Ireland-based CRH plc. CRH is one of the world's largest building product manufacturers with 93,000 employees in 32 countries. With over $5 billion in revenue, Old Castle Inc. has subsidiaries making architectural and construction building products for U.S. and Canadian customers. Oldcastle Glass sells architectural glass products and has two manufacturing facilities in Los Angeles.

- PRL Glass Systems, Inc. is a fast-growing privately held producer of architectural glass/metal products founded in 1989. PRL has facilities totaling 70,000 sq ft in City of Industry, California and employs over 200 people. Focused on California, Arizona, and Nevada, PRL serves the commercial and residential construction industry as well as the furniture and interior design markets.

- In 2003, Trident Consolidated Industries, which operates a manufacturing plant in City of Industry, California, was acquired by South Florida-based Arch Aluminum and Glass, which is privately held. Arch Aluminum & Glass Co. is among North America's largest architectural glass and aluminum fabricators and distributors with 1,800 employees and 28 facilities in 17 states. Arch had $250 million in revenue in 2008 and expected less than $200 million in revenue in 2009. On November 25, 2009 Arch Aluminum and Glass filed for chapter 11 bankruptcy protection. The company agreed to sell of its assets to Grey Mountain Partners, LLC, a Boulder, Colorado-based private equity firm. Since 2005, the firm has changed hands three times. Hedge fund Cravey Green took ownership from Long Point Capital in 2005 and South Equity was a successor to Cravey Green.

- Owens-Corning is a major manufacturer of fiberglass, as well as other building materials such as asphalt roofing and composite construction materials. Emerging from Chapter 11 bankruptcy in 2006, the company refocused on building materials, including fiberglass insulation. Owens-Corning had revenues around $6 billion in 2008 and operations in 30 countries worldwide. The company is based in Toledo, Ohio and has two manufacturing facilities in PG&E's territory: a large insulation plant in Santa Clara, California and a smaller roofing materials plant in Napa, California that does not make glass.

- Pilkington North America produces flat glass and glazing products for the construction and automotive industries. Pilkington North America is a subsidiary of Pilkington plc in the U.K. Pilkington plc was acquired by the Japan-based NSG (Nippon Sheet Glass) Group in 2006. With manufacturing facilities in 29 countries, sales in 130 countries, and 31,000 employees, the NSG group has annual worldwide sales of just under $8 billion, 90 percent of which come from flat glass products. North America accounts for 13 percent of the NSG Group's sales. Pilkington North America has a plant in Lathrop, California, which produces glass for building products and solar panels.

- Gallo Glass is a subsidiary of E & J Gallo, Inc., one of California's largest winemakers. With a Modesto, California manufacturing facility, Gallo Glass produces over 1 billion bottles for its parent company.

For both SCE and PG&E, a small number of customers consume the bulk of the energy used by the sector.

3.3 Competitive Issues

The glass industry has steady, moderate competition. In the past, glass production relied on local supplies, manufacturing, and demand. Glass users usually surveyed a limited landscape of local producers and signed a long-term contract with the supplier deemed most reliable. The high relative costs of transporting glass necessitated local production and distribution. Increases in the reliability transport process, along with the trend towards globalization have ended that era. Nevertheless, the legacy of long-term contracts remains. Hence, the industry is dominated by a set of large producers who have long-term contracts with their customers.

Individual facilities tend to serve regional markets in order to minimize transport costs, but imports are growing steadily and now make up one-fifth of the United States market. Cross-regional sales are increasingly common. Large global players soak up most of the revenue from automotive, construction, and food and beverage demand, but niche players abound coexisting through a wide variety of strategies.

Price differentiation, created from leaner manufacturing processes and global access to labor, is a competitive pressure. However it is somewhat mitigated by the presence of long-term contracts. At the same time, the constant threat of further import penetration or competition from suppliers in the neighboring region, keeps an upper bound on profit margins. Product differentiation, distribution capability, and the availability of substitutes can also become important competitive drivers in certain segments.

For flat glass producers, demand is driven by the automotive and construction industries and long-term contracts are the norm, giving stable market share to a small number of dominant players. Roughly 20 percent of domestic flat glass is imported, enough to ensure domestic producers continuously maintain competitive prices and quality. Glass container producers also tend to sign long-term contracts to meet demand, but face real competition from plastic and metal substitutes. Hence, glass container makers must be efficient in production, have superior distribution channels, constantly seek out new technology, create superior designs, and devote considerable resources to marketing and sales. The specialty glass and products made from purchased glass segments compete in a much more fragmented market principally on quality and ability to produce for specialty applications. Success often depends on becoming the highest quality producer in a given individual market niche.

The largest customers in California are flat glass manufacturers and glass container manufacturers, mostly subsidiaries of multi-national corporations. They are subject to competitive pressures from the import market, especially from places with lower labor costs like China and Mexico. The economic downturn has been especially difficult for flat glass producers, who primarily serve the automotive and construction industries. The construction industry has been especially hard hit in California, giving the largest players with the deepest resources and the best access to technology an even greater advantage.

Flat glass has an unmatched combination of transparency, low cost, and longevity which ensure it will continue to be used in construction and auto making for the foreseeable future. However, flat glass manufacturers are heavily dependent on demand from cyclical industries. Furthermore, globalization has made price the primary differentiator among glass manufacturers. In such an environment, the largest players are at an advantage.

Container glass manufacturers face competition from plastic and metal manufacturers to supply the food and beverage industries. Glass has a considerable advantage over plastic and metal in that it is the most impervious, inert, and sanitary material for containers. Winemakers and olive oil producers have long recognized that glass is the superior option to maintain true flavors over time. Glass is also the most easily sanitized material, which prevents contamination in food and beverage products. On the other hand, glass is heavy and fragile when compared to plastic and metal, making shipping costs significantly higher. The balance of fragility, sanitation, and inertness has very visibly played out in the consumer baby bottle market, where a longstanding debate rages over the merits of plastic versus glass. Taken together, these were factors driving regionalized glass production under long-term contracts – food and beverage manufacturers could have daily delivery of the exact number of containers needed. Some food and beverage makers even wanted glass plants closely linked to their production facilities in a symbiotic relationship that minimizes transport costs. These relationships naturally led to the long-term contracts so prevalent in the glass manufacturing industry.

Specialty glass manufacturers rely on the optical and physical properties of glass and their ability to manufacturer products designed for targeted applications. While the competitive products may be non-existent and competition thin, the segment served by a given manufacturer is usually very narrow and growth capped by the small market size. The inbound logistics of small specialized manufacturers are similar to large factory glassmakers, but they tend to operate on smaller scales, and rely on thoughtful packaging to deliver their products to clients. Modern small-scale producers may or may not be regionally focused, but many work very closely with clients.

To summarize, the industry is dominated by large, multi-national, heavily regulated players that remain entrenched with their largest customers via long-term contracts and worry about ever-increasing competition from cheaper production facilities abroad. Agility is limited to the small, niche players which make up most of the individual establishments, but little of the revenue. PG&E and SCE's largest customers are subsidiaries of the multi-national leaders, although a few niche players are large energy users. Taken together, this suggests change in the industry is likely to be slow and met with some amount of resistance.

3.3.1 Business Models

The business model for the large industry leaders tend to rely on keeping their products and production processes simple and focus on economies-of-scale production; and small specialty producers tend to focus on niche products requiring more complicated custom processes.

Large players typically make flat glass or container glass. Customers in the automobile and construction industries require large quantities of uniform product which meet fairly stringent safety requirements and can be “dropped” into a house under construction, a car on the assembly line, or right into the beverage production center. Large glassmakers procure production inputs locally around the factory since they are widely available, and enforce uniform tolerances and timelines in order to deliver large quantities of glass meeting customer specifications on time. Because glass is fragile, they have their own distribution channels which rely on specialized trucks and equipment to safely deliver shipments to their customers. For the big players serving the auto, construction, and food and beverage industries, it is critical to achieve economies of scale. Price can be a differentiator, but quality and reliability is just as important. Customers are on tight production schedules and depend on the glass manufacturers to meet government-mandated safety requirements. Because reliability is so important, large manufacturers compete on price and production capacity, but also leverage relationship marketing and loyalty to generate sales. Long-term contracts ensure reliable supplies for customers and predictable revenue for glass producers. Gross operating surplus (operating profit before deduction of taxation, interest, and depreciation) averages 28 percent according to IBIS World, and this is representative of large producers.

Small players survive by finding a dedicated niche and responding directly to the needs of their customers. Users of specialty glass typically come to manufacturers with a need for a unique glass product with very detailed design specifications—for instance a lab beaker with over 80 percent silica and special coating, a small tube which can resonate at particular frequency, or high grade optical fiber—and usually do not require huge volumes. Glassmakers use their expertise in mixing, melting, forming and post-forming to produce exactly what their customer needs. Price can be a differentiator, but most critical is the expertise and production capacity to meet a detailed design need. Manufacturers create products and use productive packaging and standard shipping for distribution. Profit margins are higher, but production volume is much lower than for the large manufacturers. Reputation and loyalty help maintain sales, and network marketing can help manufacturers grow into similar niches.

There has been consolidation of ownership within the glass industry over the last twenty years with several of the large-scale multinational companies selectively acquiring dominant players in regional player in various locations. This strategy allows the multinational giants to boost capacity without the heavy investment needed for building from the ground up and captures market share across several of the faster growing regions.

3.3.2 Cost Structure

The cost structure varies across the industry, although purchases of bulk materials are the largest cost to most glass manufacturers. Material inputs absorb roughly 40–50 percent of revenue, labor costs absorb just under 25 percent, and energy costs absorb 5–15 percent.[31] Energy costs are split between natural gas and electricity with the breakdown quite variable. The remainder of revenues represents an operating profit margin.

Glass manufacturing has a high level of capital intensity. Manufacturers must build large plants capable of achieving economies of scale to gain significant market share, meaning capital is a sunk cost prior to any production. Furthermore, much of the market is controlled by large international manufacturers. These are significant barriers to entry for new players and allow the global leaders to remain entrenched. Developing capability in specialty markets does not demand as much of a capital outlay, but the initial cost of building remains nonetheless. Many companies have high debt loads, as companies raise debt to finance initiatives.[32] Smaller, newer players have more significant liabilities and many devote a higher portion of their revenues to debt service. As such, the smaller firms may have a much higher hurdle rate for capital investments.

Once established, long-term contracts provide predictable operating income and companies maintain operating income directly from sales revenue. However, the glass industry as a whole is highly dependent on demand from the construction, automotive, and food/beverage industries.[33] Because the construction and automotive industries have led the decline into the current recession, the glass industry has lost significant amounts of revenue. Large companies have responded in part by taking on some additional debt and lowering labor costs via layoffs. Nevertheless, because of the high sunk costs and the need to demonstrate considerable reliability to customers, factories are hesitant to make dramatic changes to the manufacturing process in place. However, slackened demand has squeezed profit margins enough that cost-saving improvements are inevitable, especially because of the ever-present threat of imports.

3.3.3 Technology Development

Three factors have driven technological change in glass industry over the past decade. First is the economies of scale that can be achieved by transporting glass long distances without

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[31] IBISWorld Industry Report. *Glass Product Manufacturing in the U.S: 32721*. August 2009.

[32] First Research. *Industry Profile: Glass and Fiber Optic Manufacturing*. Quarterly update, November 2009.

[33] IBISWorld Industry Report. *Glass Product Manufacturing in the U.S: 32721*. August 2009.

breakage. Innovation in glass transport, especially in the flat glass segment, has allowed global players to dominate because they can apply economies of scale beyond the local markets that were previously established. Substitution, either of glass for other products or of other products for glass, is a second major factor driving change. Flat glass has benefited, as innovations in reliability and toughness have made glass a popular lower cost alternative for building facades, awnings and the like. Indeed, it is now possible to imprint flat glass to closely mimic the feel of marble and granite at much lower cost. The glass container industry is under constant pressure from the plastics and metals industries. They have responded by creating lighter glass bottles which use fewer raw materials and resources to produce, led the way with innovative labeling technologies, and computer designed high-efficiency cost-optimized manufacturing processes, but have lost market share nonetheless. The third factor driving innovation has been environmental regulation. As rules regarding emissions of criteria air pollutants have stiffened, factories have responded with heavy investment in factories which burn fuels cleanly and minimize emissions during the melting process. A trend towards increased use of recycled glass cullet as an input is another noticeable trend.

3.3.4 Supply Chain Management

The major raw inputs into glass manufacturing include sand (silica), soda ash, and limestone. These materials are commonly available around the world and usually obtained regionally in order to avoid transportation costs. Additional inputs can include boric acid, lead oxide, feldspar, potash, lithium carbonate, lithium alumino silicate, litharge (lead monoxide), alumina, magnesia, barium carbonate, zinc oxide, zirconia, iron, cobalt oxide, nickel oxide, and selenium. Major glass producers obtain these smaller inputs as necessary for their production processes on the global minerals and chemicals markets.

Glass manufacturers are increasingly turning towards recycled glass cullet as a raw input. It has a significant advantage because it requires less heat to melt. However, the advantage of cullet depends on the quality and color of the glass and the ability to separate usable clear or colored glass components from chemical coatings, laminates, and adhesives during melting. A major problem for glass manufacturers wishing to use more cullet has been finding a reliable recycled glass supplier. This has typically capped the maximum percentage of cullet used in a glass plants to 35 percent. Most cullet users obtain upstream supply from local glass recyclers.

Once produced, container glass is shipped directly to beverage and food makers, often within the region. Due to relatively recent technological innovations, specifically extra lightweight boxes and redesigned specialty vehicles, flat glass can be shipped globally to large users in the construction and automotive industries. Fiberglass is usually sent to the construction industry worldwide or to regional firms who mold it for the marine, construction, or automotive industries. Specialty glass is usually shipped directly to users, with channel and scope of distribution highly variable. Controlling distribution arrangements and having an effective network of distribution centers tailored to the needs of core customers is a significant competitive advantage.

3.3.5 Product Development and Roll-out

Product development is driven primarily by ability to substitute glass for other more expensive materials, which is driven by technological change to make glass cheaper, stronger, and more resilient. In turn, developing new technology depends in some part on research and development into new blends of raw materials, new ways of heating and finishing glass products, and the application of novel coatings. At the same time, the distribution channel must reliably support delivery to customers.

New products are rolled out via marketing campaigns, often to existing customers. This is especially true for firms targeting the construction, automotive, and food/beverage industries. Innovation is one way for existing domestic producers to compete with the plastics and metals industries, as well as lower cost imports. Specialty glassmakers often create new products to respond directly to a customer need. Customers may approach specialty glassmakers on the basis of reputation or through an existing relationship. At the same time, specialty glass producers may try to expand their niche by marketing to users of very similar glass items, or grow their niche by suggesting an application for their product where it is not currently used.

Photovoltaic solar panels represent a potential new opportunity for glass manufacturers. Common photovoltaic cells consist of crystalline silicone layered between two panels of rigid glass or thin film semiconductors with glass covers or silicon substrates. As new renewable energy mandates are enacted around the world, the demand for solar panels is expected to grow. The solar panel material supplier market is dominated by global blue chips like Intel, Samsung, and Texas Instruments. Although the revenue growth is impressive, it is still a fraction of the market. First Solar of Arizona, a market leader in supplying thin film finished solar panels has annual revenues just over $1 billion, or about one-eighth of GKN’s annual revenue. Glass for solar panels is generally produced by specialty glassmakers because it requires a formulation especially low in iron to prevent clouding over time. Some large global players have made strategic acquisitions to enter the market. For instance, AGC specialty glass is a U.S. based leader in glass for solar panels and is now a subsidiary of Japan-based Asahi glass.

3.3.6 Value Chain

A value chain is a general model of the interrelated activities which produce value from an industry that exceeds the cost of what is sold. Building upon the insight that an organization is more than a random compilation of machinery, equipment, people and money, the purpose here is to assess the value each particular activity adds to the organizations products or services.

The business model and operations provide the highest links in the value chain. Major glass manufacturers rely on commonly available inputs, allowing them to source raw materials locally on demand no matter where a factory is located and store them on site as needed. Flat glass, container glass, and specialty glass products are relatively heavy and fragile, necessitating appropriate packaging (which can add more weight) or special distribution logistics. Thus, the largest glass manufacturers often own or hold captive their distribution channels, while niche players tend to create specialized solutions to leverage existing shipping options.

In the past, wide availability of inputs and distribution challenges resulted in a heavily geographic industry, where local manufacturers served local customers and relied on relationship marketing. Because the number of glass manufacturers in any given region was likely to be relatively small, consistency, quality, and reliability of supply were the most important factors for success. As the demand for glass coming from construction, auto, and food and beverage manufacturers has grown, flat glass and container glass manufacturers have increased in size and become worldwide enterprises. Specialty glass manufacturers remain niche players, but now can ship anywhere in the world. Consolidation has allowed major manufacturers to deliver larger and larger amounts of standardized, quality-controlled glass to new and growing markets throughout the world.

3.3.7 Pricing

Price differentiation is a major competitive advantage in glass manufacturing, so there is strong motivation to minimize costs. This is especially true in the glass container segment, where plastic and metal substitutes compete heavily, but a reign on prices exists throughout the industry in part due to globalization. Downward competitive pressures on price are somewhat mitigated by a market structure dominated by a few large players with long-term contracts. Flat glass and fiberglass have become globalized, with big players leveraging an advantage in technology, financial resources, and production knowledge to compete on price. Small- and mid- market players differentiate themselves with reliable distribution networks and high quality. In the specialty glass and products made from purchased glass segments, an understanding of user needs can make the difference along with quality. Users reward proven niche leaders with long-term contracts, especially in sub-segments where further economies of scale are hard to achieve.

Prices tend to move slowly because they are written into long-term contracts. Low volatility is possible in part because much of the cost structure is driven by raw materials which are relatively inexpensive, widely available commodities. Despite a trend towards globalization, the vast majority of production is supplied by local materials and distributed locally, keeping exposure to transportation costs and disruptions to a minimum.

Increased environmental regulation has been an added cost to the industry and has driven prices up in the last fifteen years.

3.4 Economic Factors

3.4.1 Business Cycles

The current recession is causing a sharp decrease in demand in the glass sector, as might be expected in an industry where primary demand comes from cyclical industries. The construction industry remains the largest single source of demand for glassmakers and construction activity has been significantly curtailed. A downward trend for construction started in 2006, and accelerated through 2008. Money from the economic stimulus cushioned the decline, but much of it is directed towards public works, which does not benefit the glass industry as much as residential or commercial construction. The automotive industry has also been hard hit. The impact on glassmakers is apparent—according to Credit Suisse, sheet glass production fell 9 percent year over year in May 2009, the 22th consecutive monthly drop, and overall domestic demand was down 43 percent year over year in May 2009, the 28th consecutive monthly drop. Inventory turnover has steadied with an inventory of 4.3 months and remains at the worst level on record. Others are more optimistic about the long-term market of the flat glass business, citing higher levels of glazing from the trend toward natural light in buildings.[34] Fiberglass has been hard-hit with slackened demand in the construction industries.

Container glass has maintained strong, steady demand, buoyed by strong recent performance in the beer and wine industries, as well as the relatively resilient food production industry. However, competition among glass, metal, and plastic substitutes is fierce and the trend is towards increasing use of plastic, which is a detriment to the glass manufacturing industry.

[34]NSG Group. 2010. *Pilkington and the Flat Glass Industry 2010*. http://www.pilkington.com/resources/pfgi2010.PDF

In a January, 2010 New York Times article, Russel Ebeid, chairman of Guardian Glass noted losses brought on by the domestic construction and automobile industries and indicated that a majority of sales are now overseas. Because many of industry establishments are sole proprietorships and small businesses, a certain percentage will likely cease operations. This should open up some market niches, but they will likely remain not fully filled in short term due to the dearth of available credit and the high capital costs associated with entering the industry.

3.4.2 Availability of Capital and Credit

Large multi-national corporate players can fund new projects, facility improvements, and even some new facilities from operating cash. They also have access to the corporate debt market and issue bonds most often to pay for acquisitions. The major players are neither highly leveraged nor under a large amount of existing debt, meaning that their bond ratings are favorable enough to support issuing bonds and notes without penalty rates. Mergers and acquisitions, which had been the norm from the mid-1990's through 2007, were down significantly in 2008 when credit markets froze. With the thaw of the credit markets, the major players are again issuing bonds, with the eye of making further acquisitions of smaller competitors weakened by the recession.

Smaller players typically need new capital up front to establish operations and therefore can be saddled with debt from launch. During the recession, few new businesses began operations because little credit was available to pay for the sunken costs associated with startup. Venture capital is generally not available because the conceivable markets are so specialized that they will likely not achieve the rapid growth sought by venture capitalists. Therefore, most small businesses take collateralized loans to begin operations. Costs for such credit have gone up considerably, representing a higher barrier to entry for new entrants into the field.

3.5 Regulatory Issues

The glass industry is subject to myriad environmental regulations on federal, state, and local levels. The following sections describe the regulatory issues facing the glass industry.

3.5.1 Environmental

The glass industry must comply with the following environmental laws:

- The Clean Air Act (CAA) regulates air emissions from stationary and mobile sources. The pollutants are defined as particle pollution (often referred to as particulate matter), including ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Regulated sources are stationary sources or group of stationary sources that emit or have the potential to emit 10 tons per year or more of a hazardous air pollutant or 25 tons per year or more of a combination of hazardous air pollutants. As a group, California glass manufacturers have made significant reductions in their overall air emissions during the last decade. Much of the improvement was due to sizeable investments prompted by a tightening of the rules. Currently, the EPA is preparing to move forward with regulation of greenhouse gases under the Clean Air Act, as discussed in Section 3.5.2.

- The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. Under the CWA, EPA has implemented pollution control programs such as setting wastewater standards for industry. The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained.

- The Resource Conservation and Recovery Act (RCRA) gives EPA the authority to control hazardous waste from the cradle-to-grave. This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of non-hazardous solid wastes. The 1986 amendments to RCRA enabled EPA to address environmental problems that could result from underground tanks storing petroleum and other hazardous substances. HSWA—the Federal Hazardous and Solid Waste Amendments—are the 1984 amendments to RCRA that focused on waste minimization and phasing out land disposal of hazardous waste as well as corrective action for releases. The California Beverage Container Recycling and Litter Reduction Act (CA Beverage Container Recycling Program) and Fiberglass Recycled Content Act of 1991 require glass container manufacturers in California to use at least 35 percent cullet in their products and fiberglass manufacturers that manufacturer or sell in California to use at least 30 percent cullet in their products. The Department of Conservation is the agency that implements the Bottle and Can Recycling Law and the Fiberglass Recycling Content Act of 1991.

Responsibility for enforcing environmental laws is distributed between the federal government (usually the EPA), state agencies, counties and municipalities. In California, regional air districts are charged with developing and enforcing air quality regulations that are more stringent than federal standards. In general, facilities in the glass industry are long accustomed to complying with existing environmental regulations as part of their normal course of business.

3.5.2 Climate

California Global Warming Solutions Act

In 2006, Assembly Bill 32, the Global Warming Solutions Act (AB32) became the first legislation signed into law in the United States to establish mandatory limits on greenhouse gas emissions. The California Air Resources Board (ARB) was designated as the lead agency tasked with developing the regulatory structure to achieve emissions reductions targets for carbon dioxide (CO_2) and other greenhouse gases.[35] California facilities that emit more than 25,000 metric tons of CO_2 equivalents must report their emissions to the Air Resources Board. All California glass facilities which use a large amount of energy are required to report verified GHG emissions.

In January 2009, ARB adopted a Scoping Plan that provides the blueprint for achieving the reductions through a mix of incentives, direct regulatory measures, and market-based compliance mechanisms.

Key elements of the Scoping Plan include:

- Expanding and strengthening existing energy efficiency programs, as well as building and appliance standards
- Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system
- Establishing targets for transportation-related emissions for regions throughout California, and pursuing policies and incentives to achieve those targets.

The glass industry in California is affected in the planned cap-and-trade program which was adopted by ARB in 2011.[36] After collecting three years of data from the largest emitting industries, ARB will establish emissions caps. For each business sector, an emissions benchmark will be established, and business will be allowed emissions up to 90 percent of the benchmark (cap) in 2013. Cap and trade requires large emission sources to surrender

[35] These gases include methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). Since each of these gases' unique physical properties causes them to have varying heat trapping effects, they are normalized into carbon dioxide equivalents. For example, one metric ton of methane is equivalent to 21 metric tons of CO_2 equivalents (CO_2e).

[36] Cart, Julie. 2011. "California becomes first state to adopt cap-and-trade program," Los Angeles Times. October 21, 2011.
http://articles.latimes.com/2011/oct/21/local/la-me-cap-trade-20111021

emissions permits equal to their actual emissions in any given year. The amount of total available permits declines over time, thereby making it more and more expensive to emit greenhouse gas emissions. Emissions permits are tradable among market actors and emissions reductions from non-capped sectors, known as offsets, can also be used for low-cost compliance purposes. As California implements AB32, glass manufacturers can expect to be treated as capped sources. ARB has composed a working group to determine the technical feasibility of emission reduction measures, and glass manufacturers will likely be required under California regulations to adopt measures, as determined by ARB through the current stakeholder process, in the next few years.

Starting in the first compliance period of 2013, all large industrial facilities that emit over 25,000 metric tons CO_2e per year will be required to acquire and hold emissions permits. Starting in the second compliance period of 2015, industrial fuel combustion at facilities with emissions at or below 25,000 metric tons CO_2e per year will be included. Saint Gobain Containers and Guardian Industries both are under ARB reporting requirements in advance of compliance obligations.

For some energy-intensive industrial sources, stringent requirements in California, either through inclusion in a cap-and-trade program or through source specific regulation, have the potential to create a disadvantage for California facilities relative to out-of-state competitors unless those locations have similar requirements. Recent analysis by the California Legislative Analyst suggests that this effect will not be significant for the overall economy. Sectors most affected are likely those with high energy intensity and significant trade-related activities where increased costs may not be able to be reflected in higher prices.[37] Glass is one of the identified sectors, although mitigating factors apply. For example, glass containers are generally geographically tied to their customer base.

EPA Mandatory Reporting

The U.S. Environmental Protection Agency (EPA) issued a rule for mandatory greenhouse gas (GHG) reporting from large emissions sources in the United States. In general, the rule calls for facilities that emit 25,000 metric tons or more of GHG emissions per year to submit annual reports to EPA. From 85–90 percent of total national U.S. GHG emissions, from approximately

[37] Taylor, Mac. 2011. *Letter to Honorable Dan Hogue*. California Legislative Analyst's Office. May 13, 2011. http://www.lao.ca.gov/reports/2010/rsrc/ab32_logue/ab32_logue_051310.PDF

13,000 facilities, are covered by the proposed rule. Large glass manufacturing plants have sizable enough emissions that they are required to monitor and report them to the EPA.

EPA Regulation of Greenhouse Gases under the Clean Air Act

Greenhouse gas emissions are now regulated in the United States under the Clean Air Act. According to the Tailoring Rule,[38] GHG permitting requirements will cover for the first time new construction projects that emit GHG emissions of at least 100,000 tons per year (tpy). Modifications at existing facilities that increase GHG emissions by at least 75,000 tpy will be subject to permitting requirements, even if they do not significantly increase emissions of any other pollutant. By 2016, the EPA may lower the threshold to 50,000 tpy.

Under the EPA rulemaking for New Source Review proposed emissions sources will be required to install best available control technology (BACT). Typically, this means installing energy efficiency equipment. Large sources permitted through the Title V program may have emissions limits on GHG emissions in the future.

3.5.3 Glass Standards

Glass standards exist to provide uniformity and ensure safety. Most standards come from ASTM International and are designed to ensure adequate transparency and strength against breakage. Because glass is used in so many ways, this had led to a long list of standards. There are eleven standards for flat glass, four standards for glass containers, nine standards for glass decoration, four standards for glass pipe, five standards for optical properties, and twenty-three standard methods to evaluate physical and mechanical properties of glass products. Details on all 56 standards can be found on ASTM's website.[39]

3.6 Industry Network

The industry network for this sector provides a list of potential partners for energy efficiency. No single industry group could represent all the various interests across different segments of the glass manufacturing industry, so industry associations tend to align around individual segments. Major industry associations promote standards, lobby, market, and provide education and

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[38] Federal Register. 2010. *Environmental Protection Agency: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule*. Vol. 75, No. 106, June 3, 2010. http://www.gpo.gov/fdsys/pkg/FR-2010-06-03/pdf/2010-11974.pdf#page=1

[39] ASTM International. *Glass Standards and Ceramic Standards*. http://www.astm.org/Standards/glass-and-ceramic-standards.html

networking for glass manufacturers. Glass production processes are viewed as proprietary within the industry, so glass manufacturers tend to favor mergers and acquisitions to joint ventures and partnerships. Companies associate primarily to promote common interests to the government and the community, which is furthered by creating standards, centralizing common reference materials, training, and networking. Combined, the following associations represent the vast majority of California's glass manufacturers. Smaller industry associations serving an ecosystem of specialty producers (e.g., insulating glass, scientific glassware, etc.) also exist, but without the clout of those mentioned below.

- The Glass Manufacturing Industry Council (GMIC, www.gmic.org) serves all sectors of the glass industry and focuses on education and cooperation. GMIC organizes conferences and education programs, publishes newsletters and magazines, and directly supports research into innovation and energy efficiency. Members include all the major U.S. glass manufacturers, all the major suppliers to the glass industry, and many customers and partners of the industry.

- The Glass Association of North America (GANA; www.glasswebsite.com) is a smaller professional organization that brings together flat glass and fiberglass manufacturers in the U.S. through educational programs, networking opportunities, meetings and conventions, and publications like "U.S. Glass." Different divisions serve different needs including building envelope contractors, flat glass manufacturing, insulating, laminating, mirrors, and tempering.

- With 4,000 member companies across the United States, the National Glass Association (NGA; www.glass.org) is the largest trade association for flat glass manufacturers. With an emphasis on networking and standards, the NGA focuses on education and training programs in addition to serving as a clearinghouse for job lists, supplier lists, and technical documentation.

- The North American Insulation Manufacturers Association (NAIMA; www.naima.org) is the association for U.S. manufacturers of fiberglass, rock wool, and slag wool insulation products. NAIMA markets itself as a promoter of energy efficiency and environmental preservation through the use of fiberglass, rock wool, and slag wool insulation, and to encourage the safe production and use of these materials. However, its activities include funding research by universities, lobbying state and federal governments, offering training on safety and installation, and serving as a liaison to companion associations in Mexico, Canada, Europe, Australia, and Japan. It is the largest organization for U.S. Fiberglass manufacturers. Many fiberglass manufacturers also join the American

Composites Manufacturers Association (ACMA; www.acmanet.org), which has a considerably larger scope, but engages in many of the same activities as NAIMA, but with a larger budget and more emphasis on publications.

3.6.1 Supplier and Trade Allies

Glass manufacturers have a number of trade allies, companies that work with or support the industry. The decision to upgrade to the best available technology occurs as part of the build/rebuild process for plants. Suppliers of furnace equipment can supply the needed equipment. When converting to oxy-fuel, glass manufacturers must secure a reliable supply of oxygen and typically use the major industrial gas suppliers like Praxair, Air Product Supply, or others. Increased cullet use typically involves signing agreements with local glass recyclers who can provide regular supplies, which is often a challenge.

The global distribution of trade allies mirrors the trend towards globalization within the industry itself. Trade allies can be broken down generally into firms that focus on design and engineering, firms offering efficiency and optimization, consultants, and environmental service providers. There is significant overlap between the consulting organizations and the design and engineering firms. Many of the firms focusing on efficiency and optimization specialize in the glass industry only, but the environmental firms are more general, typically working with all types of industry, not just those in the glass industry. Size amongst various trade allies is inversely proportional the specialization—smaller companies tend to focus intensely on subsectors within glass manufacturing while the larger companies tend to include all glass manufacturers as only a part of a larger portfolio of clients. The following list provides some examples of trade allies of glass manufacturers.

- Design and engineering firms offer services related to site selection for plants, architecture, plant engineering, equipment design, construction, technical services for furnaces, expertise around forming, problem solving, training, innovation, production supplies and management.
  - Toledo Engineering Co (TECO) [United States]
  - Stewart Engineers and Associates [United States]
  - Glass Incorporated International [United States]
  - Continental Glass Engineering GMBH [Germany]
- Efficiency and optimization contractors provide services to assess and enhance plant efficiency, process design, and management, often around niches such as thermal imaging of boilers.
  - Thermaltec [United Kingdom]

- Outotec OYJ [Finland]
- Glass Furnace Management [United States]

- Consultants often employ former glass industry employees and provide solutions encompassing analytic services, evaluation work, design, management, financials, and specialized expertise around materials and coatings.
  - The Float Glass Consortium [United Kingdom]
  - Tascon [Germany]
- Environmental and air quality firms provide equipment, emission control systems, and expertise to enable environmental compliance.
  - Ducon [United States]
  - CECO Environmental [United States].

4. Target Technologies / Processes and Energy Efficiency

Glass manufacturers tend to view their individual processes as proprietary. Hence, it is relatively straightforward to get a general sense of glass manufacturing and the largest potential points of efficiency improvement in each of the subsectors, but the improvement potential of any particular manufacturer cannot be precisely predicted. The largest efficiency improvements require the largest investment in capital and therefore intimately depend on the lifecycles of plants and major equipment. Energy efficiency opportunities exist across all businesses, however, the potential for energy efficiency improvements could be higher at smaller facilities, as the biggest plants often spend considerable effort to optimize their production processes. A 2007 survey of glass manufacturing representatives, vendors and consultants found respondents believed energy savings opportunities were about 20 to 25 percent of energy use.[40] By some accounts, small businesses as a group may be able to increase energy efficiency by up to 40 percent, but may lack free working capital to pursue efficiency gains and realize this potential. Furthermore, the small business community is diffuse and diverse, making it a challenging target. The discussion of energy efficiency presented here applies generally to all glassmakers in California, but major plant modifications are realistically only within reach for major producers. Because the industry is heavily concentrated at the top, total potential energy savings is almost entirely driven by actions of the leading manufacturers.

4.1 Energy Use

Glass production requires heating raw materials like sand, soda ash, limestone, and cullet to temperatures around 1,500º C (~2,700º F) in order to melt and refine them into glass. Natural gas is the primary energy source for heating, but electricity is sometimes used for booster energy in melting tanks. Manufacturers also often use significant amounts of electricity for mixing systems, compressed air systems, fans, pumps, lights, and to run forming equipment. Natural gas accounts for roughly 99 percent of purchased fuels. Overall in the United States, the industry uses around 466 trillion Btu of energy every year, with the bulk of that coming from

[40] Rue, D. M., J. Servaites, and W. Wolf. 2007. *Final Report: Industrial Glass Bandwidth Analysis*. Prepared for U.S. DOE. August 2007.
http://www1.eere.energy.gov/industry/glass/pdfs/industrial_bandwidth.PDF

burning natural gas.[41] In 2006, glass manufacturers in California used 12.7 trillion Btu of natural gas and 3.7 trillion Btu of electricity.[42]

Recognizing energy use as a large controllable expense, large manufacturers have been instituting energy efficiency improvements since the late 1970s. Fuel consumed per ton of glass melted dropped 25 percent between the early 1980s and the early 2000s.[43] Overall energy use by fiberglass manufacturers dropped 30 percent between 1978 and 1996 and has continued to improve more slowly since then. These marked improvements are the result of computer optimized process design, computer control of the production process, the advent of new production materials, and new technologies such as electrically boosted heating and oxy-fuel firing. More recently, manufacturers have tried to make use of recycled glass as a raw input as much possible, which has the ancillary benefit of reduced fuel use because it requires a lower temperature (with correspondingly reduced energy consumption) to melt as compared to virgin materials. Use of cullet as a raw material could be more widespread, but the supply of high-quality recycled glass creates a limit.

For both PG&E and SCE, a relatively few large customers purchase the majority of gas and electricity, and the rest of the electric customers have much lower consumption.

4.2 Glass Industry: Energy Consumption by End Use and Energy Efficiency Potential

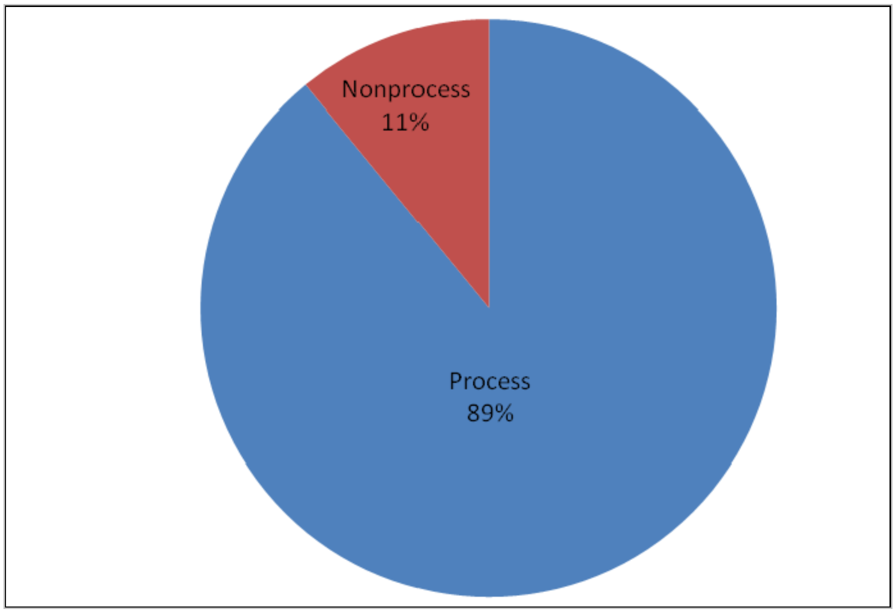
Figure 11 and Figure 12 display electricity consumption for glass container manufacturers (NAICS 327213) and are based on national industry data from the 2006 Manufacturing Energy Consumption Survey (MECS). Glass container manufacturing was chosen for this analysis both because of its representativeness of the glass industry as a whole and its significance as the largest electric and natural gas user within the glass sector in California.

[41] U.S. DOE, Industrial Technologies Program. 2010. *Manufacturing Energy and Carbon Footprint, Sector: Glass*. http://www1.eere.energy.gov/industry/pdfs/glass_footprint.PDF

[42] California Air Resources Board. 2008. *Strategies to Achieve a Reduction in Greenhouse Gas Emissions from Glass Manufacturing Facilities*. Concept Paper for Discussion. May 19, 2008. http://www.arb.ca.gov/cc/glass/docs/CONCEPTPAPERweb.PDF

[43] U.S. DOE, Energy Efficiency and Renewable Energy, Office of Industrial Technologies. 2002. *Energy and Environmental Profile of the U.S. Glass Industry*. Prepared by Energetics. DOE/GO-1020021590. April 2002. http://www.nrel.gov/docs/fy02osti/32135.PDF

Figure 11: Glass Container Manufacturers: Electric Consumption

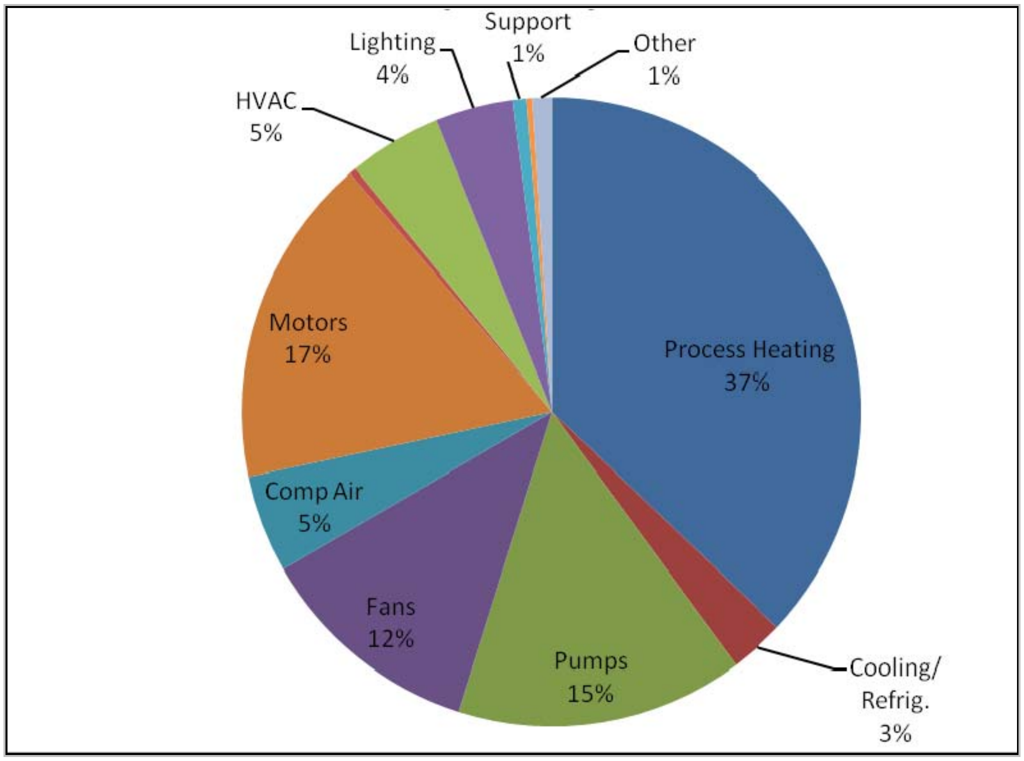


Source: 2006 Manufacturing Energy Consumption Survey[44]

Figure 11 highlights that the overwhelming majority of electric consumption (89 percent) by glass container manufacturers is directly related to the glass container making process. Non-process energy use, like facility lighting and HVAC, accounts for a small fraction (11 percent) of the sub-sector's electric consumption.

[44] U.S. Energy Information Administration. 2009. *2006 Energy Consumption by Manufacturers*. June 2009. http://www.eia.gov/emeu/mecs/mecs2006/2006tables.html

Figure 12: Glass Container Manufacturers: Electric Consumption by End Use



Source: 2006 Manufacturing Energy Consumption Survey

Figure 12 expands on the high-level consumption information presented in Figure 11 and shows electric consumption by end use for glass container manufacturers. Almost 50 percent of total electric consumption in the glass container manufacturing sub-sector can be attributed to machine drives as defined by MECs. Using information from prior research on the non-metallic mineral products industry (NAICS 327),[45,46] the machine drive consumption can be broken down into motors (17 percent), pumps (15 percent), fans (12 percent), and compressed air (5 percent). After machine drives, process heating (37 percent) is the dominant electric end use for glass container manufacturers. Facility lighting (4 percent) and HVAC (5 percent) constitute the majority of non-process electric consumption in the glass container manufacturing sub-sector.

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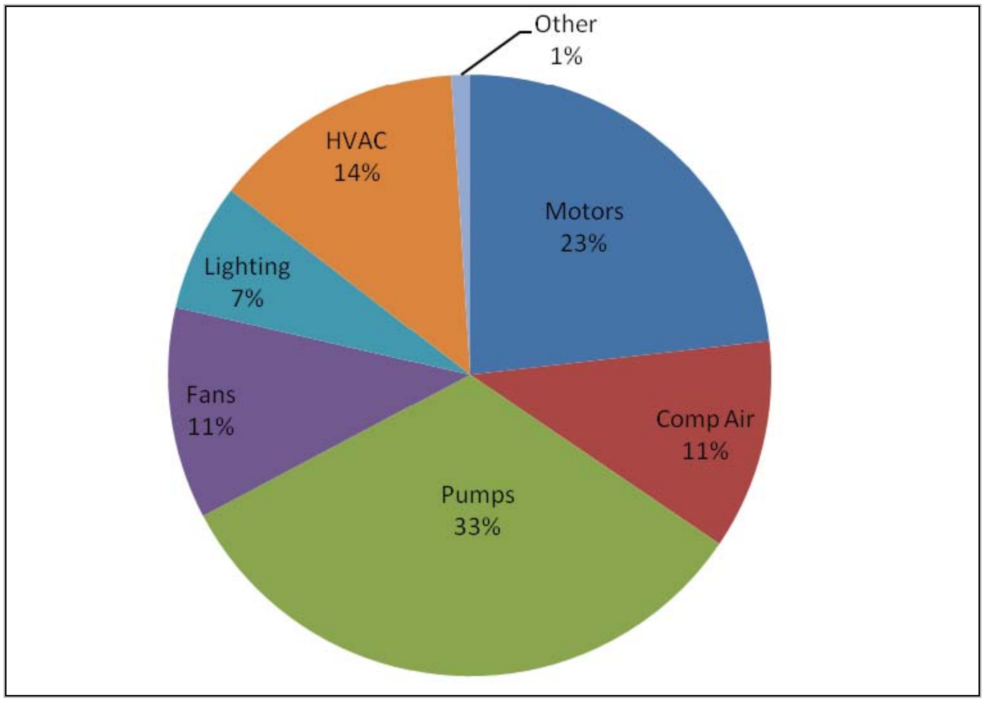
[45]KEMA and Lawrence Berkeley National Laboratory, 2005. *California Statewide Industrial Sector Energy Efficiency Potential Study - Draft Report*. Prepared for Pacific Gas and Electric Company.

[46] XENERGY. 1998. *United States Industrial Electric Motor Systems Market Opportunities Assessment.* Prepared for Oak Ridge National Laboratory and DOE's Office of Industrial Technologies. December 1998.

Figure 13: Non-metallic Mineral Products (NAIC 327): Electric Energy Efficiency Potential

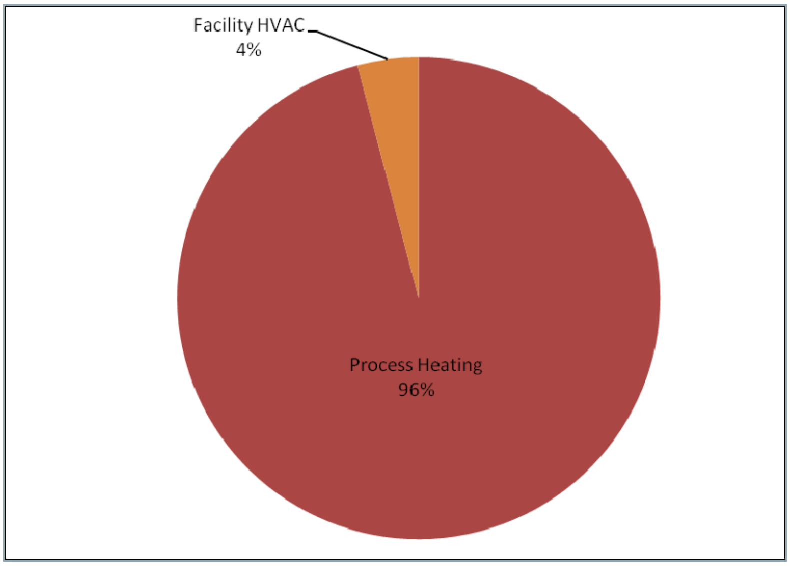


Source: 2006 Manufacturing Energy Consumption Survey

Figure 13 presents the electric energy efficiency potential by end-use for the non-metallic mineral products industrial sectors (NAICS 327), of which glass container and other glass product manufacturers, are a part.[47] The largest potential for electric energy savings lies in pumps and motors, accounting for 33 percent and 23 percent respectively of the total energy savings potential in the non-metallic industry. Given that pumps and motors are also the two largest electric end uses after process heat within the glass container manufacturing sub-sector, exploring related efficiency measures presents the greatest opportunity for large scale energy and utility bill savings.

[47] KEMA and Lawrence Berkeley National Laboratory, 2005. *California Statewide Industrial Sector Energy Efficiency Potential Study - Draft Report*. Prepared for Pacific Gas and Electric Company.

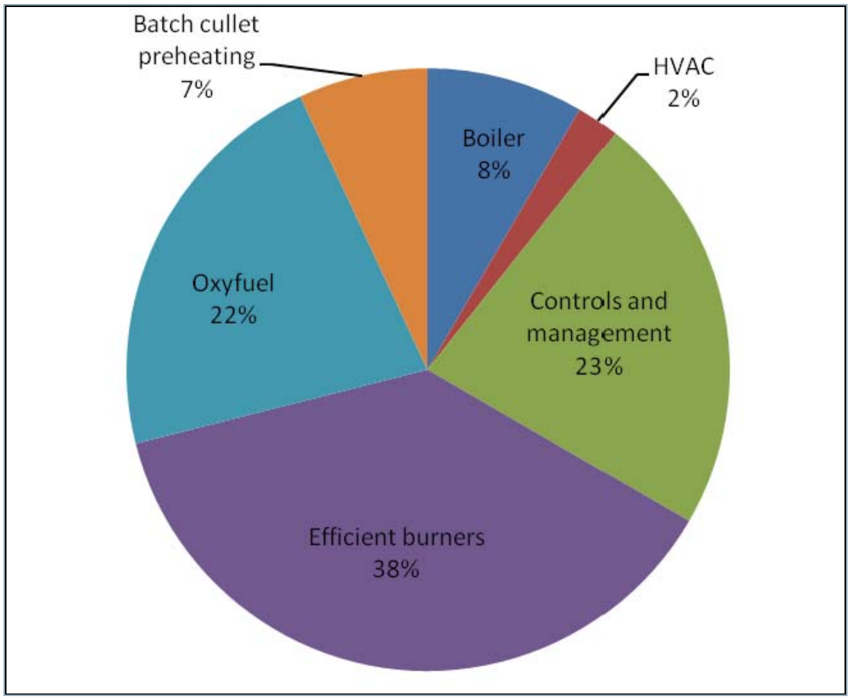
Figure 14: Glass Container Manufacturers: Gas Consumption by End Use



Source: 2006 Manufacturing Energy Consumption Survey

Figure 14 breaks down the end-use consumption of natural gas for glass container manufacturers. The overwhelming majority of natural gas is used for process heating (96 percent) by glass container manufacturers and this usage pattern is consistent in other glass sub-sectors as well.

Figure 15: Non-metallic Mineral Products (NAIC 327): Gas Energy Efficiency Potential



Source: 2006 Manufacturing Energy Consumption Survey

Figure 15 displays the energy efficiency potential related to natural gas use within the non-metallic mineral products industrial sectors (NAICS 327), of which glass container and other glass product manufacturers are a part. Efficient burners (38 percent of total potential) and oxy-fuel (22 percent) represent the largest opportunity to save natural gas within the glass industry. These technologies are appropriate for operations with furnaces, which all of the large glass manufacturers utilize.

4.3 Production Processes

The glass production process can be broken down into a series of steps (Figure 16). Batch preparation involves bringing together and mixing raw materials in proportions needed to achieve desired properties in the glass product. Raw materials almost always include sand, limestone, and soda ash, but can also include in smaller quantities boric acid, lead oxide, feldspar, potash, lithium carbonate, lithium alumino silicate, litarge, alumina, magnesia, barium carbonate, zinc oxide, zirconia, iron, cobalt oxide, nickel oxide, or selenium. Batch preparation is powered by electricity.

Once mixed, the batch is fed to a furnace for melting. There is great variety in the sizes and types of furnaces in use, with specifics determined by the desired glass product. Once melted, the next step is refining (aka "fining") where bubbles are removed from the molten glass and it is homogenized. The melting and refining steps rely heavily on natural gas in the container and flat glass industries, often with electric boosting. The fiberglass industry has smaller furnaces, a little over half of which are electric. Industry-wide, melting generally ranges from four to seven million Btu per ton of production.[48]

The subsectors operate vary differently in the forming step, where molten refined glass is shaped into a recognizable glass type through processes like casting, blow forming, sheet forming, or fiber making. Every glass product has a slightly different forming step. Finally, some products require post-forming processes including curing, coating, laminating, annealing, or tempering to achieve desired properties. Forming and post-forming operations involve a combination of gas and electricity use, depending on whether slow cooling is needed and the intricacy of the forming/post-forming processes.

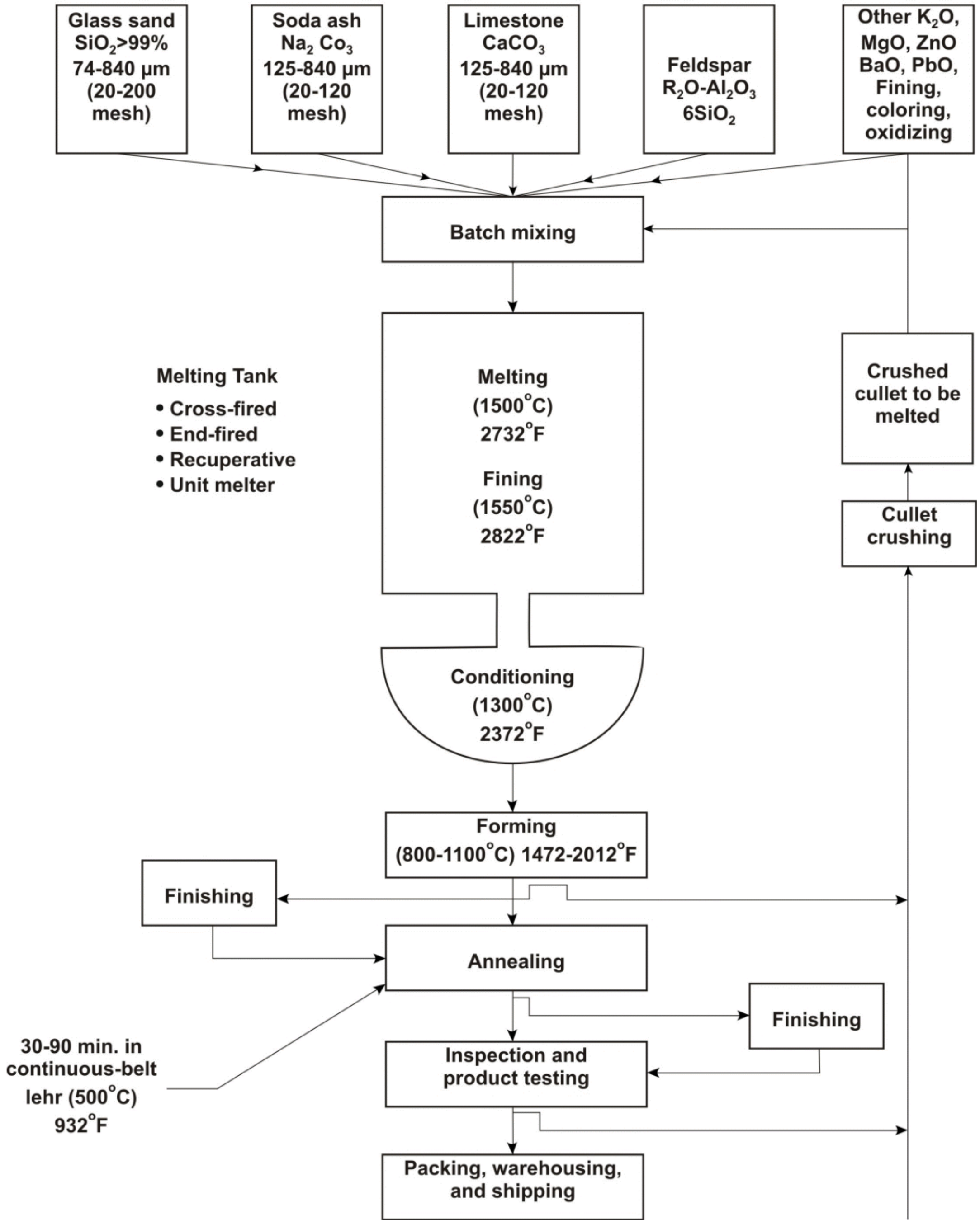
Unused cullet is the primary byproduct of finishing and can be returned to batch-step for recycling, with the exception of fiberglass.

Most of energy use is concentrated in the melting/refining process.[49] Of the energy consumed by the glass industry, melting and refining accounts for 60 percent, forming for around 15 percent, post forming processes for around 20 percent, and mixing for around 5 percent. Opportunities for energy efficiency explained below include increasing the cullet percentage, using a pre-heater either for cullet or the entire batch, computerizing the control system, using a convective melting process, and full or partial conversion to oxy-fuel. Oxy-fuel conversion involves burning pure oxygen in the furnace rather than standard air and results in more efficient combustion.

[48] U.S. DOE, Energy Efficiency and Renewable Energy, Office of Industrial Technologies. 2002. *Energy and Environmental Profile of the U.S. Glass Industry*. Prepared by Energetics. DOE/GO-1020021590. April 2002. http://www.nrel.gov/docs/fy02osti/32135.PDF

[49] Ibid.

Figure 16: Overview of Glass Manufacturing Process



Source: U.S. DOE[50]

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[50] Ibid.

4.4 Current Practices

A 2007 survey of industry executives defines state of the art technology of the industry as oxy-fuel conversion and electric boosting where most applicable.[51] The survey found that flat glass manufactures had only 20 percent use of oxy-fuel technology, while container glass manufactures had 30 percent of oxy-fuel technology. Additionally, 15 percent of container glass manufacturers used an electric boost. Among fiberglass manufacturers there were two distinct sub-segments, both already showing leadership in energy efficient melters: 1) textile fiber makers where 75 percent of manufacturers use oxy-fuel and 35 percent use an electric boost and 2) wool fiber manufacturers, which rely primarily (55 percent) on electric furnaces for their smaller melters and 35 percent use oxy-fuel/natural gas. Backstopping the industry survey is data from oxygen suppliers indicating oxy-fuel uptake is below 10 percent for flat glass, around 25 percent for container glass, just below 50 percent for fiberglass (where some rely on electric furnaces) and 85 percent in the pressed and blown specialty glass sector.

4.4.1 Efficiency Improvements

Opportunities for energy efficiency improvements exist in moving to best practices and technologies[52,53] as follows. Lawrence Berkeley National Laboratory has published the most comprehensive list of energy efficiency measures to date, which are excerpted in 5.

1) Increasing cullet percentage because cullet melts more readily than virgin materials and thus requires less energy to produce per ton. Technologically, it is relatively easy to implement because most glass manufacturers already make some use of cullet as a raw material anyways, especially among container glass manufacturers. The more precise compositions of flat glass and specialty glass can increase the difficulty of using recycled glass in those industries. Any manufacturer desiring to use more cullet must have access to steady stream of high quality recycled glass, which is often a limiting factor. Recycling fiberglass is not currently possible because there is no available technology to fully remove resins at scale.

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[51] Rue, D. M., J. Servaites, and W. Wolf. 2007. *Final Report: Industrial Glass Bandwidth Analysis*. Prepared for U.S. DOE. August 2007. http://www1.eere.energy.gov/industry/glass/pdfs/industrial_bandwidth.PDF

[52] Ibid.

[53] Lawrence Berkeley National Laboratory. 2008. *Energy Efficiency Improvement and Cost Saving Opportunities for the Glass Industry: An Energy Star Guide for Energy and Plant Managers*. Prepared for the U.S. EPA LBNL-57335-Revision. March 2008.

2) Batch preheating involves using process waste heat to preheat the batch. Reusing heat in this way is an extremely efficient way to reduce energy use. However, it requires considerable capital investment, often involving equipment similar in scale to as the melter itself. Overall energy savings are capped because soda ash has a comparatively low melting point (and can messily stick to the sides of the pre-heater) which limits the temperature of useful preheating.

3) Cullet pre-heating is similar to batch pre-heating, but simpler because cullet melts at a higher temperature than virgin batch materials. While still capital intensive, it can substantially reduce energy use where cullet is a major input.

4) Oxy-fuel conversion requires full furnace rebuild and installation of additional specialized equipment, making it capital intensive. Oxy-fuel conversion substitutes oxygen for air in the furnace and results in much more efficient combustion. A capital investment is generally warranted only when a furnace needs to otherwise be replaced or rebuilt because oxy-fuel conversion is among the most expensive possible energy efficiency strategies. The relative cost of oxygen to natural gas is a major deciding factor in whether oxy-fuel conversion is a viable strategy. A theoretical limit caps the total amount of energy savings achievable from oxy-fuel conversion and current implementation achieves a large portion of the theoretically available energy savings.

5) Partial oxy-fuel conversion involves substituting oxygen at one or two burners of a furnace in order to produce more heat for a given use of fuel and increase the rate of production. While useful with an older melter, partial oxy-gas conversion is only a temporary fix, and does not enhance performance as much as full oxy-gas conversion.

6) Combustion system makers continuously work to improve burner efficiency. Retrofitting melters in the middle of their useful lives with the latest inexpensive, high-efficiency burners can save energy.

7) The advent of computer control systems improved efficiency at many of the biggest glass manufacturing plants. Existing furnace systems generally do not warrant costly retrofit with tighter control systems, which can be difficult to implement on older equipment. However, during rebuild the tighter control systems can pay for themselves through increased efficiency, so upgrades most often occur during furnace rebuild. Fewer than half of the furnaces by number in the United States have computer-control systems, but the largest manufacturers typically employ them. Hence it can improve efficiency most with smaller businesses.

8) Glass is often melted mostly by radiation with only a small amount of convection. By retrofitting a burner onto the crown of the melter for downward heating, the amount of convective heating can be increased resulting in energy efficiency improvements. This technology is currently under widespread trial.

9) For manufacturers who are unable to justify major energy improvements, best practices around energy efficiency center on modifying batch preparation, making changes to existing furnaces, optimizing energy use during forming and annealing, optimizing heat and steam distribution, optimizing compressed air systems, and using lighting more efficiently. 5 is excerpted from the Lawrence Berkeley National Laboratory (2008) report.

Table 5: Energy Efficiency Opportunities

Glass Specific	General Manufacturing Recommendations
Batch Preparation • *Use newer grinding technology* • *Use fluxing agents* • *Reduce batch wetting* • *Optimize conveyor belts* • *Use smaller or higher efficiency motors* • *Use motors with variable speed drives* • *Use high efficiency conveyer belts*	**Heat and Steam** • *Improve insulation* • *Perform regular maintenance* • *Reduce excess air* • *Repair leads* • *Recover heat (steam or boiler heat)*
Existing Furnaces • *Minimize excess air and air leakage* • *Add Premix burners* • *Use adjustable speed drives on fans* • *Properly position burners* • *Use sealed burners* • *Use high luminosity burners (oxy-fuel only)* • *Use a tall crown furnace (oxy-fuel only)* • *Top heat (electric only)* • *Optimize electrode placement (electric only)*	**Compressed Air** • *Reduce leaks* • *Turn off unnecessary compressed air* • *Minimize pressure drops* • *Reduce inlet air temperature* • *Use air at lowest possible pressure* • *Properly size regulators* • *Properly size pipes* • *Maximize dew point at air intake*
Forming and Annealing • *Optimize plant layout* • *Reduce air leakage* • *Improve insulation* • *Upgrade drying system*	**Lighting** • *Install lighting controls* • *Replace incandescent bulbs with LEDs, CFLs, fluorescent, or high pressure sodium lights* • *Use daylight wherever feasible* • *Install reflectors*

Source: Lawrence Berkeley National Laboratory[54]

Glass engineers and chemists have numerous other ideas about ways to improve efficiency and save money in the glass manufacturing process. Of note at commercial scale are ways to speed up the refining process, known as rapid refining, through applying a vacuum or a thin film process. The utility of advanced approaches to refining varies because refining differs greatly

[54] Ibid.

between segments and individual manufacturers. Improvements in heating through oscillating combustion, segmented melters, plasma melters, and submerged combustion melting are all options that are in some stage of experimental use.

The glass industry has long experience with furnaces and melters, meaning there are few technological or cultural barriers to implementing energy efficiency improvements. Knowledge of best technologies is widely disseminated within the industry. The technical barriers that do exist generally revolve around interfacing old furnace technology with new control systems or add-on improvements to energy efficiency. Given a free financial hand, a manufacturer building a new plant would have little difficulty putting in advanced technology to get a highly energy-efficient plant. Capital costs and ROI are the deciding factors in implementing capital intensive improvements which result in energy efficiency, and often energy efficiency is secondary to lifecycle cost savings.

4.4.2 ENERGY STAR Program for Glass

ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy to encourage energy efficient products and practices. There are two parts of the program relevant to the glass industry. The first part relevant to glass manufacturers is the consumer label for windows and doors. To obtain the ENERGY STAR label, windows and doors must meet guidelines set by the National Fenestration Rating Council (NFRC), an independent non-profit rating agency dedicated to rating the energy performance of windows and doors. Products must go through a certification process that involves simulations based on product specifications, lab testing, and filing appropriate documentation. The standards set by NFRC specify regionally specific thresholds for U-factor, a measure of heat transfer and insulation, and solar heat gain coefficient, which measures the amount of solar energy transmitted and the amount of heating caused by sunlight. The U-factor and solar heat gain coefficient both depend mostly on the optical and physical properties of the glass, including the composition and glazing. Glass manufacturers therefore can supply ENERGY-STAR-ready glass to their building materials customers. This is an opportunity for glass manufacturers to capitalize on a growing trend and create public engagement around their products.

The second part of the ENERGY STAR relevant to glass manufacturers is the buildings and plants program, which has a focus area specific to energy efficiency in glass manufacturing. The ENERGY STAR Glass Manufacturing focus is a voluntary partnership between the U.S. EPA and glass manufacturers to improve energy efficiency in operations. Any glass manufacturer may participate; the central goal is improving strategic corporate energy management. Corporate energy managers working for glass manufacturers can employ a series of documents to guide them in assessing their current energy management activities, developing an overall energy strategy, and creating or improving a comprehensive energy management program. Many materials are specific to glass manufacturing industry. Most substantially, the ENERGY STAR Glass Manufacturing Focus has developed a set of energy performance indicators, a rating tool to assess the energy efficiency of a given glass manufacturing plant compared to similar plants nationwide. Achieving a score of 75 out of 100 (50 is average) qualifies the plant for ENERGY STAR recognition. Finally, there is an annual meeting for energy managers at participating companies to network and exchange experiences. Currently there are about 10 companies participating in the Glass Manufacturing Focus, including major players like Saint Gobain and Guardian Industries.

4.4.3 Capital Expenditures for Energy Efficiency

State of the art technology typically means oxy-fuel conversion for container and flat glass manufacturers and conversion to mixed oxy-fuel burners or high-efficiency electric melters for fiberglass manufacturers. The decision to transition typically hinges on the capital cost of rebuilding with new technologies at existing plants and the need for new plants. Underlying all analysis is the projected cost of fuel and newly enacted or potential environmental regulations. Many of the upgrades over the last decade were driven in part by new restrictions on criteria air pollutants and toxics. Higher natural gas prices naturally make upgrades and retrofits around energy efficiency far more appealing. It is expected that a price on carbon emissions would have a similar effect.

The container glass industry is not building very many new plants; rather, the industry is contracting as the dominant players consolidate their positions. Because container glass has lower margins and is under pressure from competitors in the plastics and metals industry, it has generally been unable to generate the ROI needed to justify conversion to oxy-fuel firing. Flat glassmakers are building new plants and individually some are making the conversion to oxy-fuel firing. Fiberglass makers are moving much more rapidly adopting state of the art technology including oxy-fuel firing and high-efficiency electric melters. Although pre-heating can drive down energy costs, U.S. manufacturers are not currently following their European counterparts due to the high cost of implementation and perceived problems with reliability whether justified or not.

In a 2007 survey of U.S. glass manufacturing executives prepared by the Gas Technology Institute for the U.S. DOE,[55] most realized that the biggest gains for energy efficiency were afforded by batch preheating and oxy-fuel conversion, but those were also the most expensive improvements to implement. Executives scored partial oxy-fuel retrofit, convective melting, and increasing cullet percentage as much lower on cost, but also realize that the corresponding energy savings for these technologies is also lower.

[55] Rue, D. M., J. Servaites, and W. Wolf. 2007. *Final Report: Industrial Glass Bandwidth Analysis*. Prepared for U.S. DOE. August 2007. http://www1.eere.energy.gov/industry/glass/pdfs/industrial_bandwidth.PDF

5. Market Intervention

This section presents the results from primary research conducted in two ways: an industry leader meeting via Webinar and one-on-one interviews conducted with industry stakeholders. Industry-leader meeting attendees included vice presidents and other executives, trade association directors, energy managers from major manufacturers in the glass industry, and representatives from PG&E, SCE, KEMA, ACEEE, and LBNL. KEMA also conducted six one-on-one interviews with customers in PG&E's and SCE's service territories to solicit input from those unable to attend the industry-leader meeting and to confirm feedback from the meeting. Interviewees included corporate energy managers and plant operations staff. The respondents discussed their energy efficiency efforts and the motivations driving their decisions to improve energy performance. We present our insights and conclusions below.

5.1 Effective Utility Programming

Customers interviewed in the glass sector support utility programming, and most have participated in rebate programs. While the customers voiced satisfaction with their participation in the programs, it was evident there were knowledge gaps of their program. Most of the respondents expressed not being too familiar with the energy efficiency programs offered by their utility. The respondents provided feedback that included not understanding information being provided on the utility's website, having knowledge/awareness of only the custom programs, and having scarce communication with their utility representatives. One customer reported meeting his/her utility representative only twice over fifteen years. These experiences suggest additional education and communication may be needed to inform customers about the utilitys' customer programs and to increase program participation. The following discussion provides more details on these findings.

- *Program Participation.* Many customers reported having positive feedback regarding their participation in the utility-sponsored energy efficiency programs; however, their participation was limited to rebate-based programs. The customers were not aware of other utility programs but expressed interest in participating in more programs.

- *Communication/Education*. Program knowledge gaps appear to hinder broader program participation. Most of the interviewed customers reported that interaction and communication with their utility representatives were limited. They expressed the desire to increase dialogue with the utilities. Since the glass industry has a concentrated market structure, the effects from working with a relatively small number of customers could be significant.

5.2 Drivers of Energy Decision-Making

The following sections describe glass manufacturers' approach to planning and implementing energy efficiency projects.

Many respondents affirmed that glass is an energy-intensive industry and discussed obstacles toward their efforts to reduce their energy costs. The two main constraints respondents mentioned were capital limitations and risk of compliance failure.

During the interviews, many companies reported financial constraints due to the economy. With the current state of economy, companies have shifted energy investments to a lower business priority. This shift in energy investment priority was clear with the customers' self-reported requirement for shorter payback periods before investing in energy efficient projects. Many companies are first looking into low-cost or no-cost activities before investing time and capital into new technology. Additionally, manufacturers look favorably on value-added investments, such as lighting upgrades, which save energy and promote safety and productivity. Some of the measures customers identified as recently installed are:

- Lighting retrofits
- Combustion burners upgrades
- Sub-metering installation
- Variable-speed-drive installation on motors
- Energy controls installation

These low- or no-cost activities also included looking into behavioral changes of the staff before investing in technology, due to limited capital availability.

The customers were probed if they would be interested participating in integrated-approach-based programs that offered demand response, distributed generation, and continuous energy improvement.

One customer expressed caution about participating in Superior Energy Performance certification, due to the reporting requirements, preferring to focus on projects instead.

Glass manufacturers are risk averse about changes that could affect their air-emission permitting requirements. Given that the permitting process requires about a year, the timing of any large capital investment must be planned to minimize production effects. However, customers were willing to employ solutions that did not require intensive restructuring. For instance, one of the customers installed oxy-fuel firing burners by replacing the air and gas burners in the furnace. The customer noticed significant energy savings and claimed that this change extended the life of the furnace. The customer selected this technology because of regulatory flexibility; if the new technology did not improve performance, the customer could change out the new burners with the pre-existing burners rather than lose its permit.

Manufacturers face high regulatory risks when attempting capital-intensive experimental technologies. If the technology does not succeed, they could lose years of planning as well as their permit to operate. Customers recommended that utilities and regulators work with the industry to provide incentives to experiment with emerging technologies.

5.2.1 Energy in Business Operation

The glass industry is energy intensive, and energy costs usually rank as one of the top operating expenses. The companies interviewed reported energy as ranking as the second or third highest operating cost in their business. Table 6 displays the manufacturers' ranking of energy costs in their business operation. The average score was 2.5 where "1" means highest operating cost. As reported by the companies, energy costs constitute a large portion of the overall cost. In the forum, participants consistently identified energy in the top three variable costs of the product. Participants cited management recognition of the value of energy efficiency as a key variable in making improvements.

Table 6: Ranking of Energy With Respect to Operation Costs

Manufacturer Type	Ranking of Energy as Operation Cost
Flat Glass Manufacturing	No response
Glass Container Manufacturing	3
Glass Product Manufacturing Made of Purchased Glass	2
Glass Product Manufacturing Made of Purchased Glass	3
Glass Product Manufacturing Made of Purchased Glass	2
Other Pressed and Blown Glass and Glassware Manufacturing	No response

Note: 1 = Highest operating cost 1; 2 = second highest operating cost

Companies placed energy costs ranging from low to high priority in their business decisions. Table 7 displays manufacturers' self-reported priority of energy costs in their business decisions. The average ranking seems to be between medium to high priority. Customers sought out low-or no-cost activities to cut energy costs in their business.

Table 7:Self-Reported Rating of Energy as Business Priority

Manufacturer Type	Priority of Energy in Business	Notes
Flat Glass Manufacturing	Low	Would need the incentive to cover all project cost and have zero out of pocket expenses.
Glass Container Manufacturing	High	1. Looking at behavioral of employees/personnel with respect to energy usage 2. Lighting retrofits 3. recovering heat from waste gas stream from the stack
Glass Product Manufacturing Made of Purchased Glass	High	Upgraded furnace
Glass Product Manufacturing Made of Purchased Glass	Medium	Upgraded the following measures: 1. VSDs 2. Stackable Structural Reactor furnace firing 3. Energy Controls.
Glass Product Manufacturing Made of Purchased Glass	High	1. Looking at behavioral patterns. 2. Combustion burners 3. improving furnaces
Other Pressed and Blown Glass and Glassware Manufacturing	High	Upgraded the following measures: 1. VFDs 2. Metering 3. Lighting

5.2.2 Investment Priorities

Customers and utilities need to work together to eradicate customers' belief that energy efficiency is not a cost-effective effort due to economic times. It is evident that energy is one of the top-ranking operation costs in the glass sector. It would be unwise to shy away from energy efficiency investment and perceive it as a fixed unavoidable cost. Education about the potential opportunities of reducing operation costs through employing energy efficiency efforts is needed. Though many companies consider controlling energy consumption as one of their top operational priorities, they are unaware of what is available to endorse their energy goals.

During the forum, the respondents noted that investment criteria may vary based on the business unit as well as economic status. There was no set formula or minimum payback requirement for projects; however, most of the respondents reported that a payback period of two to three years was usually sought to implement projects. Table 8 shows customer-reported intended payback periods.

Table 8: Minimum Payback Requirements for Investment in Energy Efficiency

Manufacturer Type	Minimum Payback required
Flat Glass Manufacturing	8 months
Glass Container Manufacturing	3 years
Glass Product Manufacturing Made of Purchased Glass	2 years
Glass Product Manufacturing Made of Purchased Glass	3 years
Glass Product Manufacturing Made of Purchased Glass	2 years
Other Pressed and Blown Glass and Glassware Manufacturing	2 years

Other determining factors for energy efficiency investment include safety, regulatory compliance, return on investment, and meeting customer requirements for product quality.

5.2.3 Project Financing

Energy efficiency projects are paid for by internally generated funds, whether capital or operating. In some companies, a budget is established for energy efficiency activities, and projects are prioritized internally. Loans or lease financing were not common. Internal capital restraints were reported due to business cycles. In a good year, payback periods could be stretched, but in tougher times, payback criteria are shorter. Energy efficiency projects compete with other investments. One company identified a preference to address low-cost and no-cost behavioral and operational opportunities first to avoid spending capital.

5.2.4 Cycles of Innovation

Glass making is an energy-intensive industry, and as such, many possible innovations to improve efficiency have been identified, as described in section 4.4.1. Glass melting is at the core of the glass-making process, with control systems, feeders, forming equipment also needed. Glass furnaces need to be rebuilt,, with focus on the refractory brick that lines the furnace, about every eight years. Participants noted that the innovation cycle is planned around the furnace repair, when production is down. Control systems, feeding systems, oxy-fuel burners, and other peripheral operations can all be upgraded or installed at the same time as the furnace is repaired. Finding additional heat recovery opportunities from exhaust gas, floor hearths, and curing ovens have been difficult to achieve.

Several respondents indicated that standard energy efficiency projects are more typical than capital intensive and/or riskier technologies. Efficiency methods employed include using higher efficiency motors and variable speed drives (VSDs), and behavioral changes.

Respondents were receptive to further forums with industry players and the utilities to discuss programs designed specifically for the glass industry. Participants in the ENERGY STAR program recommended that utilities explore working with available federal government channels, to avoid anti-trust issues. Programs like ENERGY STAR offer opportunities to discuss glass-industry-specific utility programs and gain feedback of customers and spread awareness.

Another area of innovation is to increase the amount of recycled glass. The push to use recycled glass may be driven by California's AB2622, which requires glass container manufacturers to use a minimum required percentage of recycled glass in manufacturing. The minimum recycled-glass requirement during production was 15 percent in 1992; in 2002, the requirement increased to 55 percent. In 2005, the goal had been set to 65 percent.[56] In 2006, glass recovery was estimated at 2.9 million tons, and in 2007, this trend increased to 3.2 million

[56] Beck, Patty and Grogan, Pete. 1991. *Minimum Content Legislation: an Effective Market Development Tool.* Resource Recycling, September: 90-99.

tons.[57] The manufacturers realize the benefits of using recycled glass, which lowers melter temperatures and energy usage during the glass melting process. However, recycled glass, especially from mixed streams, is more difficult to control and achieve quality standards than from virgin materials.

5.3 Customer Assessment

Customers interviewed stated they have all participated in utility programs and would consider any program that meets their needs, including internal criteria for payback, and saves energy costs. The following sections describe customers' ratings of their utility program awareness, experience, and satisfaction.

5.3.1 Utility Awareness

Reported utility program awareness was low. One of the reasons for this may have been due to scarce interaction between the utility representative and the customer. In some cases, an energy manager may be responsible for multiple facilities served by different utilities across the country, and thus may not be knowledgeable about all utility programs.

Table 9 outlines the customers' self-reported awareness regarding utility-funded energy efficiency programs. Some of the companies did not seem to have a strong idea of the programs being offered by the utilities. Though they had positive feedback regarding their previous participations in the utility programs (particularly with rebates), they were not familiar with the utilities' offerings. They reported that likely participation increases if they were more aware of the programs and resources available to them.

[57] U.S. EPA, Office of Solid Waste. 2008. *Municipal Solid Waste in the United States: 2007 Facts And Figures.* EPA530-R-08-010, November 2008; and the California Department of Conservation

Table 9: Self-reported Manufacturer's Awareness of the Utility-funded Energy Efficiency Program

Manufacturer Type	Self-Reported Awareness of Available Utility Energy Efficiency Programs	Notes
Flat Glass Manufacturing	Low	Claimed met with the utility rep. once in the past 15 years of operation
Glass Container Manufacturing	No Response	
Glass Product Manufacturing Made of Purchased Glass	Low	Had met once with their utility rep. but would like more contact
Glass Product Manufacturing Made of Purchased Glass	Low	Did not have good understanding of utility funded energy efficiency programs
Glass Product Manufacturing Made of Purchased Glass	No Response	
Other Pressed and Blown Glass and Glassware Manufacturing	Low	Not familiar with the energy efficiency programs offered by the utility since the plant ownership was fairly new

6. Next Steps and Recommendations

This investigation has revealed that glass industry customers are willing to consider new approaches, including a comprehensive approach to addressing their energy needs, beyond simply retrofitting equipment. Some suggested elements of that approach are presented below, and additional research focused on the feasibility of each of these recommendations would be prudent. Two key components of a successful effort are the participation of regulatory staff in the development of the options and CPUC recognition of the utilities' role in changes to a customer's policies and procedures regarding energy.

Our research suggests a number of opportunities for both program implementation and program evaluation.

6.1 Program Implementation

1. **Encourage No-cost and Low-cost Improvements.** Companies are most receptive to projects with the shortest possible payback in this economic climate. Programs that focus on low- and no-cost items, such as improving reliability through a predictive and preventative maintenance programs, lighting retrofits, upgrading combustion burners, or installing sub-metering, variable speed drives on motors or energy controls, can engage customers with limited financial options. Other low- or no-cost activities include pursuing behavioral and operational changes before investing in technology due to limited capital availability.
2. **Build on Customer's Internal Goals and Programs.** The more sophisticated customers have established strong internal energy efficiency programs. Utility offerings that further enable the energy-savvy customers to achieve savings have low market barriers. For example, utilities could offer benchmarking for specific unit operations or technical and management assistance for companies seeking to achieve ISO 50001 certification.
3. **Identify Planned Upgrades and Document Associated Efficiency Opportunities.** Companies will continue to invest in plants where long-term markets are perceived. Most repairs and innovations are planned around furnace rebuilds, an estimated eight-year cycle. As utilities are aware of the customers long-term plans, they can encourage the addition of energy efficiency during scheduled production down time. Early and complete documentation of the utility's involvement can assist in appropriate net to gross evaluations for energy efficiency projects.

4. **Avoid "utility speak."** Utilities often do not express the program ideas in ways that the CEO, or most employees outside of the energy management group, can understand.
5. **Integrate Energy Efficiency with Permits and Regulatory Requirements.** As part of large-scale projects, utilities may consider partnering with permitting specialists (consultants or regulators) to help move energy efficiency projects forward. Environmental permitting can be a significant barrier for large capital projects that substantially change plant operations. Utility support to help to overcome this barrier would be well received.

6.2 Evaluation

1. **Build on Existing Support.** Customers recognized the benefits of energy and cost savings through utility programs. Access to utility representatives could be improved, and is critical since many rely on the utility to learn about new programs. Companies also appreciate when utilities reach out to trade associations and speak at their meetings.
2. **Develop Innovative Pilots to Suit Differing Customer Needs.** Highly sophisticated customers are potential candidates for programs leading to certification under ISO 50001 or the U.S. DOE's Superior Energy Performance. Other firms that are less engaged or more cautious may be receptive to shorter term continual improvement programs like the Energy Trust of Oregon's "Kaizen Blitz" pilot program[58] and the Puget Sound Energy's Resource Conservation Manager Program.[59] The ETO program offers an initial audit and one year of technical assistance, but requires the participants to set goals and implement fast payback options. The PSE program offers grants for a resource conservation manager, and incentives for energy efficiency improvements. This program focuses on and rewards improvements in behavior and utility cost accounting.
3. **Develop 'Clearinghouse' Program for New Product Innovation.** Customers interviewed would appreciate technology demonstrations. A government or utility clearinghouse program that aggregates information that vets emerging technologies

[58] Navigant. 2010. *Kaizen Blitz Pilot, Report One*. Prepared for Energy Trust of Oregon. October 2010 http://www.affiliatedrecon.com/studies/OR/Energy_Trust/General/ETO-Kaizen-Blitz-Pilot.PDF

[59] Puget Sound Energy. *2010 Business Energy Management, Resource Conservation Manager Program*. February 2010.
http://www.pse.com/savingsandenergycenter/ForBusinesses/Documents/3462_RCM.PDF

would help to verify vendor's claims. Existing glass sector programs, such as Energy Star or the ARB working group, can serve as a starting point.

4. **Encourage End-use Measurement.** One of the biggest challenges in the industrial sector is getting program participation, particularly for less sophisticated customers. The glass sector has a high level of concentration such that many facilities are owned by only a few companies. One opportunity for engaging the less-sophisticated or less-engaged customers is to focus on the measurement of their utility use, and assist them in breaking down their bill to specific operations. This can then highlight energy efficiency opportunities.

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A. ATTACHMENTS

Glass Industrial Research Forums: Question Set

Interview Guide

Glass Industrial Research Forums: Question Set

Introduction:

- Introduce KEMA
- Go over the project and the objectives
- Go around the room or make introductions via telephone. Tell us about your job. How do you contribute to the decisions around energy in your organization?

Section 1: What drives decision-making for energy? Who initiates ideas for projects?

How does energy fit in with key priorities in your industry? **(For KEMA forum leader: list priorities identified in each report here and prompt discussion as required. Typically, priorities are safety, quality, meeting regulations, cost, competition.**

1. Where does energy rank in the management and operations of your business? Would your executive management agree with this ranking of importance?
    a. In your knowledge of the industry, is energy efficiency an integral part of strategic planning and risk assessment? Why or why not? If yes, in what ways? If not, what are other factors that are more important?
    b. Generally speaking, what proportion are energy costs relative to your operating costs? Do you see this proportion increasing in the future? By how much?
2. How have energy use patterns changed over the past 10 years? What drives the growth of energy use?
3. What drives investment in energy efficiency in the **glass** industry?
4. What drives investment in energy efficiency in the minerals industry?
5. What are the main opportunities for your organizations to save energy?
    a. Behavioral, operations? (i.e., Management systems, preventative/predictive maintenance, Smart Mfr. – use of sensors, controls, , EMS, process optimization including EE)
    b. Retrofits and equipment upgrades? (Heat recovery, efficient motors,

c. Process upgrades? (major changes, such as new kilns, major equipment conversion)

6. What are the primary barriers to adoption of these opportunities?

7. Regarding capital and maintenance investments at your organization (i.e. major capital projects of any type, including mid-sized retrofits):

    a. How is energy efficiency financed? Operating budget vs. capital budget.

    b. How difficult is it to acquire capital for investment? Does the industry have alternative or innovative ways of raising capital? (i.e., private partnerships)

    c. How aware are you of IOU programs to help you manage your energy? Their technical support? Their incentives?

8. Would you say it is typical or not for firms to solicit input from employees at various levels and departments into investment decision making? If not typical, does it happen at all? If so, in what way(s)?

9. For major investment decisions, what is the typical process and timing from idea to start of implementation?

10. How are investment priorities determined?

    a. What are your investment criteria? What is the typical and shortest payback period needed to make an efficiency upgrade that requires capital investment attractive?

    b. How do you determine which project to invest in? How does management determine a project is worthwhile? What are the key deciding criteria to move forward on a project? (e.g. regulatory, safety, cost, increased production capacity, improved quality, new products, etc). How would you rank these criteria in terms of influencing how projects are prioritized?

    c. If the project could include energy efficiency improvements, do you involve your utility?

11. How has the recession/recovery affected your energy use? More, less or about the same? Any shift in types of fuels used?

Section 2: Cycle of innovation. What kinds of changes or innovations would cause you to retool or rebuild? Examples?

12. How mature is the industry infrastructure in regards to age of equipment and systems? Do you foresee a need for substantial upgrades in the future? About how long? Near-term? Long-term?
13. What types of efficiency investments have been popular in the past ten years?
    a. Energy Management Systems and process control optimization
    b. Process and product optimization – feeds, rates, heat input, combustion process, etc
    c. New products or processes
    d. Steam projects- efficient boilers, dryers, kilns, leak repairs
    e. Electric loads: VFDs, efficient motors
    f. Heat recovery
    g. Air compressor optimization
14. What do you foresee the trend will be (regarding efficiency investments) in the future?
15. What organizations would you point to as particularly innovative? Why do you see these organizations as innovative, what are they doing that makes them innovative? (i.e. vendors? Utility engineers, consultants?)
16. What internal needs are shaping innovation?
    a. New products, Product improvements,
    b. New processes,
    c. Quality, cost, reliability, safety
17. What external factors drive innovation that effect energy use?
    a. Fuel prices
    b. Carbon trading
    c. Regulations and legal issues

18. (for companies operating in California) Do you foresee the implementation of AB-32 or other upcoming regulations will make a difference in your operations? Do you see that this will change how you manage energy?
19. How do your organizations access the latest information on energy efficiency technology?
20. If not mentioned, probe for comments on the following:
    a. Do you foresee more efforts to increase self-generation to service your own electricity demand?
    b. Validate the trends in innovation in operations such as; storage to facilitate load-shifting; plant optimization; improvements in optimization technology beyond SCADA

Section 3: Experience with Utility Programs and Networks of Expertise

21. What roles do others (e.g. contractors, consultant, etc.) play in moving EE projects forward?
22. Do you partner with the utility? Do you see the utility as a partner? What kind of resources and assistance do you look for from the utility? Is there more they could be doing to help you manage your energy use? What else should they be doing?

23. Have you participated in any energy efficiency or management programs offered by either the Department of Energy or your utility? Why or why not? Did the program address your needs? Would you participate again? Why or why not?
24. What would encourage your company's management to sign up for energy efficiency or demand response programs? Any past examples of either participation or non-participation and why?

Interview Guide

Section 1: Introduction

Hello. My name is [Interviewer Name] calling from KEMA Inc., an energy consulting firm. Your utility [Pacific Gas & Electric or Southern California Edison] has hired KEMA to conduct research to improve their industrial energy efficiency programs in the glass sector. You have been identified as someone knowledgeable at your company about energy efficiency decisions and participation in utility energy efficiency programs. Is this correct? [If no, ask for a colleague referral. If yes, start the interview questions below.]

First, I'd like to ask you about what drives decision-making in energy efficiency first, then ask about your thoughts on your utility's energy efficiency programs. Your responses are confidential. This interview will take approximately 30 minutes.

Section 2: What Drives Energy Efficiency Decision-Making?

1. What does energy efficiency mean at your company?
2. On a scale of one to ten, with 1 being the highest and 5 being the lowest, How would you describe your company's commitment to implementing energy efficiency practices or investments? (where 1 = invests heavily in energy efficiency or your company has taken all or nearly all cost-effective actions to reduce energy costs, 5 = only replace equipment on burnout)
3. Where does energy rank in terms of your business operation decisions?
   (Not a priority * low priority * medium priority * high priority * very high priority)
   a. What factors drive that ranking? i.e., need energy reliability for production/will pay any costs; energy costs in top 10 operating costs/huge impact on variable costs; or both?
4. What are the primary energy efficiency improvements that your company plans to make over the next…
   a. 2-5 years?
   b. 5-10 years?
5. How short of a payback does your company require to invest in energy efficiency measures?
6. How does your company typically pay for energy efficiency investments?
   a. What are the challenges involved with access to capital?
   b. How can the utility help with those barriers?

7. What other barriers are there to investment in energy efficiency in this industry?

Section 3: Utility Programs Communications

1. Please describe the typical process at your organization, from how you hear about energy efficiency programs offered by your utility to the final decision to participate or not.
    a. Who is involved?
    b. Who needs to participate in the decision-making process?
2. Are you familiar with the energy efficiency programs offered by your utility?
    a. How do you hear about utility sponsored programs? e.g. vendors, utility rep, colleagues, other?
3. Do you feel you have enough knowledge about the energy efficiency programs your utility offers? If no,
    a. Why not?
    b. How do you gather information to make an informed decision?
4. How often do you speak or meet with your utility representative?
    a. Would you prefer to meet: *more/less or the same?*
    b. How would you prefer to meet? *1-on-1, group, seminar?*

Section 4: Utility Programs Experience

1. What are the major factors your company considers when deciding whether to participate in a utility-sponsored program?
2. 2. What type of utility sponsored program(s) are you most likely to participate? Least likely? Has this shifted over time? If so, why?
3. Does your utility offer energy efficiency and/or energy management programs that address your important energy concerns?
    a. If not, what is missing?
4. Has your company participated in any utility sponsored energy efficiency program recently (e.g. past 2-3 years)?

If NO,

a. What factors have contributed the most to your decision not to participate in an energy efficiency program?
b. What would encourage you to participate? i.e. different type of program offerings; better/more communication about program opportunities; business need; other?

If YES,

a. What is the most effective and beneficial energy efficiency program you have participated in? Please explain what you found beneficial.
b. What led to your company's decision to participate i.e., how did you learn about the program, who at your company spearheaded the decision to participate?
c. Did participating meet your expectations?
   i. If yes, how?
   ii. If not, why not?
d. Would you participate in this program again? Why or why not?

Would you mind if I contacted you again as needed?

Thank you for your participation.