CHAPTER 2

High-Performance Windows

Reduced Heating and Cooling Costs Through Energy-Efficient Technology

by

Gary Gereffi and Kristen Dubay

Contributing CGGC researchers:

Jess Robinson and Yuber Romero

CENTER ON GLOBALIZATION Governance & Competitiveness

Summary

High-performance window technology is well developed, and widespread use of these more efficient windows is leading to demand for even better performance. For example, ENERGY STAR plans to make the criteria for its high-performance window labeling more stringent in the next few years in response to greater efficiency within some building code regulations. In addition, the U.S. Green Building Council uses current ENERGY STAR criteria as the prerequisite for Leadership in Energy and Environmental Design (LEED) certification, and windows exceeding those criteria help the home qualify for a higher home energy rating. Almost 60% of the current windows market meets existing ENERGY STAR criteria, but it is expected that the market penetration of existing windows meeting updated ENERGY STAR criteria will drop to approximately 45% in Phase 1 of the criteria changes and 25% in Phase 2. The majority of existing penetration is in the replacement or remodeling of residential buildings with up to three stories. Close to 90% of the remodeling market uses high-performance windows. In new construction, the market share is slightly lower than 50%.

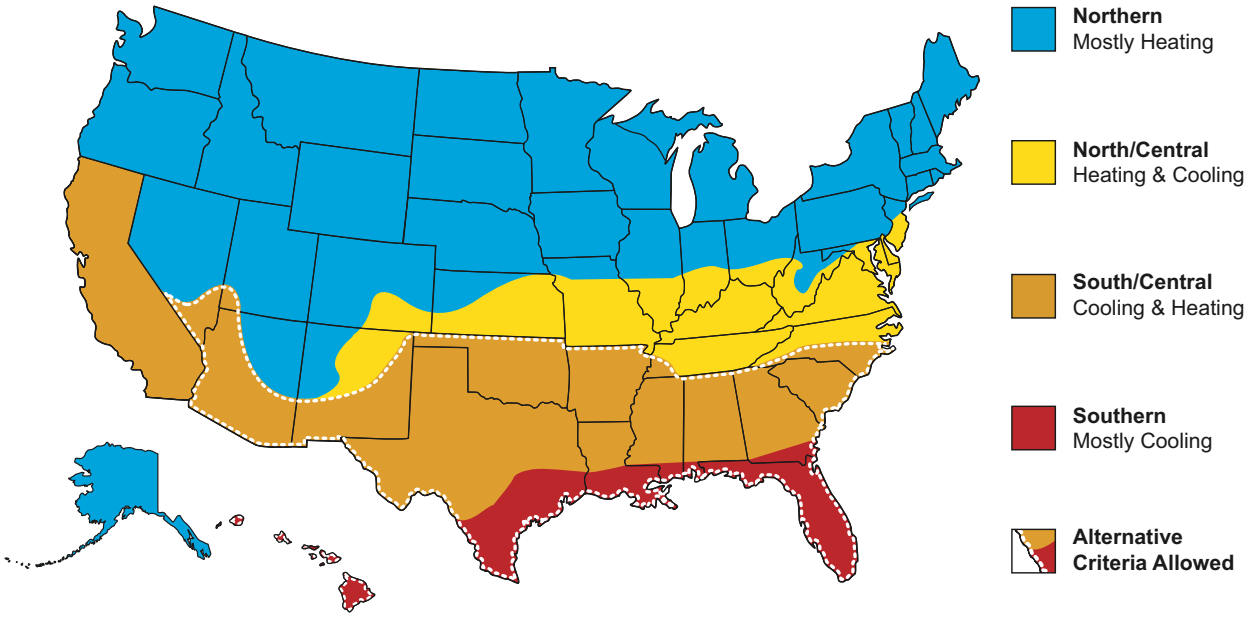
ENERGY STAR criteria changes will impact both the component manufacturers and the window manufacturers, which will need to develop new products to meet the criteria. Phase 1 criteria will have more limited impacts than Phase 2 criteria. Over the course of both criteria changes, jobs will be affected at the component and product stages of the value chain: Component manufacturers may have to develop more efficient products. Window manufacturers will likely make design and component changes, modify production lines, and have new products tested and certified. The ability of companies to respond to the criteria changes may determine which companies will benefit and which will struggle to compete. Furthermore, if the market for more efficient windows continues to increase, this could positively impact installation jobs in the value chain.

Introduction

High-performance windows can greatly reduce energy consumption and, thus, heating and cooling costs. Many new homes are built with windows that have some form of insulating technology, and the majority of retrofitted windows are high-performance. This change has improved home energy efficiency over the course of the last decade. The most energy efficient window models can save homeowners up to 16% on their heating costs and up to 23% on their cooling costs (Center for Sustainable Building Research, 2008). Additional benefits of this evolving technology include better air quality in homes, reduced condensation, and the ability to filter 98% of ultraviolet rays (Efficient Windows Collaborative, 2008).

The National Fenestration Rating Council (NFRC) is the U.S. non-profit organization responsible for independently rating and labeling the energy performance of windows, doors, and skylights. The NFRC uses five criteria to test for energy efficiency: the U-factor, the solar heat gain coefficient, visible transmittance, air leakage, and condensation resistance. The U-factor measures how well the window prevents heat from escaping, the solar heat gain coefficient determines how well a window blocks heat from sunlight, visible transmittance measures how much light passes through a window, and air leakage and condensation resistance measure the insulating value by how much air and moisture is let through the window (National Fenestration Rating Council, 2008b).

Figure 2-1. ENERGY STAR Climate Zone Map



Source: ENERGY STAR, 2008c.

Optimal numbers for each of the NFRC categories vary based on the climate zone where the window is to be installed. In the United States, there are four climate zones (see Figure 2-1). The U-factor is the most important measurement in the northern climate zones where insulation is critical; whereas the solar heat gain coefficient is more important for southern climates where minimal heat gain from the sun is preferred. Therefore, a window with good measurements for one climate is not necessarily energy efficient in a different climate.

Energy-Efficient Window Market

The production of high-performance windows is not new; the fenestration industry began to address issues related to energy efficiency during the energy crises of the 1970s. Today, there are more than 450 fixed window manufacturers whose products are rated by the NFRC (National Fenestration Rating Council, 2008a). However, the energy efficiency of these windows varies greatly, and more advanced products are being developed each year. NFRC rating is important to manufacturers because ENERGY STAR, an organization developed and overseen by the U.S. Department of Energy and the U.S. Environmental Protection Agency and dedicated to promoting energy efficient products, uses the NFRC rating to determine if a window meets the qualifications for an ENERGY STAR label. The ENERGY STAR label is well recognized within the industry and it is highly valued by consumers. The label is so important to consumers that some retailers, such as Home Depot, only sell windows with an ENERGY STAR label (Home Depot, 2008). Furthermore, in the U.S. Green Building Council LEED certification program, using windows that meet ENERGY STAR criteria is mandatory, and extra points are awarded for windows that are 10% more efficient than required by the criteria (1 extra point) and 20% more efficient (2 extra points). Higher overall points, of course, enable buildings to meet LEED certified platinum, silver, or gold levels.

The criteria outlined by ENERGY STAR have had a direct impact on the level of energy efficiency targeted by manufacturers. Windows meeting current ENERGY STAR criteria have a penetration

rate of approximately 60% of the total windows market (ENERGY STAR, 2008a). However, new building codes such as the 2009 International Energy Conservation Code (IECC) are pushing window efficiency further than current ENERGY STAR criteria. In fact, the proposed 2009 IECC has higher prescriptives and will affect building codes for more than 70% of the U.S. population (U.S. Department of Energy, 2008). Wanting to ensure that the ENERGY STAR label continues to differentiate superior-performing products in the window market, ENERGY STAR is in the process of developing more stringent energy efficiency criteria over the next few years, with Phase 1 going into effect in August 2009 and Phase 2 planned to take effect January 1, 2013. Energy consumption savings from these changes are estimated at 8.51 trillion BTU after Phase 1 implementation and 11.41 trillion BTU after Phase 2. The new criteria also will help the ENERGY STAR label continue to drive technology developments and efficiency improvements in the market. It is estimated that 45% of existing windows will meet Phase 1 criteria set by ENERGY STAR and 25% will meet Phase 2 (U.S. Department of Energy, 2008). These criteria changes will impact the value chain at both the component and window manufacturer levels. Component manufacturers may see an increase in demand for their most efficient products, and they may be incentivized to develop even more efficient components. For Phase 2, window manufacturers will likely make design and component changes, may have to modify production lines, and will need to have new products tested and certified (J. Swanson, 2008).

High-Performance Window Value Chain

A high-performance window has approximately 10 components, and the value chain incorporates four major stages: materials, components, finished product, and end use. Figure 2-2 illustrates this value chain. A more complete value chain with illustrative company information appears at the end of this chapter. Improvements in window energy efficiency will have job implications for component and window manufacturers and the window replacement installation market.

Materials

The main materials used in the production of high-performance windows are fiberglass, vinyl, argon, and silica. Other mineral and chemical components found in these windows include nickel, titanium dioxide, chromium nitrate, polystyrene foam, steel, and argon (see Figure 2-3). The United States has more than 50% of the international markets for both lumber and plastic (vinyl and fiberglass), showing growth potential and positive job implications as the high-performance window market expands.

Components

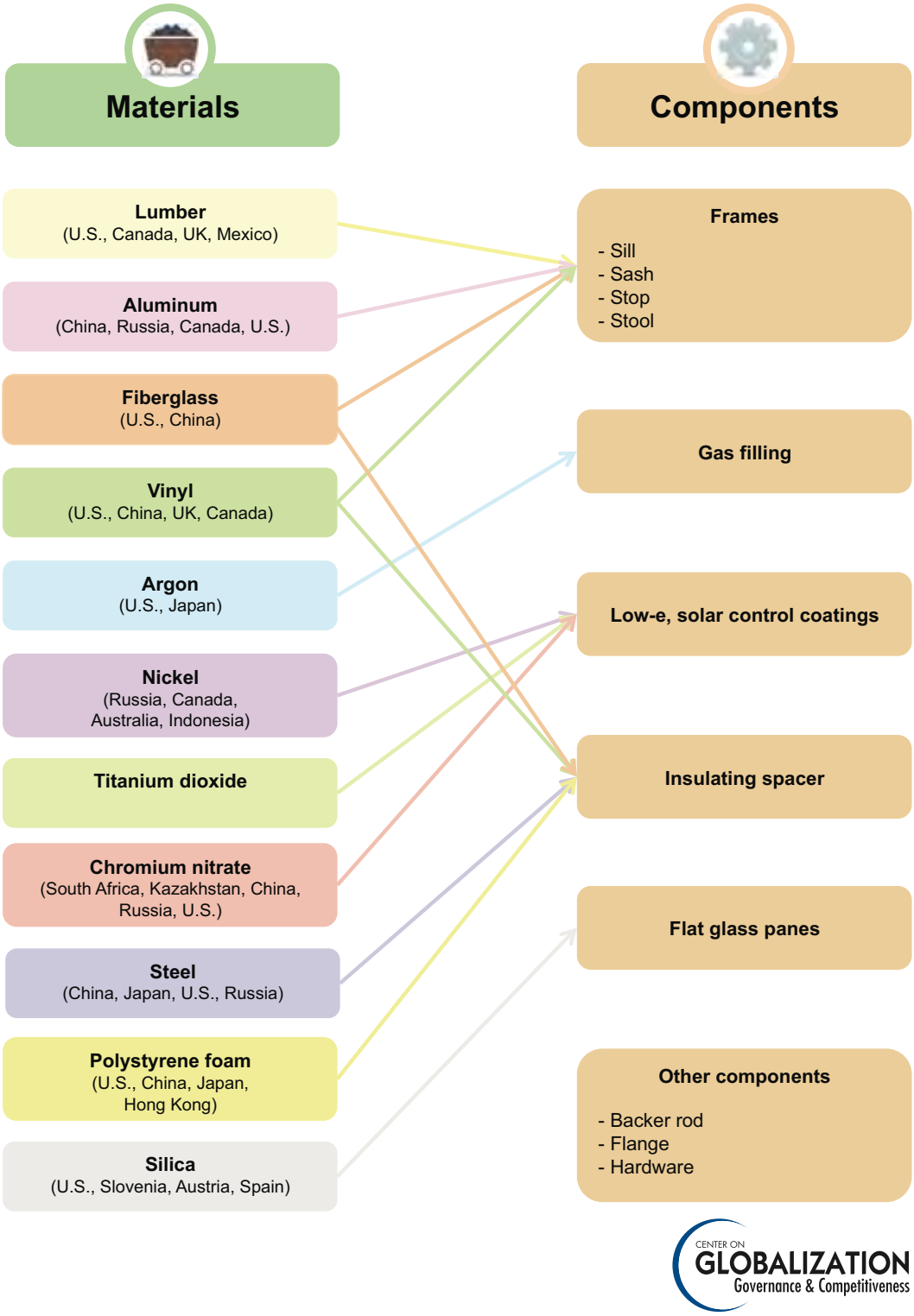
The four components essential to the energy efficiency of windows are low-emissivity (or low-e) coated glass, gas fills, spacers, and improved frames. The low-e coated glass includes the manufacturing of the flat glass pane as well as the production of an infrared-reflective coating. This type of glass provides a durable, film interference filter that reflects infrared rays while allowing for the transmittance of visible light. The gas fills mainly use argon as the insulator. Krypton has a higher performance rating as a gas filling but its price is too high to make it a feasible alternative. The insulating spacers use either fiberglass or vinyl and polystyrene foam to space the glass panes (in double or triple pane windows) to the correct distance for minimizing heat flow and condensation. A small proportion of the window market is replacing insulating spacers with Sashlite technology which has a molded sash with a groove that functions as a spacer and results in even greater efficiency and a lighter window (Collins, 2008; Sashlite,

2008). Finally, insulating frames can be made from many different materials including wood, aluminum-clad wood, fiberglass, and vinyl. Fiberglass and vinyl frames with insulation-filled cavities have the best energy efficiency performance in most climate zones (Hanlon, 2008).

Figure 2-2. Simplified High-Performance Window Value Chain

Source: CGGC, based on company annual reports, individual interviews, and company websites.

Figure 2-3. High-Performance Window Materials, Producing Countries, and Corresponding Components



Source: CGGC, based on company annual reports, individual interviews, and company websites.

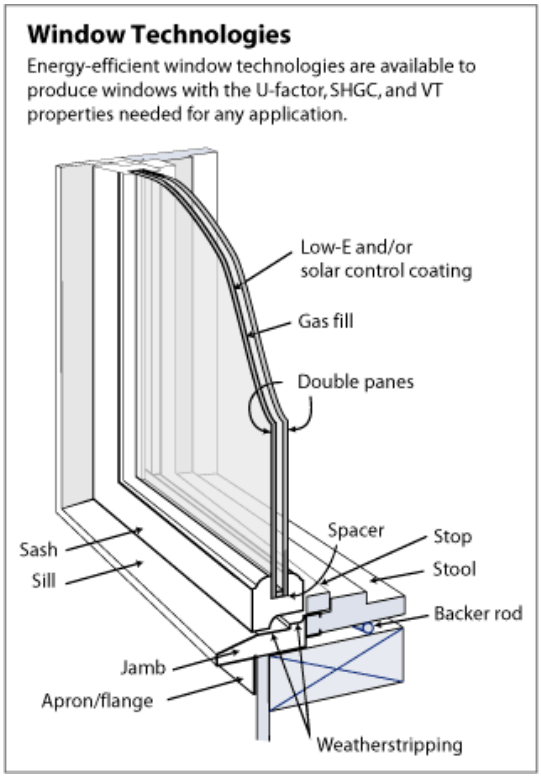
Figure 2-4. General Description of High-Performance Windows

Multiple Panes

Two panes of glass, with an air or gas-filled space in the middle, insulate much better than a single pane of glass. Some Energy Star-qualified windows include three or more panes for even greater energy efficiency, increased impact resistance, and sound insulation.

Improved Frame Materials

Wood composites, vinyl, and fiberglass frames reduce heat transfer and help insulate better.



Low-E Glass

Special coatings reflect infrared light, keeping heat inside in winter and outside in summer. They also reflect damaging ultraviolet light, which helps protect interior furnishings from fading.

Gas Fills

Some energy-efficient windows have argon, krypton, or other gases between the panes. These odorless, colorless, non-toxic gases insulate better than regular air.

Warm Edge Spacers

A spacer keeps a window's glass panes the correct distance apart. Today's warm edge spacers—made of steel, foam, fiberglass, or vinyl—reduce heat flow and prevent condensation.

Sources: Energy Efficiency and Renewable Energy. (2005) Window Selection. Retrieved June 17, 2008 from http://www.eere.energy.gov/consumer/your_home/windows_doors_skylights/index.cfm/mytopic=13370; ENERGY STAR. (2008b) Anatomy of an Efficient Window. Retrieved June 17, 2008 from http://www.energystar.gov/index.cfm?c=windows_doors.pr_anat_window

Each component of a high-performance window has many variations that directly impact the performance of the window. Therefore, Phase 2 ENERGY STAR criteria changes will likely impact component manufacturing companies. Coating and flat glass manufacturers may need to improve their coatings to lower the solar heat gain coefficient for windows targeted to warm, sunny climates. For colder climates, air gas fills may need to change to argon. Representative component manufacturers are listed in Table 2-1. Frames are often made on-site at the plant that assembles the finished window, as is the case for Pella, Jeld-Wen, and Milgard, three of the top window manufacturing firms. ENERGY STAR criteria will significantly affect the frame technology used by these firms. Manufacturers will likely switch to triple pane windows to meet criteria for products sold in northern climates. Accommodating the resulting additional weight may require product redesign for a stronger frame and hardware (J. Swanson, 2008).

Table 2-1. Representative Component Manufacturers

Component	Company	Location	Employees	Sales (USD million)
Gas Fills	Praxair	Danbury, CT	27,992	n/a
	Air Liquide	Paris, France	40,300	$16,151.9
	Air Products and Chemicals, Inc.	Allentow, PA	21,500	$10,037.8
	GKN plc.	Redditch, UK	42,100	$7,739.9
	Airgas	Radnor, PA	14,500	$4,017.0
	Linde, AG	Munich, Germany	51,017	$16,842.8
Low-E Coatings	Seki-Sui-Lec	Kita-Ku, Japan	19,211	$7,919.7
	Emirates Glass/Dubai Investment Group	United Arab Emirates, Dubai	1,633	$1,013.7
	Arkema, Inc.	Philadelphia, PA	600	$1,500.0
Insulating Spacer	Edgetech I.G., Inc.	Cambridge, OH	50	$29.1
	GED Integrated Solutions, Inc.	Twinsburg, OH	110	$40.0
	TruSeal Technologies, Inc.	Solon, OH	40	n/a
Flat Glass	AFG Industries, Inc. (subsidiary of AGC America, Inc.)	Kingsport, TN	380	$1,000.0
	Cardinal Glass Industries, Inc.	Eden Prairie, MN	5,500	$603.0
	Guardian Industries Corp.	Auburn Hills, MI	400	$5,330.0
	Pilkington North America, Inc.	Toledo, OH	2,972	$755.8
	PPG Industries, Inc.	Pittsburgh, PA	34,900	$11,206.0
	SCHOTT Gemtron Corp.	Sweetwater, TN	365	$140.0

Source: CGGC, based on company annual reports, individual interviews, and company websites.

Window Manufacturing

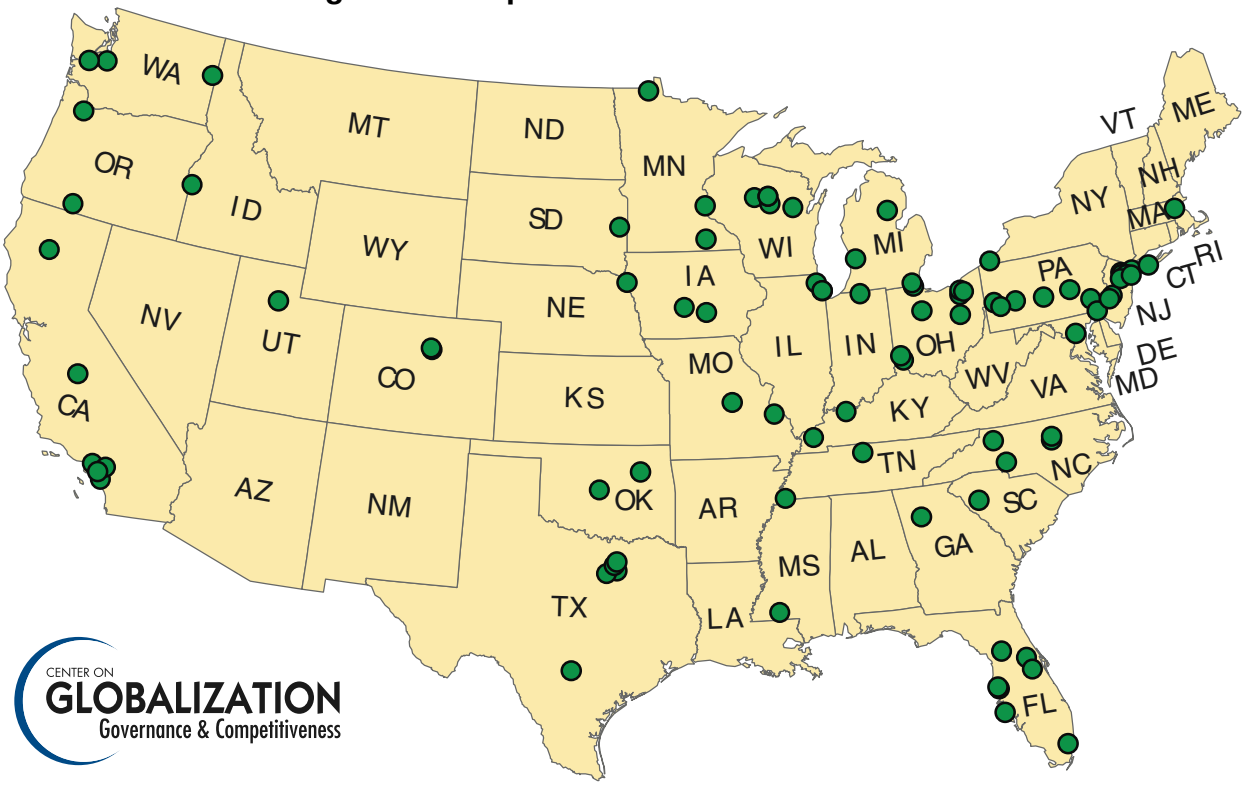
The fixed window manufacturers rated by the NFRC are located across the United States. The largest companies with the greatest market share are listed in Table 2-2. Figure 2-5 illustrates the locations of the 2008 *Window & Door* top U.S. window manufacturers (J. G. Swanson, 2008). They include Andersen, Jeld-Wen, Masonite International, and Pella. These firms focus mainly on window assembly but also manufacture the frames. They have the greatest capacity for research and development and offer a wide range of windows with varying levels of energy efficiency performance, including products that are not ENERGY STAR qualified. However, the demand for ENERGY STAR qualified windows has become so high that the majority of new windows sold meet ENERGY STAR criteria.

Table 2-2. U.S. Window Manufacturers

Company	Location	Employees	Sales
Andersen Corp.	Bayport, MN	14,000	More than $1 billion
Jeld-Wen, Inc.	Klamath Falls, OR	25,000	
Masonite International, Inc.	Canada	14,200	
Pella Corp.	Pella, IA	10,600	
Atrium Windows & Doors	Dallas, TX	6,000	$500 million to $1 billion
Fortune Brands	Deerfield, IL	4,000	
Marvin Windows & Doors	Warroad, MN	5,000	
MI Windows & Doors	Gratz, PA	3,500	
Milgard Windows & Doors	Tacoma, WA	5,000	
Ply Gem Industries	Kearney, MO	7,000	
Weather Shield Windows & Doors/ The Peachtree Cos., Inc.	Medford, WI	4,500	

Source: Swanson, 2008.

Figure 2-5. Top U.S. Window Manufacturers



Source: CGGC, based on Swanson, 2008.

End Use

High-performance windows are distributed to the end user through three different channels. The first is direct to the consumer from manufacturers. Depending on the manufacturer, direct sales can be a significant proportion of total sales. For example, 99% of Champion Window Manufacturing Company sales are direct to the homeowner (Champion, 2008). The second distribution channel for windows is from the manufacturer to a dealer, such as a stock building supply company. The dealer then sells to the consumer. Similarly, windows also are sold by the manufacturer to Big Box stores, like Lowe's and Home Depot, and then to the end user. Lastly, there is a three-step distribution process whereby the manufacturer sells to the wholesaler, the wholesaler sells to the dealer, and the dealer to the consumer. This last distribution process is less common because logistics improvements have allowed the value chain to skip the wholesaler (Collins, 2008).

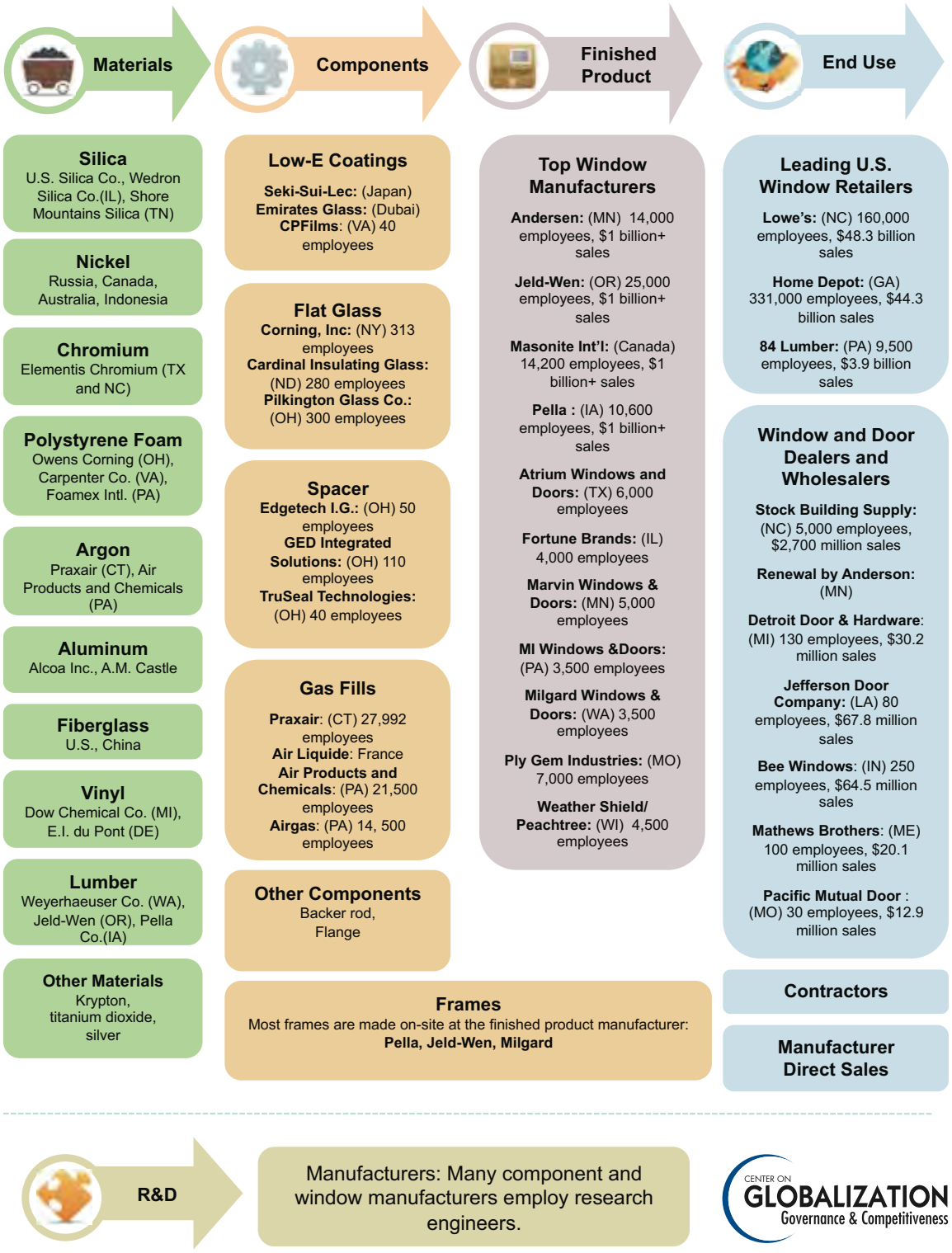
Case Study: Alpen Energy Group, LLC Grows by 50%

Alpen Energy Group, LLC in Boulder, Colorado, is a market leader in high-performance, high efficiency glass windows. The Heat Mirror films in its windows reduce heat transfer and improve window insulation. According to Building Green, LLC, Alpen's most energy efficient windows, which have an R-value of 10 and a U-factor of 0.10, are the highest performing in the world (BuildingGreen.com, 2008). Alpen was named one of the 2007 Top-Ten Green Building Products by BuildingGreen, publisher of GreenSpec and Environmental Building News. The company experienced 50% growth in 2007 (Clarke, 2008) and was acquired by Serious Materials in June 2008 (Serious Materials, 2008). Serious Materials plans to mainstream these highest-performing windows and will market them across the United States and internationally.

Conclusion

There are multiple drivers demanding greater energy efficiency performance in the windows market, and these code and criteria changes are expected to affect all levels of the value chain. Component suppliers will see an increase in demand for their most efficient products and may feel incentivized to develop new, more efficient components. Window manufacturers may have to retool production by increasing the number of triple pane windows produced and consider product redesign to improve efficiency. These changes will be challenging in the current economic environment. In 2007, the housing downturn led a number of window manufacturers, including Atrium, Pella, and Masonite, to stop production at some facilities (J. G. Swanson, 2008). Furthermore, manufacturers across each step of the value chain will have to consider whether in some cases incremental performance improvements may have significantly higher production costs. Determining whether customers will be willing to pay for these advances will impact the extent to which newer products will be manufactured extensively within the industry. Nonetheless, changes in ENERGY STAR criteria and the International Energy Conservation Code are likely to incentivize new research and development and increase the demand for even more efficient windows across the country.

Figure 2-6. High-Performance Window Value Chain, with Illustrative Companies



Source: CGGC, based on company annual reports, individual interviews, and company websites.

References

BuildingGreen.com. (2008). Alpen Fiberglass Windows. Retrieved October 6, 2008, from http://www.buildinggreen.com/auth/productDetail.cfm?ProductID=3653

Center for Sustainable Building Research. (2008). *The Efficient Windows Collaborative Builder Toolkit*: Regents of the University of Minnesota, Twin Cities Campus.

Champion. (2008). Champion Products. Retrieved October 6, 2008, from http://champion.webfeat.net/products.aspx

Clarke, Robert. (2008). President, Alpen Energy Group, LLC. Personal communication with Environmental Defense Fund Staff. May 7.

Collins, Michael. (2008). Vice President, Jordan, Knauff & Company. Personal communication with CGGC Staff. September 29.

Efficient Windows Collaborative. (2008). Benefits: Energy & Cost Savings. Retrieved June 23, 2008, from http://www.efficientwindows.org/energycosts.cfm

Energy Efficiency and Renewable Energy. (2005) Window Selection. Retrieved June 17, 2008 , from http://www.eere.energy.gov/consumer/your_home/windows_doors_sky lights/index.cfm/mytopic=13370

ENERGY STAR. (2008a). ENERGY STAR staff. Personal communication with CGGC Staff. June 17.

---. (2008b). Anatomy of an Efficient Window. Retrieved June 17, 2008 from http://www.energystar.gov/index.cfm?c=windows_doors.pr_anat_window

---. (2008c). Residential Windows, Doors, and Skylights Key Product Criteria. Retrieved September 10, 2008 from http://www.energystar.gov/index.cfm?c=windows_doors.pr _crit_windows

Hanlon, Scott. (2008). Laboratory Accreditation Program Manager, National Fenestration Ratings Council. Personal communication with CGGC Staff. June 16.

Home Depot. (2008). Customer Service staff, Home Depot. Personal communication with CGGC Staff. October 10.

National Fenestration Rating Council. (2008a). Certified Products Directory Search. Retrieved July 1, 2008, from http://cpd.nfrc.org/pubsearch/psMain.asp

---. (2008b). The NFRC Label. Retrieved June 12, 2008, from http://nfrc.org/label.aspx

Sashlite. (2008). Sashlite: Performance Through Innovation. Retrieved October 1, 2008, from http://www.sashlite.com/

Serious Materials, Inc. (2008, June 24). Serious Materials Acquires Alpen Windows. Retrieved October 6, 2008, from http://www.quietsolution.com/html/pr_alpen.html

Swanson, John. (2008). Editor/Associate Publisher, Window & Door. Personal communication with CGGC Staff. September 30.

Swanson, John G. (2008, February 1). Top Manufacturers of 2008: It's Been a Tough Year. *Windows & Doors*.

U.S. Department of Energy. (2008). *Windows, Doors, and Skylights: Draft Criteria Analysis.* ENERGY STAR Program. Retrieved October 28, 2008, from http://www.energystar.gov/ia/ partners/prod_development/archives/downloads/windows_doors/WindowsDoorsSkylights _DraftCriteriaAnalysis_CORRECTED.pdf