Manufacturing Climate Solutions

Carbon-Reducing Technologies and U.S. Jobs

by

Gary Gereffi, Kristen Dubay and Marcy Lowe

Center on Globalization, Governance & Competitiveness, Duke University

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A Letter from the Sponsors:
Building and Construction Trades Department (AFL-CIO), Industrial Union Council (AFL-CIO), International Brotherhood of Boilermakers, United Association of Plumbers and Pipefitters, and Environmental Defense Fund

The United States today faces **two major challenges and a choice of two futures**. Our challenges: An economic downturn occurring at the same time we are seeing the early impacts of unchecked global warming. Our **futures**:

1. **take no action on climate and follow business as usual**, a future which is already being altered significantly by the cost of relying on imported oil and one which will entail huge costs related to the impacts of droughts, floods and other climate-related disruptions; or

2. **put American ingenuity and skills to work to solve climate change**, creating a huge market driver in the United States for climate solutions—with all the necessary labor and materials to make it happen.

The U.S. Congress is considering various legislative proposals to stabilize greenhouse gas (GHG) emissions and prevent the dangerous consequences of global warming. These proposals would catalyze a national transition to a low-carbon economy. A frequent concern for workers and business is "What are the economic implications of this transition?" ***Manufacturing Climate Solutions*** describes the economic opportunity inherent in a carbon-constrained world, a world where massive investments in climate solutions and related infrastructure will be needed.

Climate Solutions=Jobs

While some seek to pit the environment against economic growth, we see economic opportunity in the solutions to the climate crisis. Many business analysts agree. They believe the economic leaders of tomorrow will be companies that manage their resources efficiently and take the lead in developing and commercializing innovative clean technologies.[1] These will also be the companies most able to create well-paying jobs and ensure that current jobs are secure.

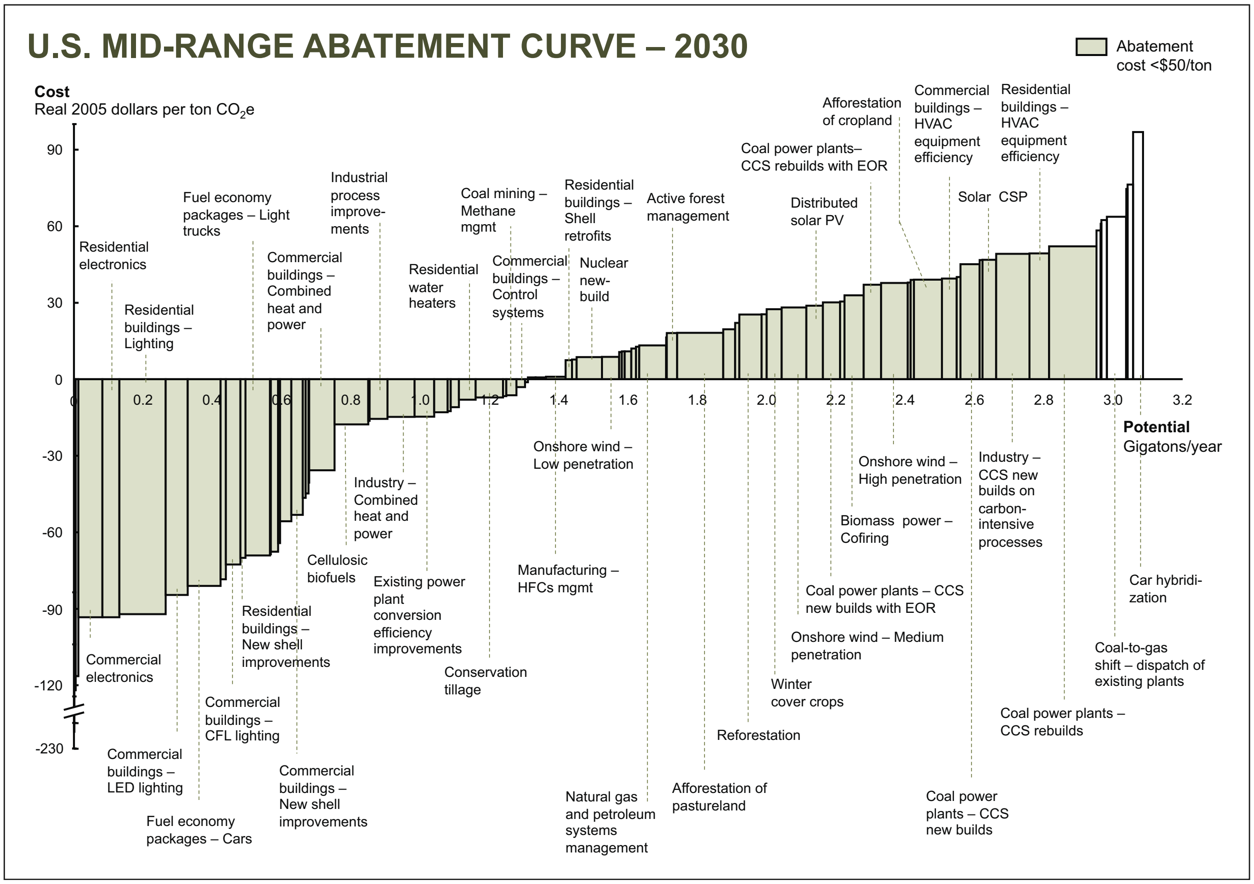
The demand for climate solutions will create—very directly—manifold job opportunities in many sectors, from core industries such as renewable and energy efficiency businesses to traditional areas such as construction trades, pipefitting and electrical jobs. Equally important, though, is the vast supporting cast of industries that make these low carbon end products possible. Consider just one example: Demand for wind turbines is rising, and that's good for turbine manufacturers. But the economic benefits don't stop there: A wind turbine contains 8,000 parts, so demand for each one of these parts is rising, too. Following the links in the "value chain" for low carbon technologies reveals that these technologies have vast potential to grow sectors of our economy that aren't traditionally associated with environmental protection.

The McKinsey 250— A Road Map of Economic Opportunity

McKinsey & Company recently identified some 250 greenhouse gas reduction solutions (more concisely "climate solutions") in their report *Reducing U.S. Greenhouse Gas Emissions: How*

Much at What Cost? Nearly 80% of these solutions are commercially available today. Together, they provide a road map for solving climate change. The McKinsey 250 also paints a picture of **vast economic opportunity**, given that each climate solution creates significant positive ripple effects throughout the economy in the labor and materials needed to supply low carbon technologies and products.

Technologies and Products for Reducing Greenhouse Gas Emissions



Source: *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost*? conducted by McKinsey & Company and published jointly with the Conference Board in November, 2007, available at: http://www.mckinsey.com/clientservice/ccsi/greenhousegas.asp

Hidden Economic Opportunities: Value Chains

To illustrate the economic opportunities "hidden" in the value chains for low-carbon technologies, we engaged Duke University's Center on Globalization, Governance & Competitiveness. They mapped out the value chains of five low carbon technologies and products: LED lighting, high performance windows (for energy efficiency), anti-idling technology for heavy duty trucks, concentrated solar, and Super Soil Systems (for hog waste management). This report provides detailed information on how these different climate solutions—all of them with the exception of Super Soil Systems commercially available today—are manufactured. Additional value chain studies in this series will be forthcoming and available at: http://www.cggc.duke.edu/environment/climatesolutions.

Real-World Success Stories

These new technologies and products may be funded by Silicon Valley and Wall Street, but the bricks and mortar jobs will be in the manufacturing heartland of America, where hundreds of companies are already benefitting from demand for renewable energy and energy efficiency. Success stories highlighted in this report include Cree, Inc. in Durham, NC, the U.S. leader in LED lighting, an energy efficient lighting technology. Cree has experienced tremendous growth in recent years, and the company's revenue grew from $228 million in 2003 to $493 million in FY2008. Cree holds patents on a large number of LED technology improvements, and as demand for its innovative products has increased, the company's work force has nearly quadrupled, from 893 people in 2002, to nearly 3,200 regular full and part-time employees in 2008. Thermo King Corporation, headquartered in Bloomington, MN, manufactures auxiliary power units (APUs), a key anti-idling technology for trucks. They are one of the top U.S. APU manufacturers, with 3,900 employees and $2.9 billion in sales for 2007. Infinia Corporation is an energy technology company that developed an innovative solar dish system, called the Infinia Solar System, specifically designed to be mass manufactured by U.S. auto manufacturers.

A U.S. Manufacturing Renaissance?

The transition to a low carbon economy may provide the best hope for a U.S. manufacturing renaissance. Some estimate the opportunity to be over 5 million jobs.[2] Other studies focus on traditional skill sets that will be needed.[3] We hope the value chain studies provided here add to the growing understanding of economic opportunity in a carbon constrained world.

In the end, jobs are created by individual businesses. Focusing on potential new market opportunities for businesses that already exist—which can be combined with energy efficiency strategies to help those same firms manage energy costs[4]—can open a clear pathway to job security.

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[1] See The Council on Competitiveness, Energy Security, Innovation & Sustainability Initiative and Harvard Business Review, "Forethought: Climate Business, Business Climate," October, 2007.

[2] Apollo Alliance, http://apolloalliance.org/blog/?p=149

[3] Robert Pollin & Jeannette Wicks-Lim, "Jobs Opportunity for the Green Economy: A State by State Picture of Occupations That Gain from Green Investments," University of Massachusetts, June 2008. http://www.peri.umass.edu/fileadmin/pdf/other_publication_types/Green_Jobs_PERI.pdf

[4] Three areas in particular shape how businesses can strategically respond to climate change: the ability to identify new market opportunities, the effectiveness of energy efficiency initiatives, and the re-tooling of logistics and transportation. This report illustrates the first of these three areas. But energy efficiency and logistics management offer equally important opportunities to enhance competitiveness. See The Council on Competitiveness, Energy Security, Innovation & Sustainability Initiative and Harvard Business Review, "Forethought: Climate Business, Business Climate," October, 2007.

Introduction

We live in an era of globalization, and there is great concern about how this affects local jobs and economic competitiveness. In addition, there is a rapidly growing awareness of the environmental impact of current development patterns, and a particular focus on the value of "clean technologies" to assure sustainable growth in the future. ***Manufacturing Climate Solutions*** is an effort to look more deeply at the linkages between low-carbon technologies and U.S. jobs.

At the Center on Globalization, Governance & Competitiveness (CGGC) at Duke University, we look at globalization largely through the lens of global supply chains. More specifically, we apply a "value chain" framework to industry studies, fleshing out the more familiar supply chain approach with additional layers of information about how and where higher value activities and industrial upgrading can occur in global supply chains.

In this cooperative enterprise undertaken with the Building and Construction Trades Department (AFL-CIO), Industrial Union Council (AFL-CIO), International Brotherhood of Boilermakers, United Association of Plumbers and Pipefitters, and Environmental Defense Fund, we asked: "What are the U.S. job opportunities in technologies that can reduce carbon emissions?"

We set out to study five very different carbon-reducing technologies—LED lighting, high-performance windows, auxiliary power units for trucks, concentrating solar power, and Super Soil Systems (a new method for treating hog wastes). These topics run the spectrum from a well-established product (windows) to a new solution (Super Soil). Some are in wide use today, while others are still struggling to get costs down, but all are proven technologies that reduce greenhouse gas emissions.

We offer these five industry analyses as a step in building an understanding of the role U.S. manufacturing can play in a wide array of climate solutions. The information in these chapters is gathered from a variety of secondary sources and direct company interviews. We have sought to present the following:

- a working understanding of each technology, broken down into its main materials and components
- a view of the value chain, encompassing main components, end products, and companies, identified with each technology
- a picture of the various types of labor involved in manufacturing and installation
- a representative list of firms and a depiction of the market structure in which they operate

For each technology, we present a simple description and diagram, a value chain, a table of relevant companies, and a map of relevant firms in the United States. With these we hope to provide a snapshot of the linkages and opportunities in these industries for U.S. manufacturing and construction jobs. At the same time, we recognize that industries are changing rapidly and continuously in the global context, and this is only a small piece of a complex and ever-shifting puzzle.

Our research at CGGC has been carried out with the help of Gloria Ayee, Stacey Frederick, Lorenzo Gui, Karolina Haraldsdottir, Jess Robinson, and Yuber Romero. We would like to thank these researchers for their valuable contributions, as well as Gloria Ayee, Karina Fernandez-Stark, Joy Stutts, and Gary Thompson for their production and design assistance. We are also grateful to the many industry sources who provided us with information and interviews and the expert reviewers who took time to lend their insights to our drafts. A special note of appreciation goes to Alex Salkever, who made additional editorial suggestions on our reports. Thanks also to Jackie Roberts at Environmental Defense Fund and our union partners.

Although ***Manufacturing Climate Solutions*** is the sum of the efforts of all of these people, any errors are the sole responsibility of the authors. The views expressed here are those of the authors and do not necessarily reflect the views of any of our sponsors or collaborators.

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Kristen Dubay
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CHAPTER 1

LED Lighting

by

Gary Gereffi and Marcy Lowe

Contributing CGGC researchers:

Gloria Ayee, Stacey Frederick and Lorenzo Gui

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Summary

Light-emitting diodes (LEDs) are a semiconductor technology whose application to general-purpose lighting is rapidly growing, with significant potential for energy savings. LED devices perform exceptionally well in lab conditions, proving up to 10 times more efficient than incandescent lights. These impressive laboratory results can be diminished in actual use in a lighting fixture because of remaining technical and design challenges. However, LED lighting products are now available that are three to four times more energy efficient than incandescent bulbs and last up to five times longer than compact fluorescents, so far the longest-lasting lighting alternative. Several large, well established firms in the traditional lighting industry have been working to resolve performance issues related to lamp and fixture design. Yet to be resolved is the cost issue; while LED or "solid state" lighting is rapidly dropping in price, it remains several times more expensive than traditional lights.

The market for general-purpose LED lighting is currently very small, but it is growing rapidly as the technology improves and costs go down. In 2007 the global LED market was $4.6 billion, and the general lighting portion represented only an estimated 7% of these sales, behind LEDs for mobile appliances (44%), signs and displays (17%), and automotive uses (15%). Within the global lighting market, estimated at an annual $40-$100 billion—roughly one-third of which consists of light bulbs—LED-based lighting represents an even smaller portion: an estimated .01%. Still, sales of LED-based lighting products have grown 40–60% annually in recent years, and they are expected to reach $1.6 billion by 2012.

Each of the three largest players in the traditional lighting market, Philips (the Netherlands), OSRAM (Germany), and General Electric (United States), has developed a strong presence in LED lighting through joint ventures and acquisitions of specialty firms. While these traditional lighting giants have so far played a leading role, they face competition from new LED firms, especially in Japan, Taiwan, South Korea, and other Asian countries.

A key technology leader in LED lighting is Durham, North Carolina-based Cree, Inc. During the 2008 Beijing Olympics, the Bird's Nest stadium and Water Cube aquatic center were lit by 750,000 red, blue, and green LED chips manufactured in Durham by Cree. The company has experienced tremendous growth in recent years, quadrupling its work force to nearly 3,200 workers since 2002. The company holds patents on a large number of LED technology improvements. Cree continues to manufacture these innovations domestically even though other semiconductor manufacturing has largely moved overseas; this way it can protect both its intellectual property and its high quality standards, two major factors in its success. Cree's experience highlights the importance of innovation, research and development in an environment of steady job loss in U.S. manufacturing.

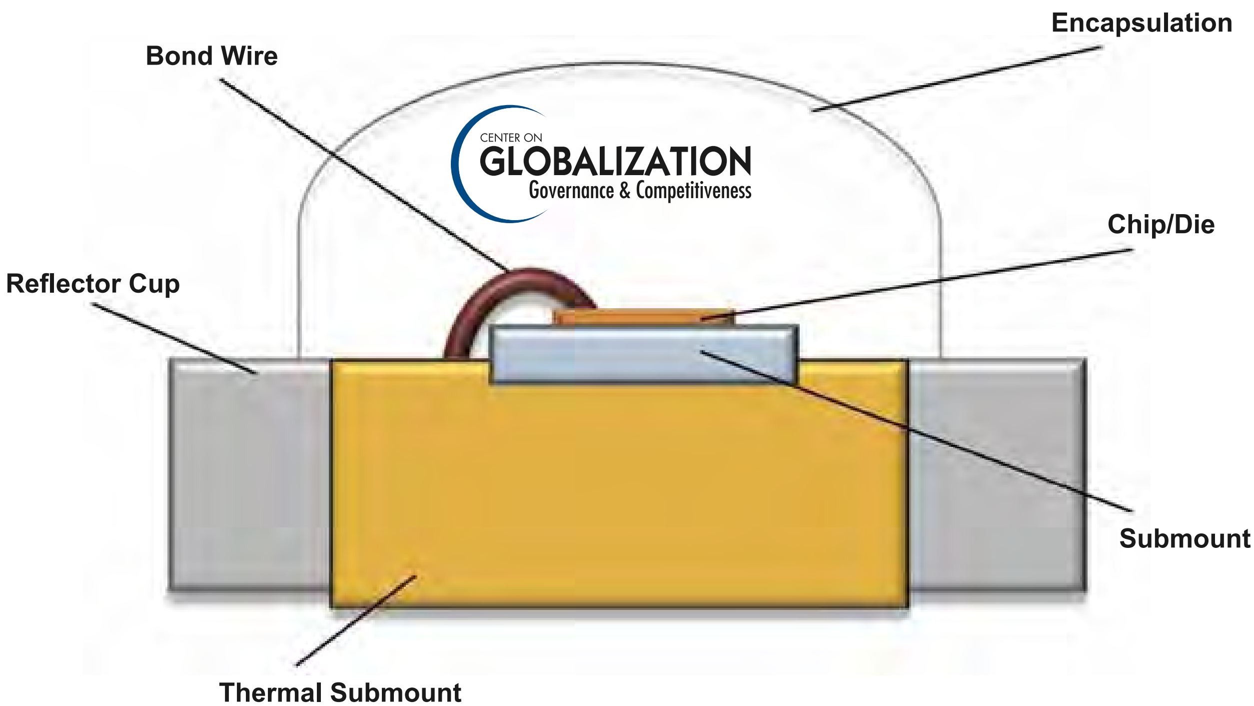
Introduction

Light-emitting diodes (LEDs) are semiconductor devices that convert electricity to light. LED lighting is also called "solid state lighting" because the light is emitted from a solid object—a block of semiconductor material—rather than from a vacuum or gas tube, as in traditional incandescent or fluorescent lights. LED technology has existed in specialized applications since the 1960s. Unlike incandescent or fluorescent lights, LEDs are not inherently white. "White" light is actually a mix of wavelengths in the visible spectrum, whereas LEDs emit light in a very narrow range of wavelengths, and so are ideal for producing colored light (U.S. DOE, 2008).

To date LEDs have been used widely to create the highly efficient red, green, and blue lights in devices including digital clocks, watches, televisions, dashboards, and traffic lights. In 1993 Japan's Nichia Corporation devised a way to create white light from a single diode. This discovery initiated the ongoing quest to develop an LED-based technology that can produce a high-quality, "warm" white light suitable for general illumination (ToolBase Services, 2008).

LED lighting technology has its own terminology distinct from traditional lighting. The light-emitting part of an LED lighting product, the chip, is a very small square of semiconductor material, (also called a die). This chip is "packaged" with several components within an epoxy dome. Unlike traditional lighting products, LED lighting does not involve a bulb. Instead, a number of LED packages are clustered in a housing to form an LED lamp. An LED lamp cannot simply be screwed into a traditional lighting fixture like an incandescent or fluorescent bulb; instead, it must be integrated into a specially designed lighting fixture, or luminaire—although the installation skills needed to install an LED luminaire are the same as for traditional lighting fixtures. A simple diagram of an LED package—the basis for an LED lamp—is shown in Figure 1-1.

Figure 1-1. Example of LED Package With Major Components



Source: CGGC, based on industry sources.

The number of solid state lighting products is growing rapidly, including recessed "downlights" (under-cabinet and ceiling fixtures from which light is directed straight downward), portable lights, lights for retail displays, and outdoor lighting for streets and parking lots (U.S. DOE, 2008a). LED lighting products have considerable potential to reduce electricity consumption and the associated greenhouse gas emissions. In lab conditions, current LED devices are up to 10 times more efficient than incandescent lights. However, while incandescent and compact fluorescent lights are measured "bare bulb," LED-based lights are measured in the fixture, or luminaire—where their efficiency is diminished because of several technical issues. Even given this difference, the best LED lighting products can be three to four times more energy efficient than incandescent bulbs, producing 45-50 lumens per watt (lm/W), compared to typical incandescents (12–15 lumens per watt) and compact fluorescent bulbs (at least 50 lumens per watt). The best solid state downlights now available produce 60 lumens per watt (Pattison, 2008).

Figure 1-2. LED Street Light and LED Indoor Lighting

Source: U.S. DOE, 2008d

Source: U.S. DOE, 2008c

Another area in which LEDs have major potential is in the product's lifespan. The devices themselves have exceptionally long life, but this can be considerably diminished in an inadequately designed fixture. Traditional fixtures are designed to take the heat generated by an incandescent bulb and radiate it outward. The heat generated by an LED must be conducted away from the device, or it will fail prematurely—but this is a significant engineering challenge, because the heat must be conducted in the opposite direction from the light output (Pattison, 2008). Nonetheless, a high-quality LED lighting product in a well-designed fixture can have a dramatically longer life span than traditional lighting, with a useful life of 30,000 to 50,000 hours under normal use, compared to 10,000 hours for comparable compact fluorescents and 1,000 hours for typical incandescent lamps (U.S. DOE, 2008a).

McKinsey & Company estimates that LED lighting in commercial applications expected to be available in 2015—along with advanced fluorescents (super T8 systems)—have the potential to reduce greenhouse gas emissions 110 million tons by the year 2030 (McKinsey & Company and Conference Board, 2007). However, the quality of currently available LED lighting products varies widely, with the poorest-performing white LEDs yielding only slightly better efficiency than incandescent lamps. Makers of LED devices are focusing on creating a high-quality, diffuse beam of white light similar to that cast by traditional incandescent, halogen, and fluorescent light bulbs, while traditional lighting manufacturers are facing a steep learning curve to accommodate LED lamps adequately in light fixture design. Still, the principal remaining issue is the cost of solid state lighting products. While dropping rapidly, the cost of LEDs is several times higher than incandescent and fluorescent lamps. Although much of this cost can be recouped in energy savings and avoided lamp replacements over the product's lifetime, the upfront cost puts off many consumers and businesses.

Meanwhile, efforts are being made to develop new standards, test procedures, and rating systems to keep up with the quickly changing market (U.S. DOE, 2008b). The U.S. Department of Energy's much-anticipated ENERGY STAR Solid-State Lighting program, a new labeling system similar to the more general set of standards for energy efficient consumer products, went into effect on September 30, 2008 (LEDs Magazine, 2008b).

The Department of Energy (DOE) has also recognized the need to support the development of solid-state lighting with a strong research and development (R&D) program. By January 2008, DOE-funded research projects had resulted in 18 solid-state lighting patents (U.S. DOE, 2008e). In FY2007 the program received $30 million in congressional appropriations, and the current value of investment contracts is $74.8 million (Wright, 2008). According to a comparison of DOE forecasts versus actual progress, the performance of LED solid-state lighting is improving much more rapidly than anticipated, and this trend is expected to continue through 2015. Analysts attribute the rapid progress in part to strong support provided by the DOE program along with intensive efforts of innovative U.S. firms, including Philips Lumileds and Cree (Wright, 2008).

LED Lighting Value Chain

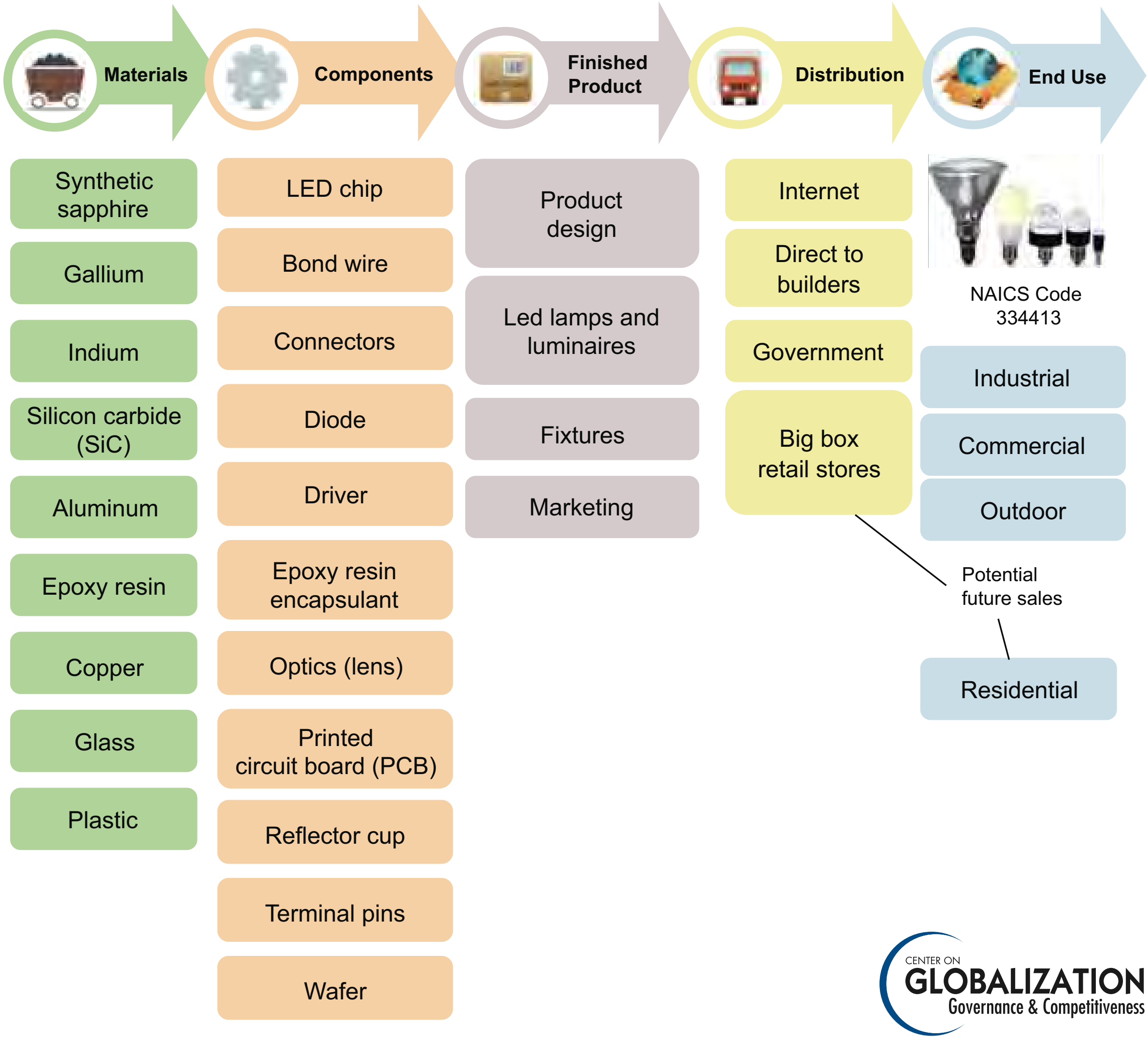
For this report we have divided the LED lighting value chain into five segments: materials, components, finished product, distribution, and final sales (see Figure 1-3). A more complete value chain with illustrative company information appears at the end of this chapter.

The major U.S. and non-U.S. firms involved in the LED lighting industry span, to varying degrees, the manufacture of LED chips, LED "lamps," and "luminaires," (fixtures), which typically integrate a number of LED lamps. Solid state lighting manufacture encompasses product design, product manufacture, and marketing and selling. Many Asian firms do the product design and manufacture for original equipment manufacturer (OEM) companies that market and sell the product under their own brand. Companies in North America and Europe, in contrast, tend to do product design, marketing and selling, but—with the notable exceptions of Cree, Philips Lumileds, and a number of smaller firms—many outsource the manufacturing to Asian subcontractors (Scheidt, 2008a).

To date, LED general-purpose lighting products have not been sold in retail stores. Instead, LED distribution has occurred primarily through Internet sales and direct sales to businesses and builders. For example, Cree has made volume shipments to significant building projects including corporate campuses, hotels, and restaurants. These large businesses find the economics of LED-based lighting increasingly compelling, especially since much of their lighting is on most or all of the time, and frequent replacement of traditional bulbs is expensive. Texas-based United Supermarkets has retrofitted refrigerated display cases in all of its 47 stores with a GE Lumination LED lighting product (GE Lumination, 2008). Recently Wal-Mart Stores Inc. decided to use LED lighting products in the refrigerators and freezers of all 4,200 of its U.S. stores, and it is now testing LED lights for store parking lots (Krieger, 2008).

Cree is also partnering with five universities, including the University of California at Santa Barbara and Tianjin Polytechnic University in China, to use LED lighting in offices, dormitories, parking garages, and other campus facilities (Cree Inc., 2008d). In another Cree-initiated program, "LED City," governments partner with industry to put LED lighting in U.S. municipal infrastructures. In the case of one participant city, Ann Arbor, Michigan, "Maintenance savings far outstrip the costs, at a 4.4-year payback" (U.S. DOE, 2008f).

Figure 1-3. Simplified LED Lighting Products Value Chain



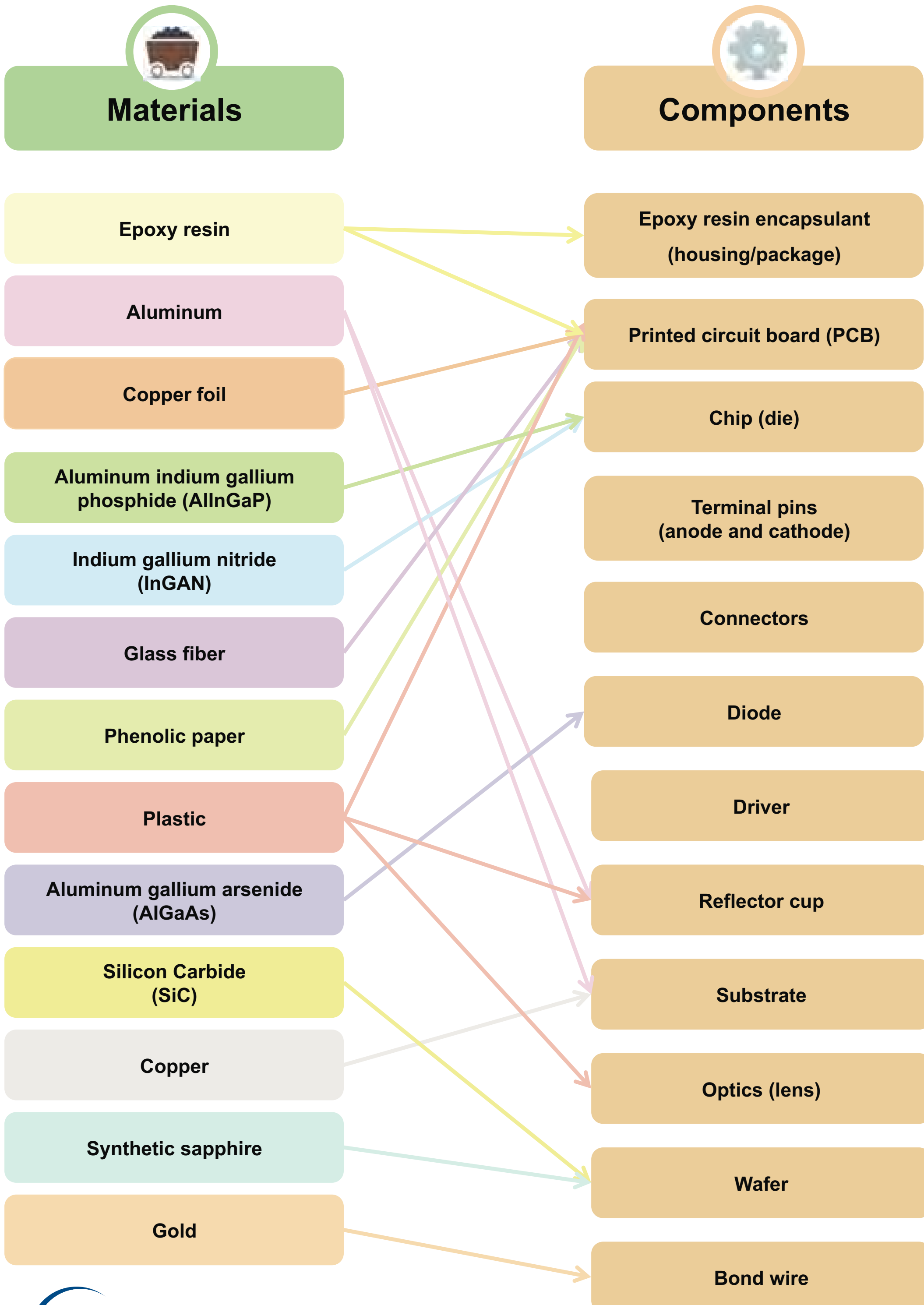
Source: CGGC, based on company websites and interviews.

Materials and Components

LEDs are made from a variety of semiconductor materials, including different combinations of gallium, indium, arsenic, nitrogen, and phosphors. A partial list of the common compounds used appears in Figure 1-4, along with resins, plastics, and metals associated with the other major components in an LED package. LEDs do not contain mercury, a toxic substance that is found in small amounts in compact fluorescent bulbs.[1] Among the major LED materials, gallium (a main-stay of the electronics industry) is the most heavily used, especially for blue LEDs (Moskalyk, 2003). Aluminum is the most cost-effective material to recycle, suitable to be used again and again without loss of quality.

[1] Compact fluorescent bulbs contain a small amount of mercury, which can be released if the bulb is broken. However, it is important to note that efficient compact fluorescents, by saving electricity, reduce mercury emissions from coal-burning power plants. According to the Environmental Protection Agency (EPA), “if all 290 million CFLs sold in 2007 were sent to a landfill (versus recycled, as a worst case), they would add 0.13 metric tons, or 0.1%, to U.S. mercury emissions caused by humans” (U.S. DOE ENERGY STAR, 2008).

Figure 1-4. LED Package Components and Corresponding Materials*



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*Not an exhaustive list.

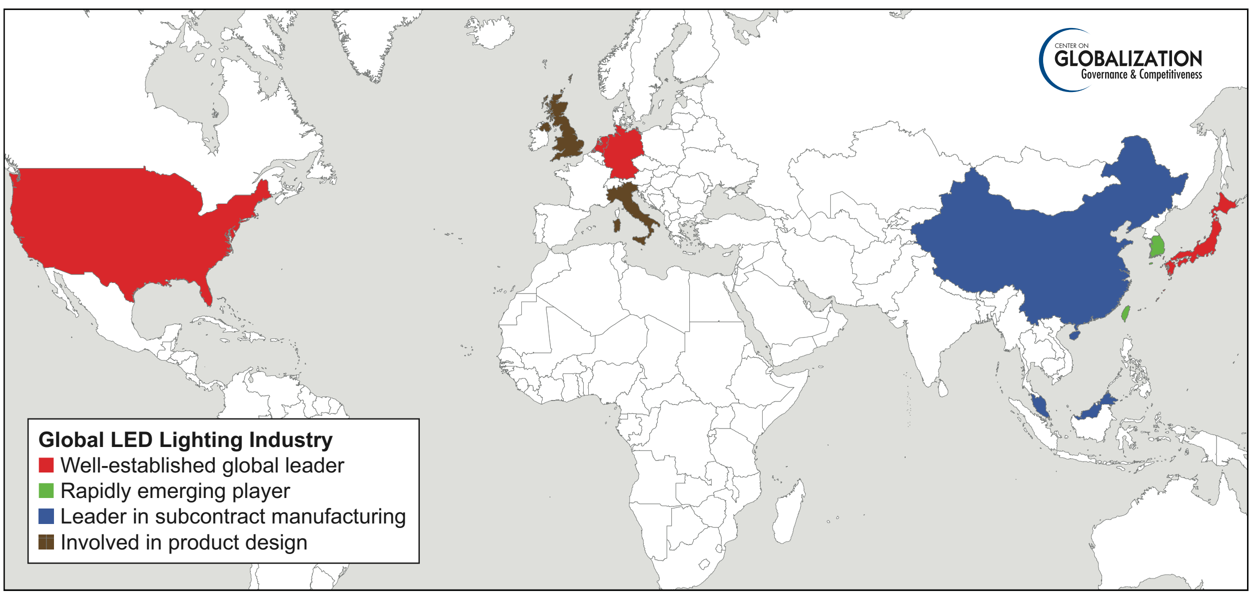
Sources: CGGC, based on company websites, interviews, LEDs Magazine, 2008a.

LED Lighting Market

The market for LEDs for general lighting purposes is currently very small, but it is growing rapidly as the technology improves and costs go down. In 2007 the global LED market was $4.6 billion, and the general lighting portion represented only an estimated 7% of these sales, behind mobile appliances (44%), signs and displays (17%), and automotive (15%) (LEDs Magazine, 2008c). Within the global lighting market, estimated at $40–$100 billion—roughly one-third of which consists of light bulbs—LED lighting represents an even smaller portion: an estimated .01% of sales (Sanderson et al., 2008). To date, commercial and outdoor applications have figured most prominently in LED lighting, ranging from retail store illumination to street lights. Residential applications are still largely under development. Still, sales of LED-based general-purpose lighting products have grown 40-60% annually in recent years, and they are expected to reach $1.6 billion by 2012 (Krieger, 2008).

Three large players have traditionally dominated the general lighting market: Philips (the Netherlands), OSRAM (Germany), and General Electric (United States). Each of these has developed a strong presence in LED lighting through joint ventures with, and acquisitions of, specialty firms. Philips, for instance, has a large facility, Lumileds, in California and is a major manufacturer of LED chips for use in the company's own packaged LED lighting products; it also sells packaged chips to other firms. OSRAM is a top manufacturer of LED components, as is General Electric, under its Ohio-based subsidiary Lumination (formerly Gelcore). While these traditional lighting giants have so far played a leading role in the LED general lighting industry, they face competition from new LED lighting firms, especially in Japan, Taiwan, Korea, and other Asian countries.[2]

Figure 1-5. Global LED Lighting Industry



Source: CGGC, based on industry sources and interviews.

An overview of the distribution of activity in the global LED lighting industry is found in Figure 1-5. Leading firms are found in Japan, the United States, and Europe (especially Germany

[2] For a thorough analysis of the development of the LED lighting industry, see Sanderson et al., 2008.

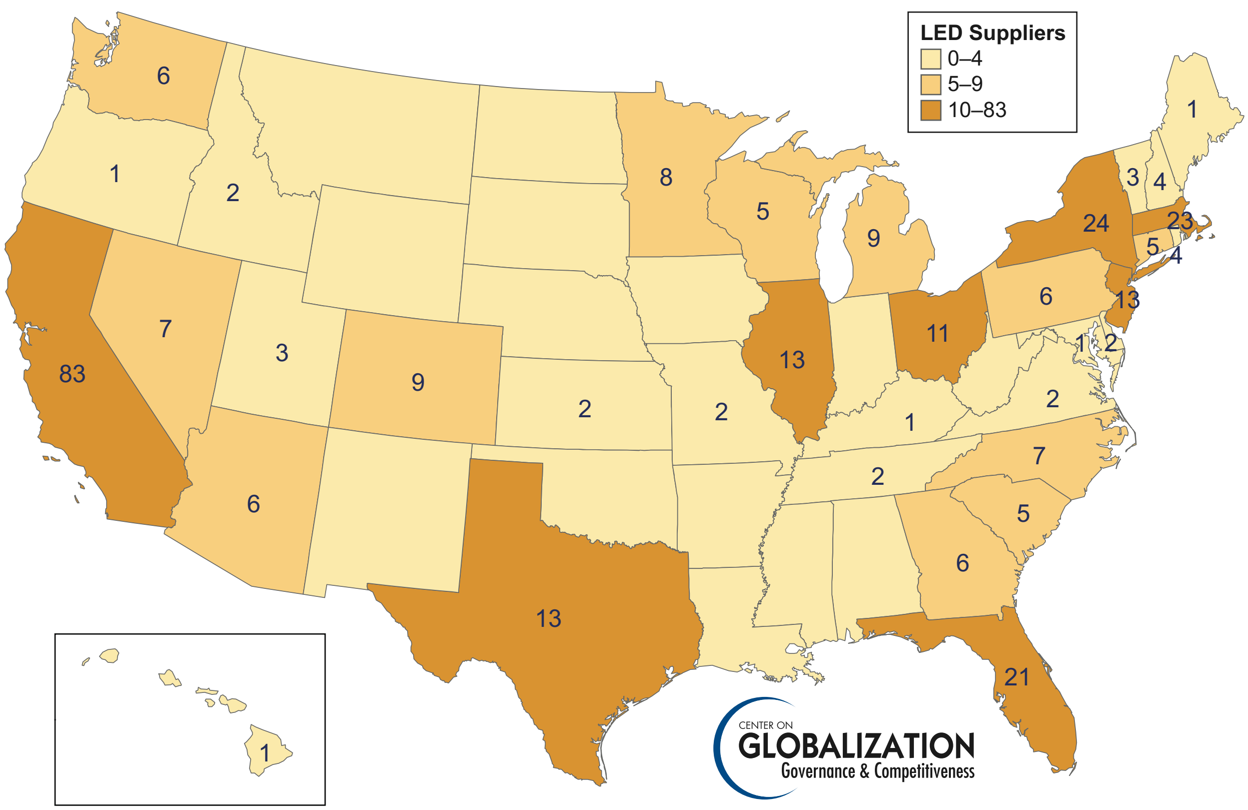
and the Netherlands). Rapidly emerging leaders are found in Taiwan and South Korea, and important players in LED product design are found in the United Kingdom and Italy (Sanderson et al., 2008). The leading country for subcontract manufacturing of LEDs is China, followed by Malaysia (Scheidt, 2008a).

Illustrative Companies

A list of important global and U.S. firms in LED lighting is found in Table 1-1. The world's leading LED firms include large suppliers that make a number of diverse semiconductor products, including LEDs. These firms include Vishay (U.S.), Toyoda Gosei (Japan), and Avago (U.S.). Other lead firms include those that focus solely on LEDs, such as the world leader, Nichia (Japan), and the top U.S. manufacturer of LEDs, Cree, Inc. in Durham, North Carolina. The LED market encompasses a large number of new entrants, especially from Taiwan, many of which are specialty firms that keep costs down by specializing in one part of the value chain (Sanderson et al., 2008).

The geographic distribution of U.S. LED supplier firms is found in Figure 1-6. These firms are spread throughout the United States, with the highest concentration of components and fixture involvement in California. Additional leading chip and component supplier firms are concentrated in North Carolina, Illinois, and Michigan. Small firms with roles in LED lighting, especially fixtures, are geographically dispersed.

Figure 1-6. 311 U.S. LED Supplier Firms, 2008



Source: CGGC, based on LEDs Magazine, LED Suppliers Directory 2008.

Table 1-1. LED Lighting: Illustrative Global and U.S. Firms[3]

Company	State/Country	Total Employees	Sales (USD mil)	Manufacturer Type
Toyoda Gosei	*Japan*	*27,036*	*$6,612.0*	LED Chips
Nichia Corporation	*Japan*	*4,600*	*n/a*	
OSRAM Opto Semiconductors	CA, *Germany*	*3,500*	*$621.2*	
Veeco	NY	1,216	$403.0	
Epistar Corporation	*Taiwan*	*3,207*	*$310.7*	
Cree	NC	3,168	$394.1	
Seoul Semiconductor	*S Korea*	*984*	*$284.2*	
Philips Lumileds	CA, *Netherlands*	300	$75.0	
Seikoh Giken	*Japan*	*853*	*$62.5*	
BridgeLux	CA	13	$3.0	
KLA-Tencor	CA	6,000	$2.7	
SemiLEDs	*Taiwan,* ID	*n/a*	*n/a*	
Toyoda Gosei	*Japan*	*25,360*	*$5,796.0*	LED Components
Everlight Electronics	*Taiwan*	*2,768*	*$309.0*	
Nichia Corporation	*Japan*	*4,600*	*n/a*	
OSRAM Opto Semiconductors	CA, *Germany*	*3,500*	*$621.2*	
Cree	NC	3,168	$394.1	
Dow Corning Corporation	MI	1,281	$2,205.0	
Supertex	CA	410	$83.0	
Power Integrations	CA	385	$191.0	
Edison Opto Corporation	*Taiwan*	*304*	*$16.8*	
Philips Lumileds	CA, *Netherlands*	300	$75.0	
Rubicon Technology	IL	144	$34.1	
GE Lumination (Formerly Gelcore)	OH	84	$15.0	
CAO Group	UT	50	$38.0	
Luminus Devices	MA	4	$1.5	
Gentex	MI	2,718	$653.0	LED Lighting Products and Fixtures
Cree	NC	3,168	$394.1	
American Opto Plus LED	CA	1,000	$450.0	
Teledyne Technologies Inc.	CA	8,130	$1,622.3	
Philips Lumileds	CA, *Netherlands*	300	$75.0	
LEDtronics	CA	300	$40.0	

[3] Please note that this is not an exhaustive or definitive list, nor is it a ranking of companies.

Company	State/Country	Total Employees	Sales (USD mil)	Manufacturer Type
GE Lumination (Formerly Gelcore)	OH	230	$6.0	
CAO Group	OH	84	$15.0	
Opto Technology	IL	50	$38.0	
Agilight	IL	29	$6.0	
Philips Color Kinetics**	MA	168	$65.0	
American Bright (subsidiary of Bright LED, Taiwan)	CA	15	$65.0	
Lighting Science Group	TX	70	$2.8	
LSI Industries	OH	1,400	$305.3	
Lynk Labs	IL	3	$2.0	

Source: CGGC, based on OneSource, ReferenceUSA, company annual reports, industry sources and interviews.

**Philips acquired Color Kinetics in 2007, changed the name to Solid State Lighting Solutions, and subsequently renamed the company Philips Color Kinetics (Hamilton, 2008).
Italicized firms are non-U.S. firms. Note: This table includes firms for which LED-related production may or may not be the main activity.

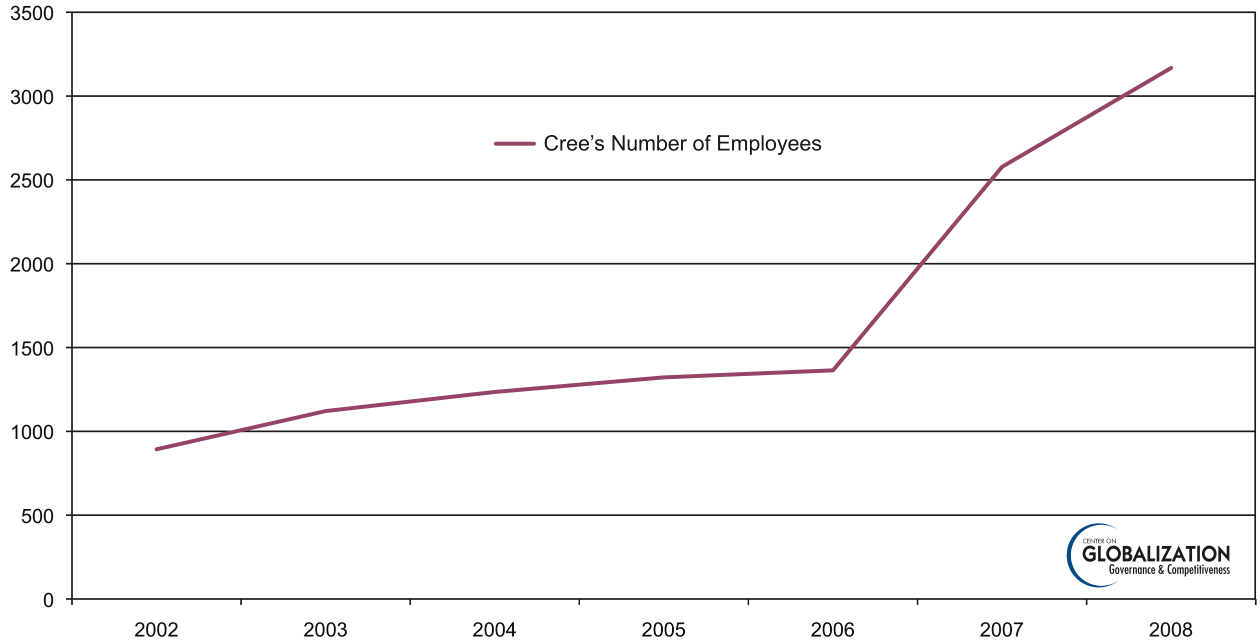
Case Study: A North Carolina LED Company Lights the Beijing Olympics

The U.S. leader in LED lighting is the Durham, North Carolina-based semiconductor company Cree, Inc. The company was founded in 1987 and introduced the first blue LED in 1989. Cree's major product families include a broad range of efficient blue and green LED chips; semiconductor materials for advanced electronic and opto-electronic devices; packaged LED lamps for many applications including general illumination; LED luminaires, or fixtures for commercial applications such as downlights used in corporate campuses, hotels, and restaurants; high brightness LEDs; power-switching devices; and radio-frequency/wireless devices (Cree Inc., 2008c).

Cree has experienced tremendous growth in recent years, improving LED technology and working with other companies to apply LED chips and lighting in new ways. The company's revenue grew from $228 million in 2003 to $493 million in FY2008 (Scheidt, 2008b). Cree has collaborative relationships with Asian LED manufacturers such as Kingbright Electronic Company in Taiwan and Seoul Semiconductor Company in Korea. Many of the company's LED products are distributed in Japan by the Sumitomo Corporation. Cree recently acquired LED Light Fixtures, Inc., and Intrinsic Semiconductor Corporation, increasing its overall share of the U.S. market (Cree Inc., 2002-2008). In October 2008 Cree announced a long-term strategic agreement with the Austrian Zumtobel Group, a global market leader in professional lighting, to sell LED downlights to the European market (Cree Inc., 2008a).

The experience of Cree highlights the importance of innovation and research and development in an environment of slow but steady job loss in the U.S. semiconductor manufacturing industry. Cree holds patents on a large number of LED technology improvements, and as demand for its innovative products has increased, the company's work force has nearly quadrupled, from 893 people in 2002, to 3,168 regular full and part-time employees in 2008 (see Figure 1-7). In the 2008 Beijing Olympics, the Bird's Nest stadium and Water Cube aquatic center were lit by 750,000 red, blue, and green LED chips manufactured in Durham by Cree (Wolf, 2008).

Figure 1-7. Cree, Inc. Employees, 2002–2008



Source: CGGC, based on Cree, Inc. 2002, 2003, 2004, 2005, 2006, 2007, and 2008 Annual Reports.

Table 1-2. Cree, Inc., Selected Milestones

1980s	
July 1987	Cree founded
August 1989	Introduced first blue LED
1991	
October	Released world's first commercial SiC wafers
2001	
November	Announced blue laser lifetimes in excess of 1,000 hours
2005	
February	Achieved standard LED efficiency of 100 lumens/watt in R&D
June	Introduced MegaBright 290 Gen 2 LED Product
2006	
June	Demonstrated a 131-lumens/watt white LED
August	Introduced EZBright1000 LED power chip for general lighting applications
October	Delivered the XLamp XR-E Series LED, the first 160-lumen white power LED

2007	
March	Expanded the XLamp XR-E and XR-C series of LEDs with warm white color temperatures
April	Acquired COTCO Luminant Device Ltd. of Hong Kong
September	Achieved 1,000 lumens from a single LED
2008	
March	Acquired LED Lighting Fixtures, Inc., expanding Cree's opportunities in the general-purpose lighting market
April	International House of Pancakes (IHOP) franchise in Northern Virginia adopts Cree LED lighting products as the preferred lighting for all existing and future restaurants
May	Volume shipments of recessed LED down lights for significant projects, including corporate campuses, full-service hotels, and global restaurant chains

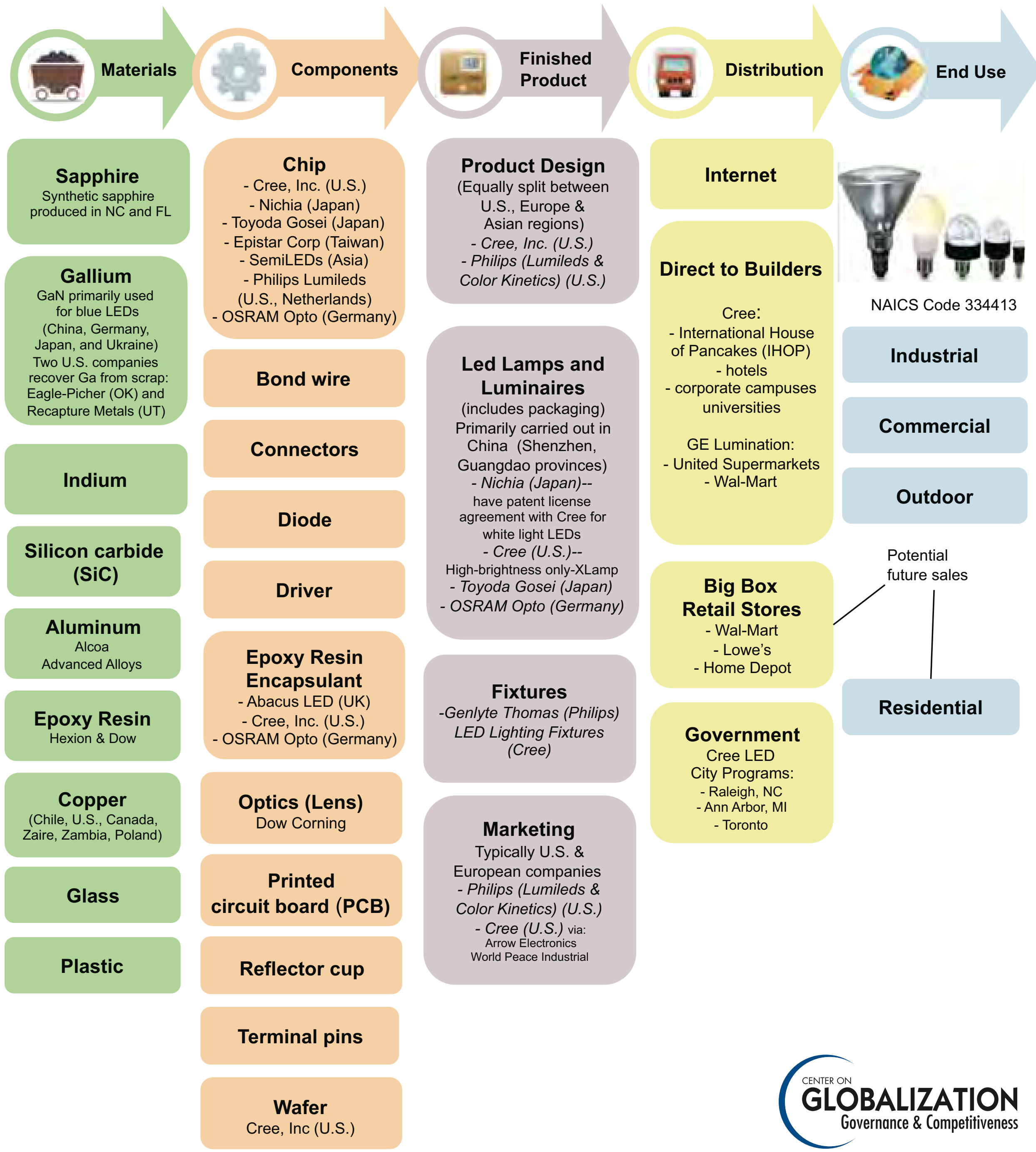
Source: Partial list of company milestones adapted from Cree Inc., 2008b

Conclusion

LED lighting products occupy a small but fast-growing segment of the global lighting industry. LED technology belongs to the semiconductor industry, in which much of the manufacturing occurs in Asia. However, U.S. firms can play a crucial role in developing and manufacturing the next generation of LED lighting products. Many LED products, especially the vital LED chips, rely on breakthrough technologies and require particularly high quality standards, indicating a preference for manufacturing close to home. This is important in today's global economy, where, as each new technology eventually stabilizes and the scale of production expands, the manufacturing base often moves to less expensive, mass operations overseas. The U.S. DOE has served a vital function by supporting U.S. research and development and by establishing labeling and standards. According to Morgan Pattison, a technology consultant to the DOE Solid State Lighting Research program, the vital question is, "Will the quality domestic and Japanese manufacturers of high-brightness LEDs be able to bring costs down before the lower-end manufacturers in Taiwan and China can bring performance up?" (Pattison, 2008).

Perhaps a piece of the answer lies in the experience of North Carolina-based Cree, Inc., which has become a global leader in high-quality, high-brightness LEDs, rolling out frequent innovations and continuing to manufacture domestically. Cree's success in this environment highlights an important link between innovation and the continued viability of U.S. manufacturing jobs.

Figure 1-8. LED Lighting Value Chain, with Illustrative Companies



Source: CGGC, based on company websites, interviews, industry sources, and Sanderson et al., 2008.

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CHAPTER 2

High-Performance Windows

Reduced Heating and Cooling Costs Through Energy-Efficient Technology

by

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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%.

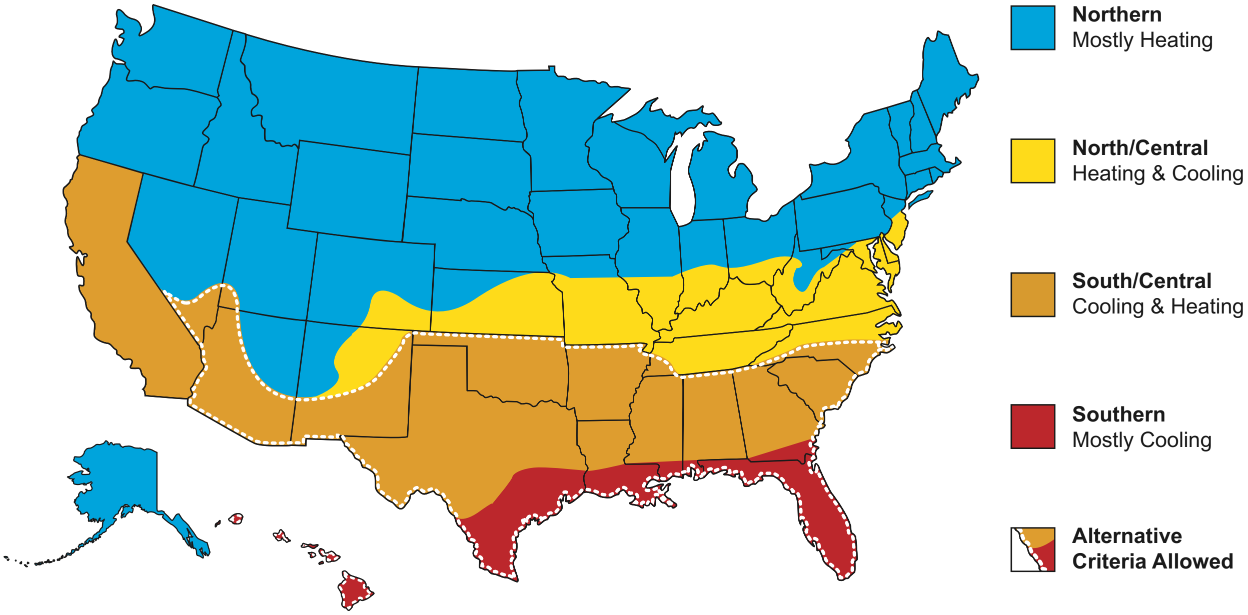
ENERGY STAR criteria changes will impact both the component manufacturers and the window manufacturers, which will need to develop new products to meet the criteria. Phase 1 criteria will have more limited impacts than Phase 2 criteria. Over the course of both criteria changes, jobs will be affected 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.

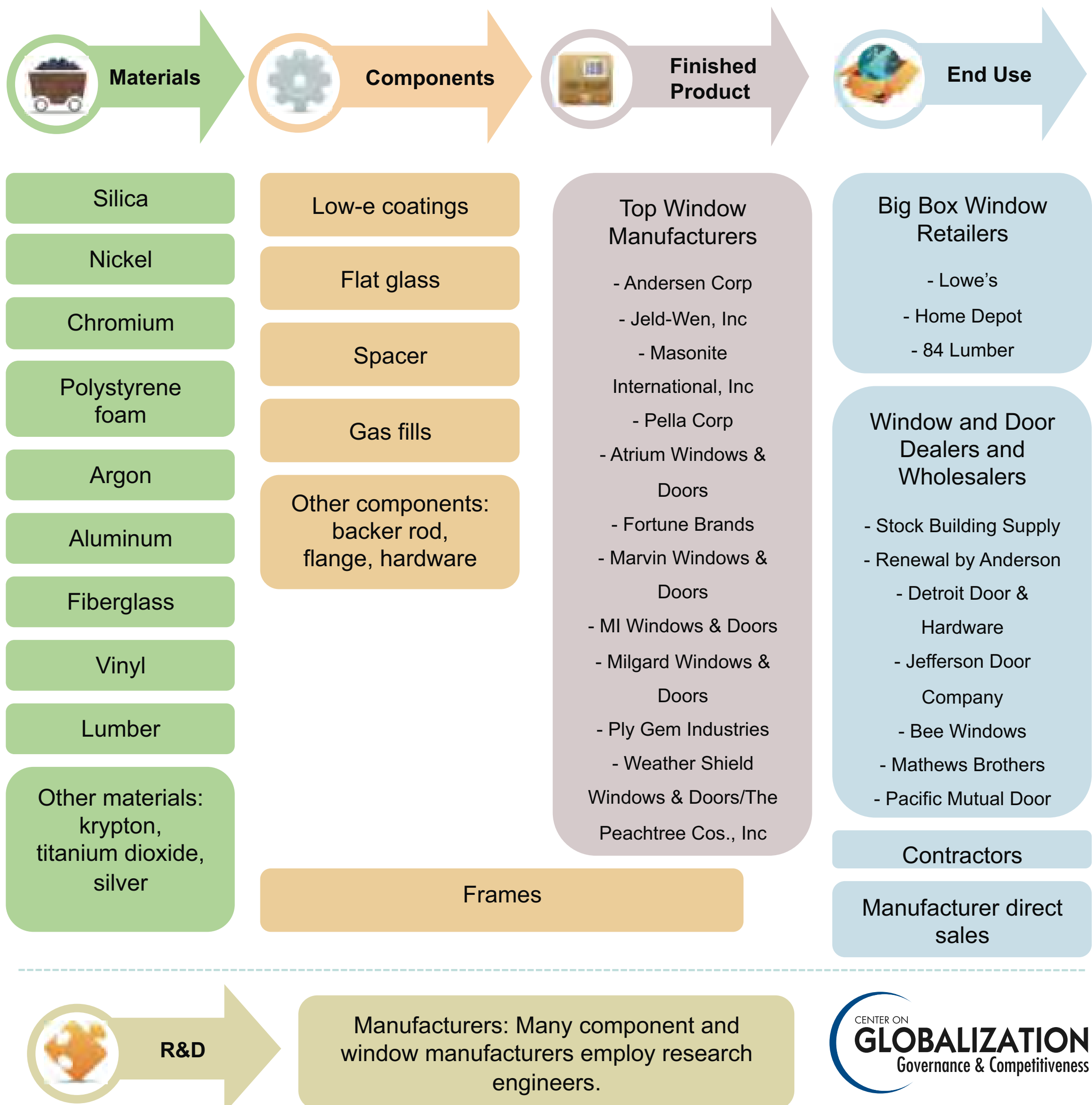
Materials

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

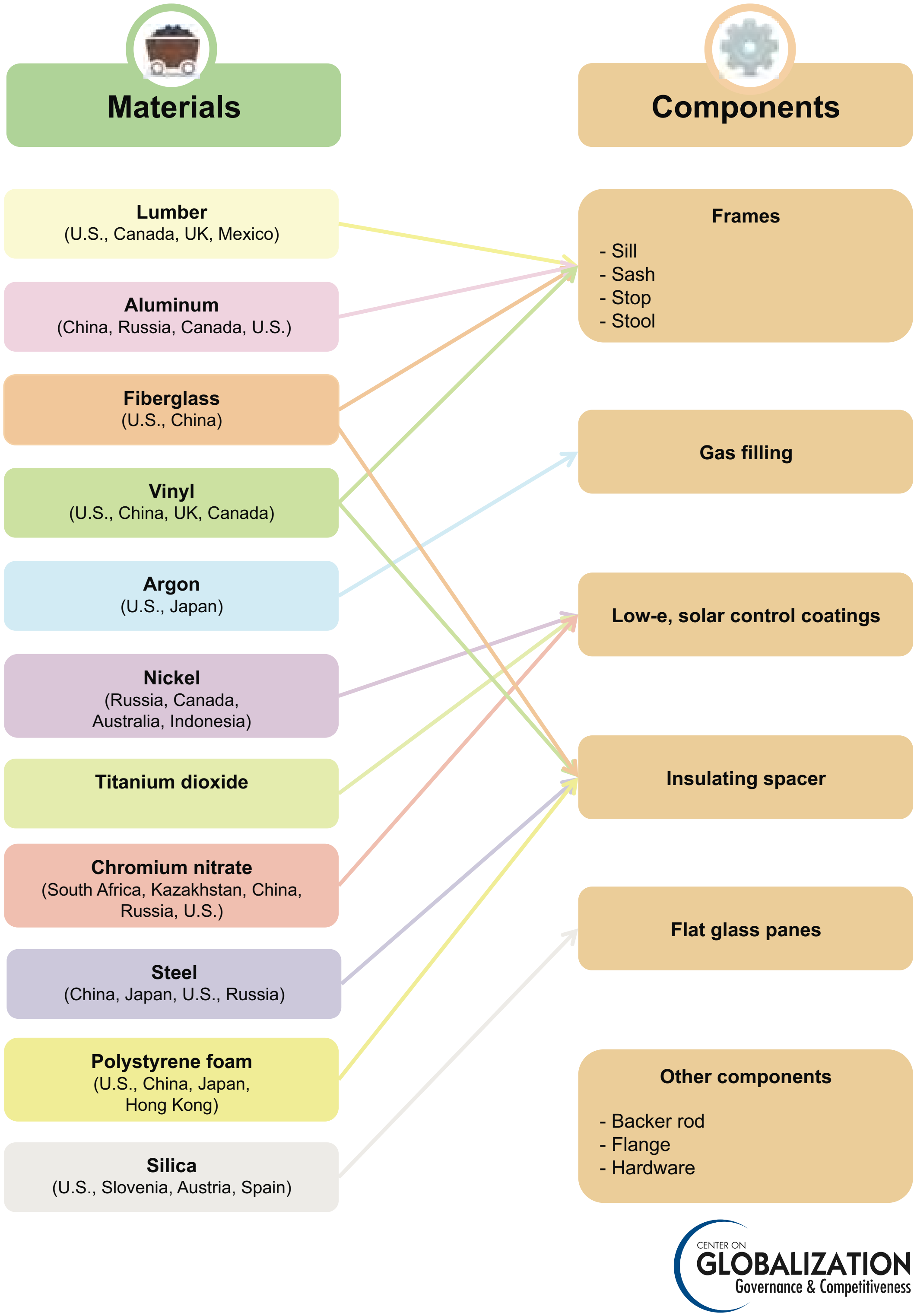
The four components essential to the energy efficiency of windows are low-emissivity (or low-e) coated glass, gas fills, spacers, and improved frames. The low-e coated glass includes the manufacturing of the flat glass pane as well as the production of an infrared-reflective coating. This type of glass 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.

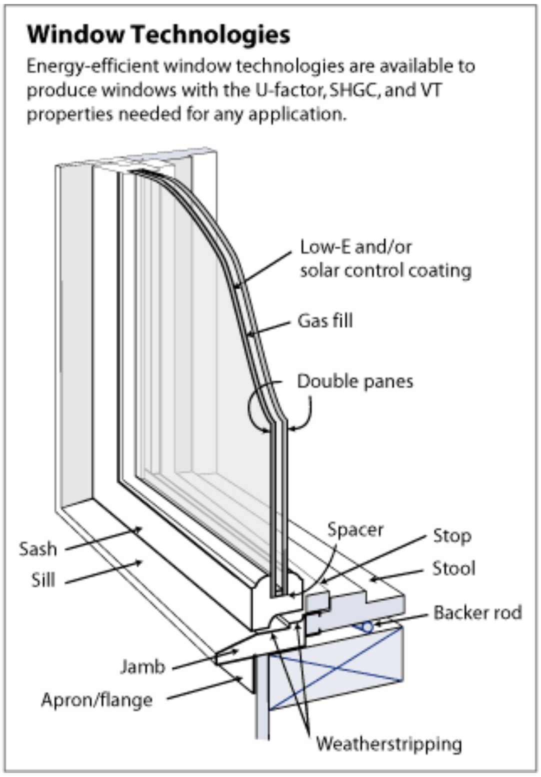
Figure 2-4. General Description of High-Performance Windows

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

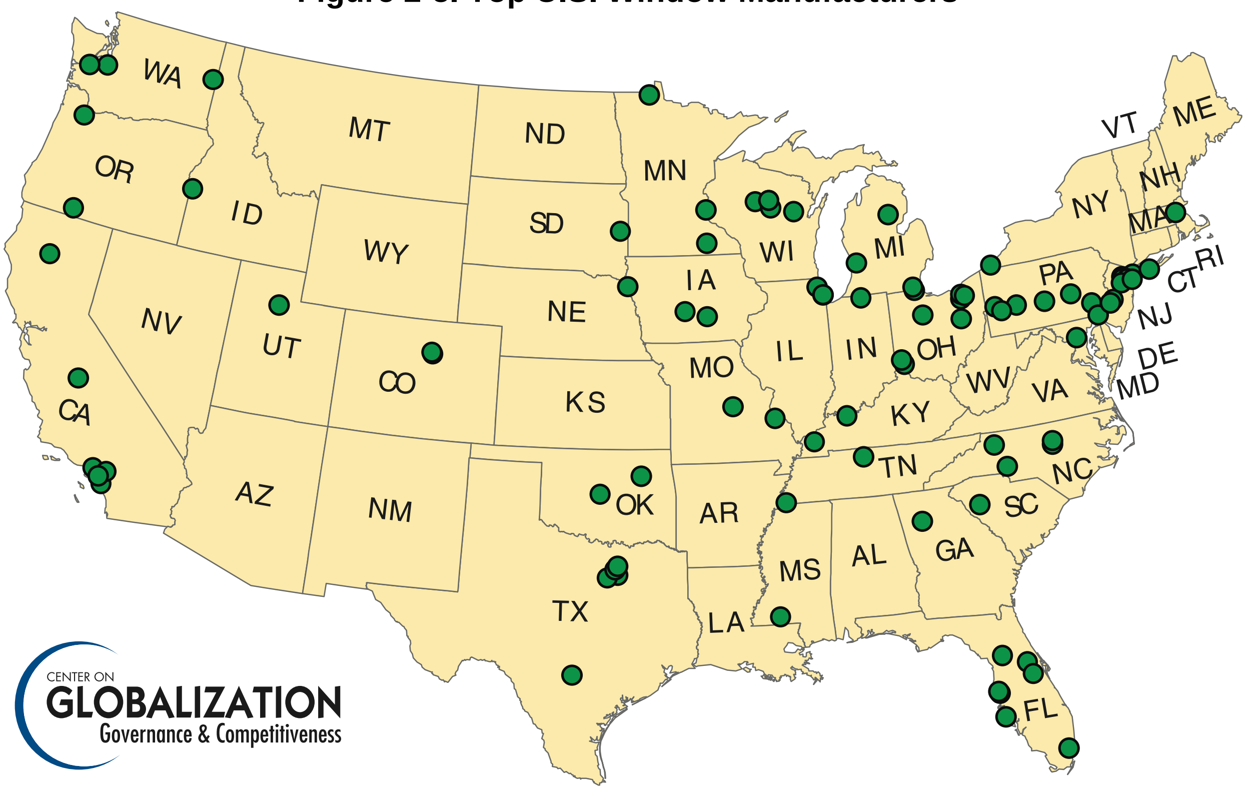
The fixed window manufacturers rated by the NFRC are located across the United States. The largest companies with the greatest market share are listed in Table 2-2. Figure 2-5 illustrates the locations of the 2008 *Window & Door* top U.S. window manufacturers (J. G. Swanson, 2008). They include Andersen, 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).

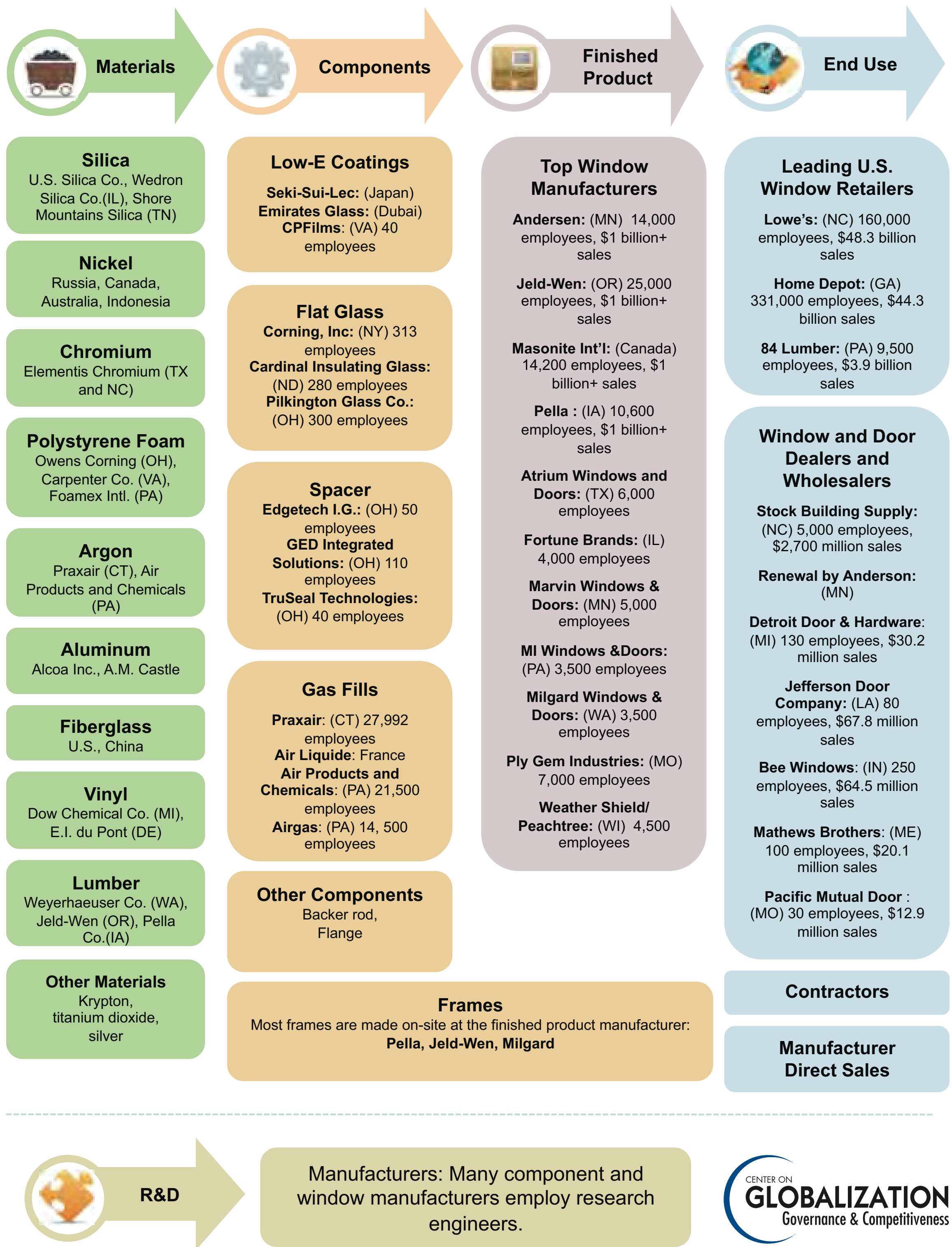
Case Study: Alpen Energy Group, LLC Grows by 50%

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.

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CHAPTER 3

Auxiliary Power Units

Reducing Carbon Emissions by Eliminating Idling in Heavy-Duty Trucks

by

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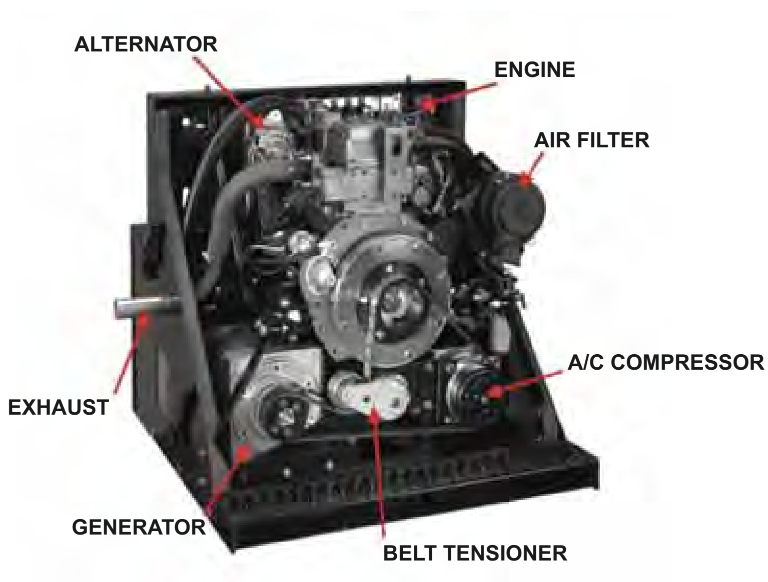
CENTER ON GLOBALIZATION Governance & Competitiveness

Summary

The auxiliary power unit (APU) offers long-haul truck drivers amenities like air conditioning during driving breaks while eliminating the need to idle the engine. This technology could help eliminate 11 million tons of carbon dioxide emissions from truck idling in the United States each year (SmartWay Transportation Partnership, 2004). The market penetration for APUs in the United States is about 5% (Bubbosh, 2008). Thus, APU technology has significant potential to reduce future carbon emissions, and it constitutes one of the U.S. Environmental Protection Agency (EPA) SmartWay Transport Partnership strategies. In addition to environmental benefits, current APUs save on average 8% in fuel costs each year, according to the EPA. High upfront costs (approximately $7,000-$9,000 per unit) limit APU penetration. To assist with the expansion of idle reduction technologies, the EPA has partnered with the Small Business Administration to set up attractive loan packages for trucking companies that implement SmartWay strategies, such as the use of APUs.

Expanded production of APUs would create economic opportunity at all stages of the value chain by increasing purchases from material and component suppliers, many of which are U.S.-based. A secondary economic impact of expanded APU production and sales could be increased demand for APU installation and service providers across the country. Additional value chain opportunities will likely come when APU technology is integrated as a component in tractor manufacturing rather than being an aftermarket product. If this occurs, APU manufacturers will become component suppliers to tractor manufacturers instead of to retailers who sell to end users. This would likely realign the supply of jobs along the value chain, with more emphasis on manufacturing and service work and away from retail and installation jobs. It is possible that vertical integration could reduce the cost barriers of adding APUs as an aftermarket product. Thus, these changes could have positive U.S. job implications if they result in more widespread use of APUs on tractors, which would require increased production and a greater need for APU service work.

Figure 3-1. Auxiliary Power Unit



Reprinted with permission from Black Rock Systems, http://www.blackrockapu.com

Introduction

There are five major types of idling reduction technologies: cab and block heaters, automatic engine start-stop controls, battery-powered air conditioning systems, on-and-off truck electrification, and auxiliary power units. While not the most commonly used idling reduction technology, APUs enable truck drivers to access the full range of cabin comforts (e.g., heating, air conditioning, electricity for personal devices such as televisions and cooking devices) without restricting where the truck must stop. Other idle reduction technologies either dictate stopping locations or provide fewer amenities.

The current market penetration rate for all idle reduction technologies is estimated at 36% of the sleeper cab market (American Transportation Research Institute, 2006). Approximately 12% of drivers with idle reduction technologies are estimated to use APUs. Fuel-operated heaters, which provide heat to the cabin when the engine is off, are more common, with a penetration rate of approximately 32% of that population (American Transportation Research Institute, 2006). Fuel-operated heaters do not offer the full range of cabin comforts provided by an APU, but their penetration rate is higher because of the lower up-front costs. The low penetration of APUs indicates untapped manufacturing and sales potential for this market, but it also illustrates the difficulty in convincing fleet owners and independent truck owner-operators to purchase and install APUs. Some barriers include the high initial costs and lack of awareness of true idling costs. These may be overcome by rising fuel prices. Other barriers include a 12% federal excise tax and APU system durability concerns (Bubbosh, 2008; Lutsey et al., 2003). However, there is an effort to address the excise tax, and a survey by the American Transportation Research Institute found that, in general, drivers are satisfied with system performance and indicate the high initial investment to be the major deterrent (American Transportation Research Institute, 2006).

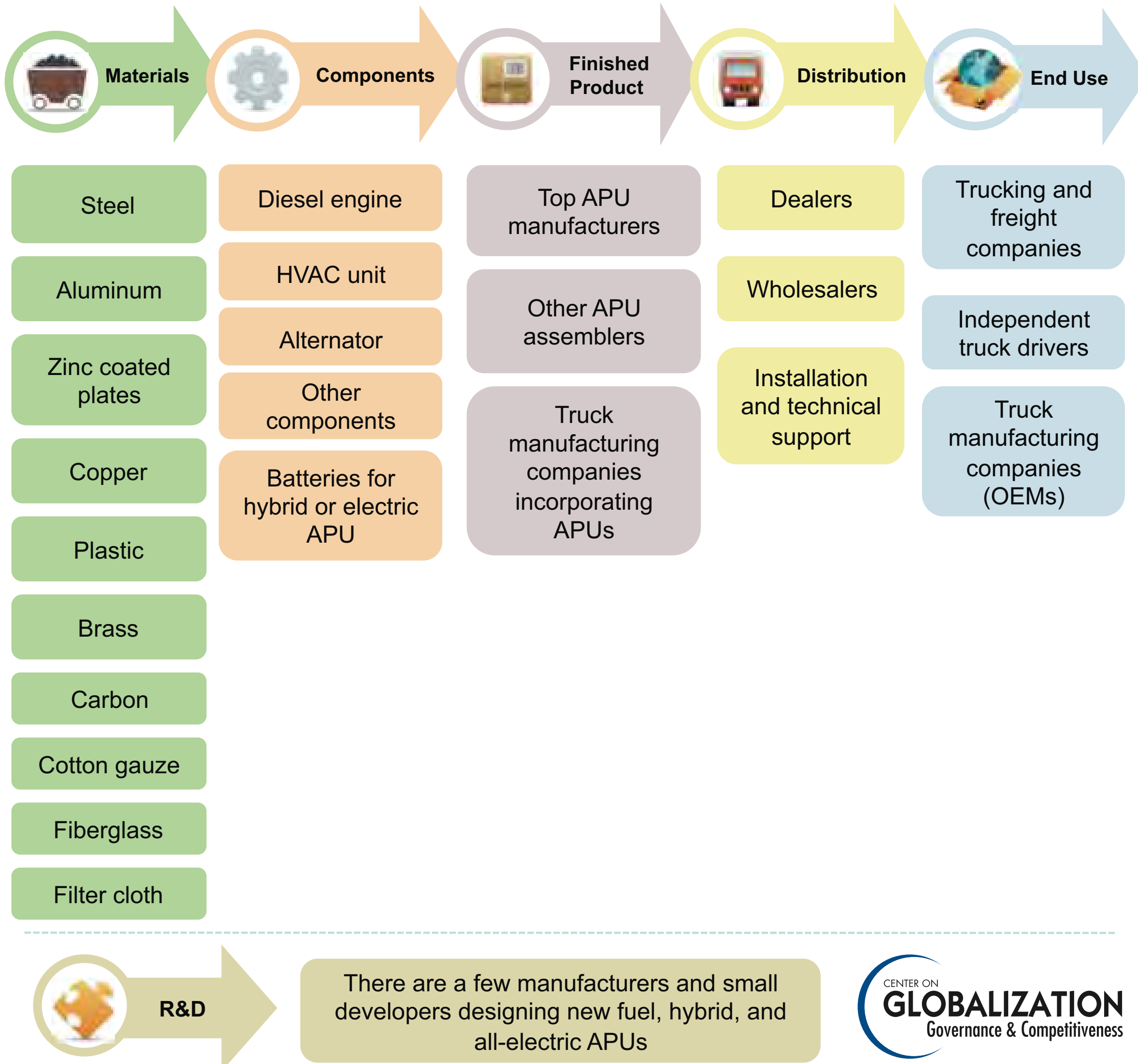
Auxiliary Power Unit Value Chain

The auxiliary power unit has more than 43 components, and the value chain incorporates five stages: materials, components, finished product, distribution (including installation and technical support), and end use. Figure 3-2 illustrates this value chain, and a more complete value chain with illustrative company information appears at the end of the chapter. Many of the companies involved across the APU value chain are located in the United States. Expanded production of APUs could create economic opportunity at all stages of the value chain.

Materials

The major raw materials used in APU component manufacturing are aluminum, copper, plastic, steel, zinc, brass, and fiberglass. Other raw materials include cotton gauze, carbon, and filter cloth. The United States is the world's largest producer of plastic and brass (United Nations Industrial Development Organization, 2007 and NBMmetals.com, 2007). The top U.S. producing companies are Dow Chemical Company and E.I. du Pont De Nemours & Company for plastics, and National Bronze & Metals and Allied Brass for brass (Hoover's Inc., 2008b, 2008c; and NBMmetals.com, 2007). The United States also supplies a significant portion of the other raw materials with the exception of zinc. The major producers for iron ore and steel are Cleveland Cliffs and U.S. Steel (Cleveland Cliffs, 2008; U.S. Steel, 2008), and the major producers of aluminum are Alcoa, Inc. and A.M. Castle (Hoover's Inc., 2008a). The market strength of and proximity between suppliers of raw materials and U.S. components and APU manufacturers is an opportunity to strengthen domestic job opportunities within the value chain.

Figure 3-2. Simplified Auxiliary Power Unit Value Chain



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

Components

Diesel APUs have three major components: the alternator; the engine (usually 2- or 3-cylinder); and the heating, ventilating, and air conditioning (HVAC) system. The main components of the alternator include the bearings, brushes, housing, rectifier, regulator, rotor, and stator. The main components of the diesel engine include the integrated rotor, stator generator, block, bearings, and cylinder. The main HVAC system components include the compressor, refrigerant, evaporator, and condenser. The major suppliers of engines and HVAC systems are listed in Table 3-1. Many APU engines are manufactured outside the United States, but company interviews indicate that a significant proportion of other component manufacturing and assembly is completed here. For example, the Thermo King TriPac APU has a Yanmar engine made in Japan, but enough of the remaining APU manufacturing and assembly is done in the United States that the APU meets classification as a U.S.-made product (Kampf, 2008).

Relatively new to the market are hybrid and electric APUs, for which batteries and an inverted charger are important components in the value chain. The components of an all-electric APU are the HVAC system, batteries, the alternator, and an inverted charger.

Table 3-1. Illustrative APU Engine and HVAC System Manufacturers

APU Component(s)	Manufacturer	Location
Engine	Isuzu	Japan
Engine	Kubota	Japan & Illinois
Engine	Perkins	Japan & Georgia
Engine	Yanmar	Japan
Engine & HVAC system	Caterpillar	Illinois
Engine & HVAC system	Cummins	Indiana
HVAC system	Dometic Environmental Corp.	Virginia
HVAC system	Mobile Thermosystems	Canada
HVAC system	Thermo King	Minnesota

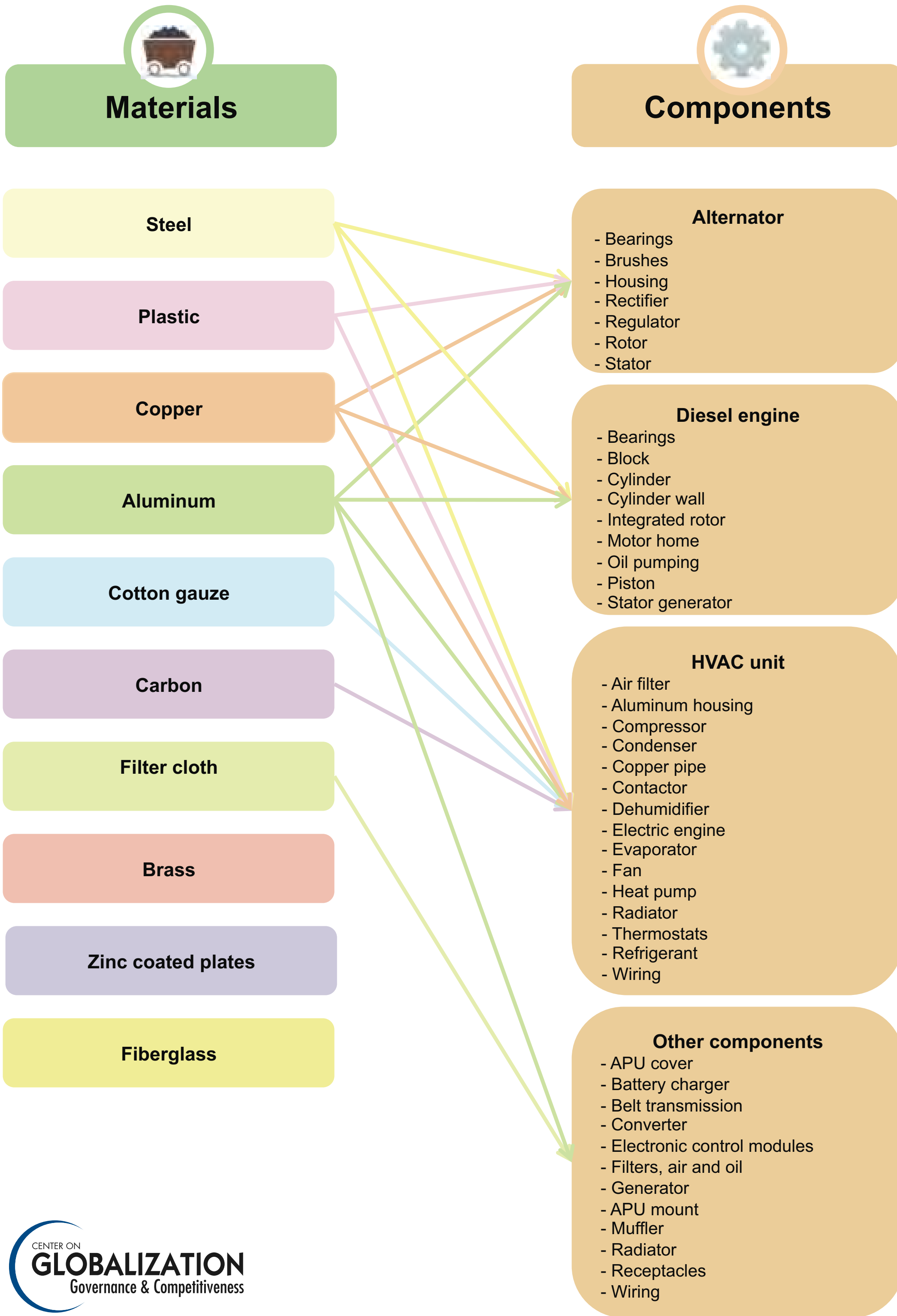
Source: CGGC, based on company annual reports, individual interviews, and company websites.

APU Manufacturing

Thermo King is the leading manufacturer of APUs with more than 50% of APU sales (Kampf, 2008). Other market leaders include Rigmaster Power (15%-20% market share), Black Rock Systems (10%), and Teleflex (which sells its APU through Carrier Transicold retailers). A number of other companies offer APUs, but these smaller companies often focus on assembly rather than component innovation, and they outsource the manufacturing of parts. The smaller APU companies have limited market share and move frequently into and out of the APU market. A more inclusive list of APU manufacturing companies and their headquarter cities and states appears in Table 3-2.

The APU manufacturing companies have a broad geographic distribution across the United States (see Figure 3-4). The majority are small companies with fewer than 100 employees. The smallest firms have limited distribution networks and operate in local markets selling and installing the APUs on location. By contrast, the big companies have multi-state distribution, installation, and service networks. Three of the most common APUs on the market are the TriPac (Thermo King Co.), the RigMaster Power (RigMaster Power, Inc.), and the Black Rock (Black Rock Systems) (Bosch, 2008; Landstar System, Inc., 2008).

Figure 3-3. Auxiliary Power Unit Materials and Corresponding Components



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

Table 3-2. Auxiliary Power Unit Manufacturers, 2007

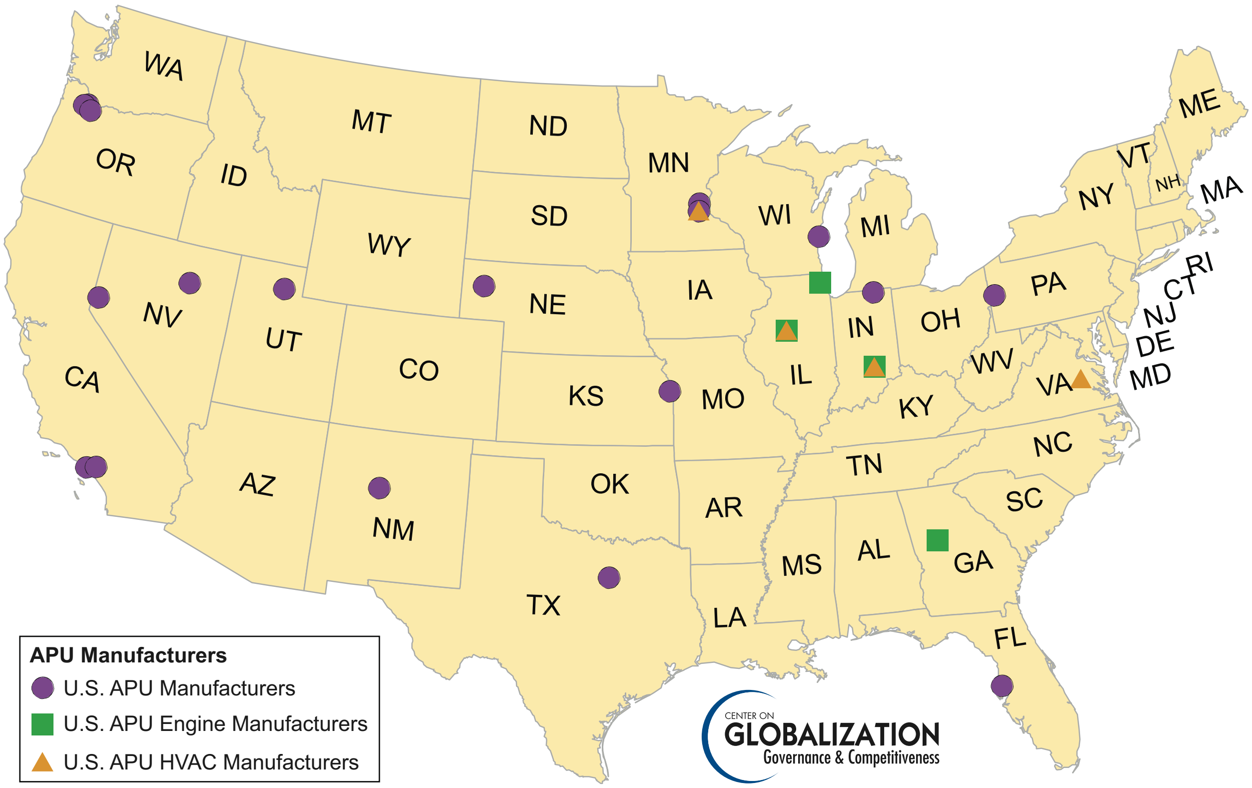
Company	APU Name	Headquarters
Auxiliary Power Dynamics, LLC	Willis Auxiliary Power System	Sparks, NV
Black Rock Systems, LLC*	Black Rock; Black Rock Evolution	Reno, NV
Comfort Master	Comfort Master	Whittier, CA
Cummins	ComfortGuard System	Minneapolis, MN
Daimler Trucks North America, LLC	NITE anti-idling system; RestSmart system	Portland, OR
Double Eagle Industries	GenPac	Shipshewana, IN
Enertek Corporation	Infini-Gen	Beaverton, OR
Florida Manufacturing Group	IdleBuster	Odessa, FL
Flying J, Inc.	Cab Comfort System	Ogden, UT
Kohler Power Systems (Mobile Div.)	Kohler 3APU; Kohler 7APU	Kohler, WI
Pony Pack, Inc.	Pony Pack	Albuquerque, NM
Rigmaster Power, Inc.*	RigMaster Power	Olathe, KS
SCS/Frigette Corporation	Alliance APU	Fort Worth, TX
Star Class, Inc.	Gen-Star	New Castle, PA
Teleflex Power Systems*	ComfortPro	Canada
Temco Metal Products*	Idle Solutions APU	Clackamas, OR
Thermo King Company*	TriPac	Bloomington, MN
Tridako Energy Systems	PowerCube	Alliance, NE

*Indicates top APU manufacturing companies

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

Some heavy-duty truck manufacturers also play a role in manufacturing idling reduction technologies like APUs. For example, Daimler Trucks North America owns Alliance Parts, which manufactures the Alliance APU. The Alliance APU is installed in Daimler trucks and also commercialized in the market. Navistar installs Maxxpower APUs in some of its trucks, and Mack Trucks, Inc. is another company installing APU technology. The fact that truck manufacturers are investing in these technologies indicates recognition of the demand for idling reduction by fleet and independent truck owners. In fact, this demand seems to be increasing, and APU technology appears to be going in the direction of vertical integration, with factory installation of APUs becoming more common than after-market sales.

Figure 3-4. Geographic Distribution of U.S. Companies Manufacturing Auxiliary Power Units and Engine and HVAC System Components



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

Distribution

Over 2,300 companies across the country provide APU retail, installation, and maintenance services. Most of these vendors are dealers, service centers, and installation centers. These vendors are generally small businesses with fewer than 30 employees. The APU dealer/retail network is well distributed across the country, with a minimum of six in the District of Columbia and a maximum of 129 in Texas. Many of these actors in the value chain employ workers with mechanical skills. Greater APU use in long-haul trucks has the potential to increase the need for service jobs nationwide.

End Use

The final stage of the value chain refers to consumers of APU technologies, including freight companies, independent truck drivers, and truck manufacturing companies. There are about 41,000 general freight trucking companies in the United States. Approximately 5% are large companies with more than 100 drivers; 37% have between four and 100 drivers; and 60% have fewer than four drivers (U.S. Bureau of Labor Statistics, 2008b). Larger companies who own the tractors and trailers may be more likely to see the value of idling reduction technologies and have the resources to install them (Plunkett Research Online, 2008a). There also are about 330,000 tractor truck owner-operators throughout the United States (Truck Info Net, 2008). Many of these individuals would like to have an APU for cost savings but are resistant to the high upfront capital costs. Trucking companies and independent truck owners are less likely to install APUs on trucks that are more than three years old, so the potential market for APUs is generally limited to Class A sleeper cabs less than four years old (Kampf, 2008).

Total revenues for the truck transportation sector were $219 billion in 2006, and expenses exceeded $201 billion (Plunkett Research Online, 2008a). The industry's relatively small profit margin of 8% in 2006 makes it a prime candidate for idling reduction technologies that lower fuel and maintenance costs (Plunkett Research Online, 2008b). Furthermore, the U.S. Department of Labor predicts the truck transportation sector will grow its total revenues by 11.1% by 2016, generating 160,000 new jobs (U.S. Bureau of Labor Statistics, 2008a). Such growth indicates potential for greater demand for APUs and other idling reduction technologies, which will help reduce long-haul truck fuel needs.

Case Study: Wal-Mart Adopts APUs

In 2005, Wal-Mart introduced a goal of doubling the efficiency of its trucking fleet by 2015. Wal-Mart has the second largest private fleet in the nation. Increasing fleet efficiency to this level will prevent 13 million tons of carbon dioxide emissions (Addison, 2007). One of Wal-Mart's first steps towards this goal was to purchase and install 7,000 APUs in its long-haul trucks. The company has estimated APUs save $25 million in annual fuel costs, a figure that has likely increased with higher global oil prices in 2007 and 2008 (Addison, 2007). Furthermore, Wal-Mart's 2007 model truck includes an APU and other improvements, such as trailer side skirts, super single tires, an aerodynamic tractor package, and a tag axle (Green Car Congress, 2005). Wal-Mart estimated these changes will save the company $52 million per year in fuel costs. For the future, the company is also evaluating various hybrid technologies, such as those by Peterbilt and Eaton, for a new class-8 heavy-duty vehicle (Addison, 2007).

Case Study: Enertek Solutions Creates an Efficient Battery-Powered APU

As more fleet owners recognize the unique opportunity to simultaneously reduce costs and present a more sustainable company image, the market for APUs could expand significantly. Specific APU technology improvements, such as widespread development of hybrid APUs, more efficient battery-powered APUs, and further research and development of other types of APUs, may play an important role in increasing the technology's appeal.

Enertek Solutions, Inc., out of Portland, Oregon, introduced the Infini-Gen, an all-electric APU, in March 2008. The APU has no engine because it runs on battery power of any kind, including advanced battery technology such as nickel-metal hydride and lithium ion rechargeable batteries. The batteries are high-powered and make the APU lighter than previous diesel and battery-powered models. Furthermore, the system recharges while the truck engine is running, and it also can be plugged into external power sources (shore power). The Infini-Gen requires only six hours to install (compared to about 24 hours for diesel APUs), and the total cost including installation is $7,500. Enertek Solutions has a commitment of 1,000 Infini-Gen APUs to a large Carrier Transicold dealer and is in licensing discussions with several companies in North America and Europe including Paccar (Baumann, 2008).

Figure 3-5. Hybrid and All-Electric Infini-Gen

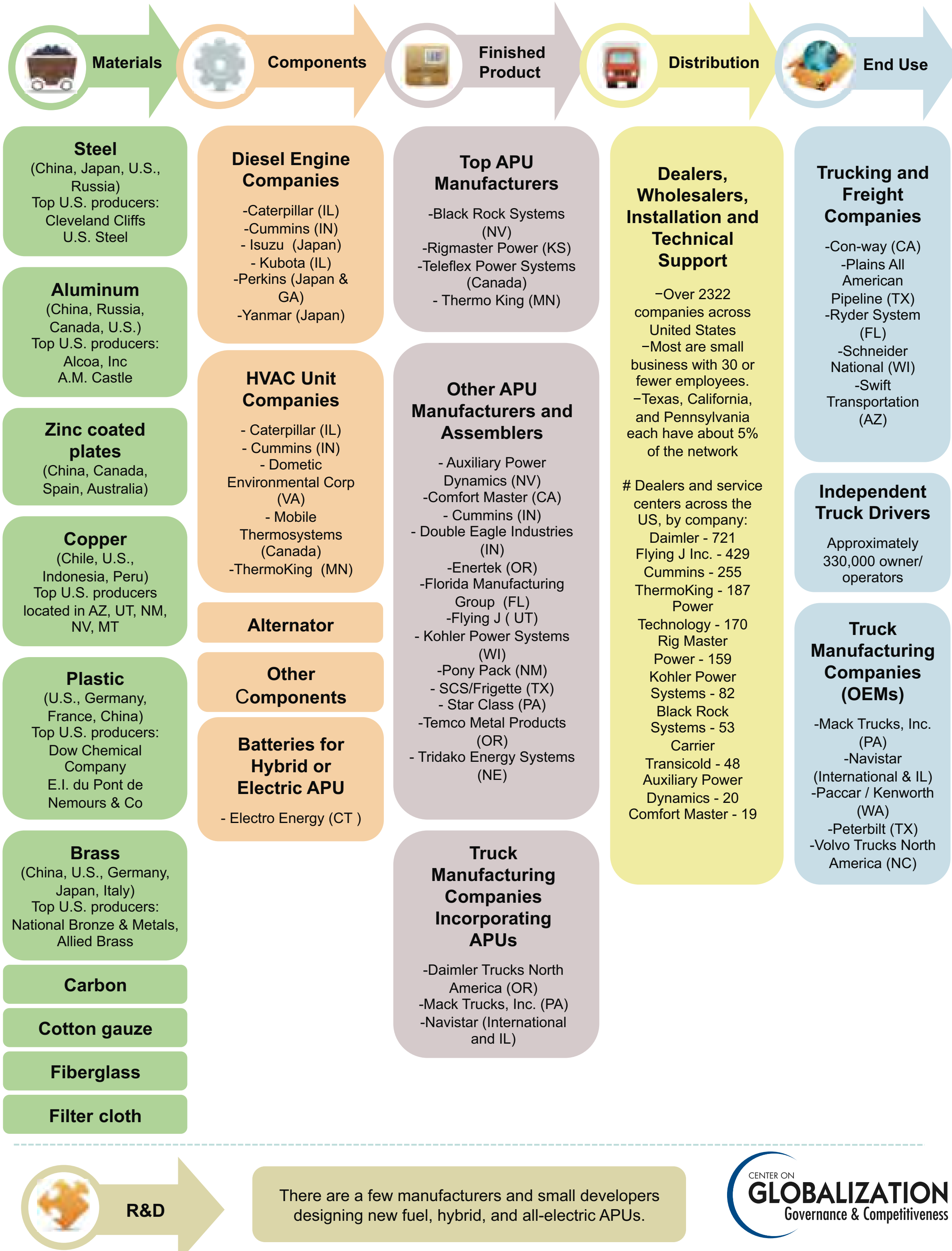
Images reprinted with permission from Enertek Corporation, http://www.enerteksolutions.com/.

Other technological advances include efforts by BMW and Boeing to develop solid oxide fuel cell technologies that would allow for lighter and smaller engines. As this technology is refined and its cost structure is reduced, solid oxide fuel cells could be incorporated into long-haul truck APUs.

Conclusion

It appears likely that idling reduction technologies will soon be incorporated into truck engine manufacturing by original equipment manufacturers. Whether or not APUs or other types of idle reduction technologies are incorporated remains unclear, although Daimler, Kenworth, and Peterbilt, among others, have adopted factory-installed APUs on some Class A sleeper cabs. Integrating idling reduction into long-haul truck manufacturing could help further reduce carbon emissions and may overcome some of the cost barriers associated with adding APUs or other idling reduction technologies as aftermarket add-ons. On the other hand, integration into truck manufacturing also could impact additional job opportunities at the manufacturing and installation stages of the value chain because this work may be subsumed by existing jobs. Nonetheless, there are clearly opportunities to reduce truck idling among existing long-haul trucks through expanding the available fuel-powered APUs and supporting opportunities to develop and manufacture new hybrid and electric APUs and other idling reduction technologies. Furthermore, vertically integrating APUs as components in the tractor truck manufacturing system offers the potential to dramatically expand use of APUs. Such an expansion, in addition to the expected growth in the trucking industry, could have positive job implications at the material, component, and manufacturing stages of the value chain as well as increased demand for service and maintenance jobs.

Figure 3-6. Auxiliary Power Unit Value Chain, with Illustrative Companies



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

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CHAPTER 4

Concentrating Solar Power

Clean Energy for the Electric Grid

by

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Summary
Concentrating solar power (CSP), also referred to as concentrating solar thermal power, represents a powerful, clean, endless, and reliable source of energy with the capacity to entirely satisfy the present and future electricity needs of the United States. Concentrating solar power plants produce no carbon dioxide (CO_2), thus reducing carbon emissions from electricity generation by approximately 600 pounds per megawatt-hour (BrightSource Energy, 2008).[4] The evolution of CO_2 emissions regulations, the pressure of international fossil fuel prices, and the experience, knowledge, and technological readiness amassed during several decades of CSP research have launched the technology into a new era of commercial reality.

The United States and Spain have integrated CSP into their national electricity supply grids through large-scale commercial plants. Eight of the 13 biggest planned CSP projects in the world will be located in California and Arizona. The Sun Belt region of the United States, particularly the Southwest, is one of the largest areas in the world for CSP exploitation because of its abundant sunshine. In addition to generating a new clean source of energy, expansion of the industry promises to create economic opportunity for many different businesses along multiple stages of the value chain, including thousands of new construction jobs and hundreds of skilled jobs in the operation and maintenance of the new plants.

Introduction
After several decades of research and pilot testing, concentrating solar power (CSP) is now commercially viable. For more than 50 years researchers, universities, laboratories, inventors, and scientists experimented with ways to produce electricity using steam generated from the heat of concentrating solar rays. The U.S. government has been collaborating with private research corporations over the last 20 years to scale up CSP technology for the energy markets. Government investment in this technology continues to increase. In April 2008, the U.S. Department of Energy announced $60 million in funding over the next five years to support further development of low-cost CSP technology (U.S. Department of Energy, 2008).

CSP plants concentrate beams of light from the sun to heat a fluid and produce steam. The steam rotates a turbine connected to a generator, producing electricity to run a traditional power plant. There are four types of CSP technologies: parabolic troughs, power towers, dish/engine systems, and linear Fresnel reflectors. The parabolic trough system was the first CSP technology, thus it is the most developed and most commonly replicated system. Deployment of the other technologies is relatively new and in some cases, as with the linear Fresnel reflector technology, projects currently being developed are the first to reach utility-scale magnitude. Parabolic trough technology uses parabolic reflectors to concentrate the sun's rays into a receiver pipe along the reflector's focal line. The receiver heats a liquid which generates steam for power. This collector system rotates with the sun's movement to optimize solar energy generation (Solar Energy Technologies Program, 2008a). Power tower systems use flat mirrors to reflect the sun's rays onto a water-filled boiler atop a central tower. The liquid is heated to a very high temperature and runs the turbine to create electricity (BrightSource Energy, 2007). Dish/engine systems use parabolic reflectors to direct the sun's rays at a receiver placed at the reflector's focal point. The liquid in the receiver is heated and runs a Stirling engine to create power (Solar Energy

[4] This compares to CO_2 emissions of 750 grams per kilowatt hour (g/kWh) from hard coal power plants and 500 g/kWh from natural gas (Solar Millennium AG 2008).

Technologies Program, 2008b). Linear Fresnel reflector technology works much like the parabolic trough system, except that it uses flat mirrors that reflect the sun onto water-filled pipes that generate steam. This is a significant cost advantage because flat mirrors are much less expensive to produce than parabolic mirrors (Ausra, 2008b). Current advances in CSP allow these technologies to produce electricity several hours after sunset and on days with low intensity of solar radiation through heat accumulators and hybrid configurations.

Figure 4-1. Concentrating Solar Technologies


Trough System


Tower System


Dish System


Linear Fresnel System

Sources: Trough, tower, and dish system images reprinted with permission from the National Renewable Energy Laboratory, http://www.nrel.gov/data/pix/; Linear Fresnel system reprinted with permission from Ausra, Inc., http://www.ausra.com/.

Concentrating Solar Power Value Chain

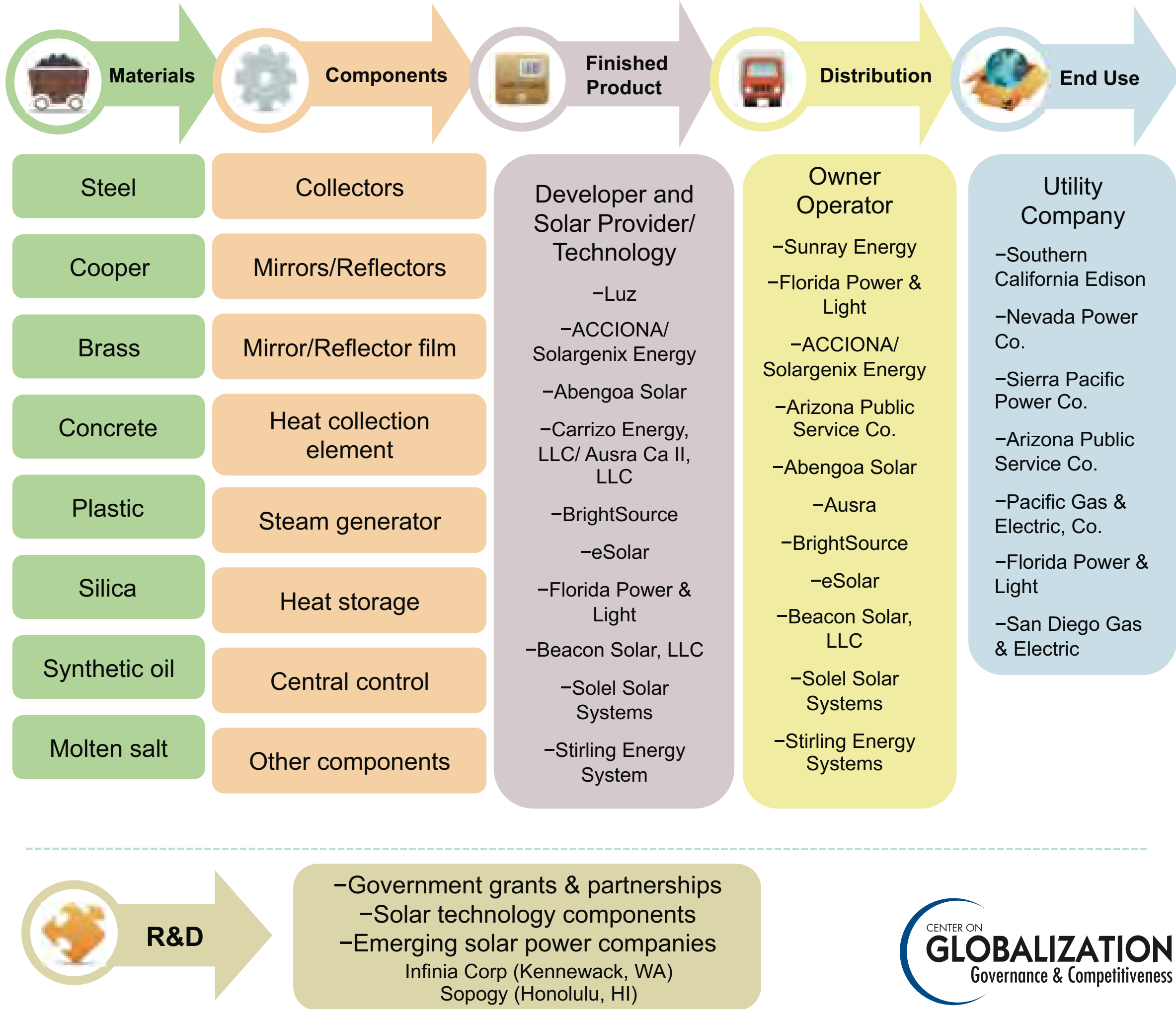
CSP is a new industry, and the roles and actors in the value chain vary significantly by technology and project. In addition, the value chain structure is still evolving. A general value chain illustration can be viewed in Figure 4-2. A more complete value chain with illustrative company information appears at the end of this chapter. At the basic level, there are five stages in the value chain: materials; components; the finished product including solar technology and plant development; distribution via ownership and operation of the CSP plant; and end use of power by utility companies. Research and development (R&D) is an integral part of the component, product, and distribution stages of the value chain. Much of the R&D, plant development, manufacturing, plant design and installation, and operation are conducted by a single company or by closely related companies. Therefore, there is significant vertical integration across the five stages of the value chain.

Materials and Components

The major materials in the CSP value chain are silica, iron and steel, concrete, plastic (or polyvinyl chloride), brass, synthetic oil, copper, aluminum, and molten salt. Figure 4-3 highlights the major country sources for these materials and their corresponding components. Table 4-1 highlights some CSP component manufacturing companies.[5] A CSP plant has four major systems: the collector, steam generator, heat storage, and central control. The collector system components vary depending on the type of CSP plant.

[5] The majority of the research on component manufacturing focuses on parabolic trough power plants because these are currently the most widely used CSP technologies. Components and component manufacturers of the Stirling engine and tower CSP plants are also included to the extent possible.

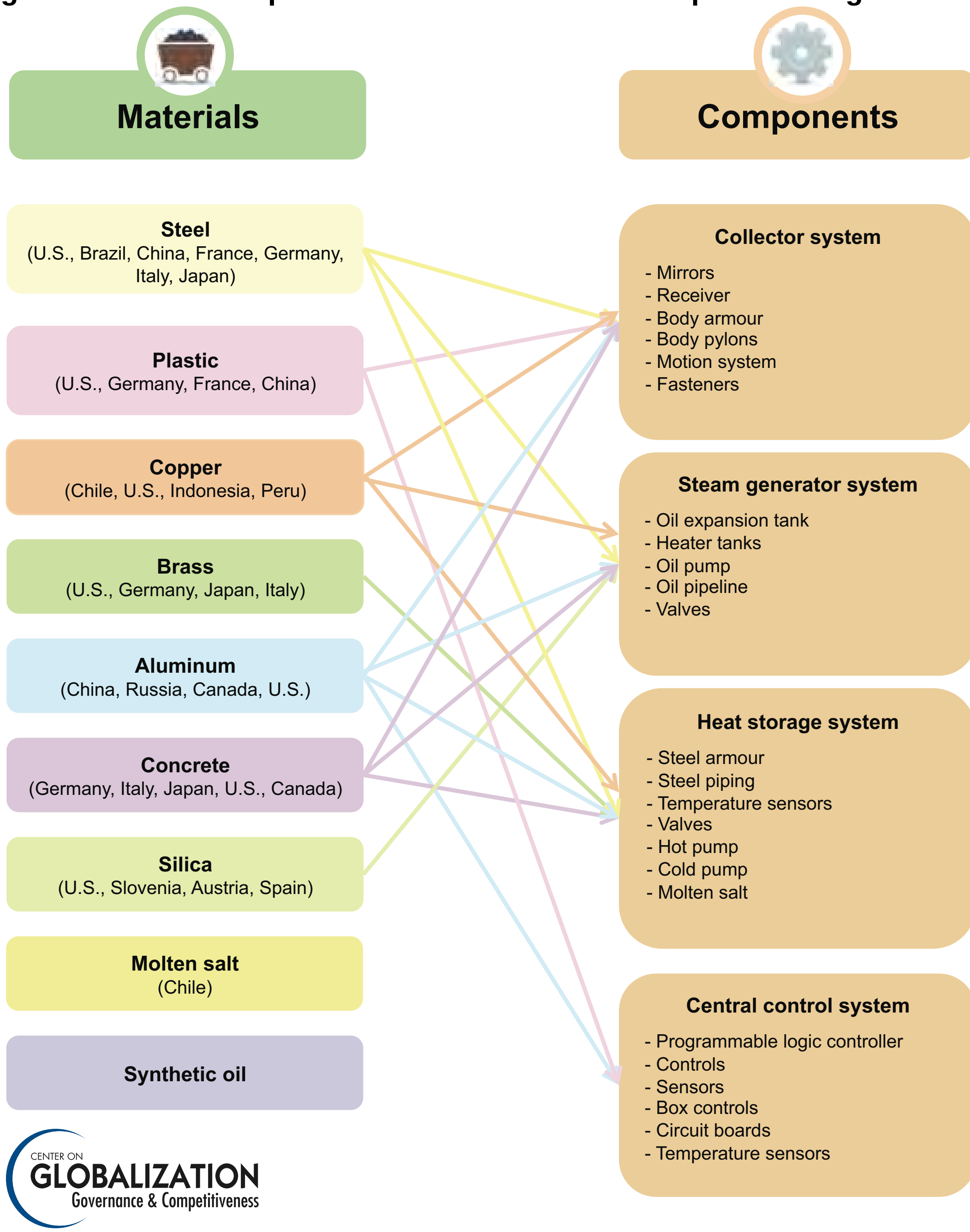
Figure 4-2: Simplified Concentrating Solar Power Value Chain



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

In addition to the components listed in Figure 4-3, concentrating solar power plants have many other elements not outlined here because they represent standard technology for generating electricity. These include a natural gas boiler, steam turbine, steam generator, condenser, and cooling tower. These components would certainly be a part of the production process for any CSP plant and would contribute to further manufacturing and construction needs.

Figure 4-3: CSP Components and Materials with Top Producing Countries



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

Table 4-1. Illustrative Companies Making Concentrating Solar Power Components

Component	Illustrative Companies	Location
Collectors	European Partners	Europe
	Industrial Solar Technology	Golden, CO
	Luz/Solel	Israel
	Solargenix Energy	Sanford, NC
	Solar Millennium AG	Germany
	Sopogy	Honolulu, HI
Mirrors/Reflectors	Alanod	Germany
	Ausra Manufacturing	Las Vegas, NV
	Boeing (formerly McDonald Douglas)	Chicago, IL
	Cristaleria Espanola SA	Spain
	Flabeg	Germany
	Glaverbel	Belgium
	3M Company	St. Paul, MN
	Naugatuck Glass	Naugatuck, CT
	Paneltec Corporation	Lafayette, CO
	Pilkington	United Kingdom
	SCHOTT North America	Elmsford, NY
Mirror/Reflector Film	Alanod	Germany
	3M Company	St. Paul, MN
	ReflecTech	Arvada, CO
Heat Collection Element	Luz/Solel	Israel
	SCHOTT North America	Elmsford, NY
Steam Generator System	Siemens	New York, NY
Heat Storage System	Radco Industries	LaFox, IL
Central Control System	Abengoa Solar USA	Lakewood, CO
Linear Receiver	Luz/Solel Solar Systems	Israel
	SCHOTT North America	Elmsford, NY
Concentrator Structure	European Partners (Euro Trough)	Europe
	Solargenix	Sanford, NC
Other Components	Other components used in power plant production but not unique to concentrating solar include a natural gas boiler, steam turbine, steam generator, condenser, and cooling tower	

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

Manufacturing & Development

CSP is appealing to developers because it is a renewable and reliable resource with predictable costs. CSP developers currently planning major power plant projects in the United States are large multinational or national companies already involved in the renewable energy field. In many cases, the developers are international firms that have established U.S. subsidiaries. These include Abengoa Solar USA, ACCIONA Solar Power, Inc., and Solel, Inc. (see Table 4-2). Therefore, although there is a significant international corporate presence in the CSP value chain, foreign-owned subsidiaries and offices are being developed in the United States along with U.S.-owned plants. Other developers include current or former utility and energy companies expanding into renewable energy, such as FPL Energy and Solargenix Energy (formerly Duke Solar Energy).

Table 4-2. Concentrating Solar Power Developer Companies

Illustrative Companies	Location
U.S.-based	
Abengoa Solar USA/Solucar Power (*Subsidiary of Abengoa*)	Victorville, CA
ACCIONA Solar Power Inc. (*Subsidiary of ACCIONA Energia*)	Henderson, NV
Ausra	Palo Alto, CA
Bright Source Energy, Inc.	Oakland, CA
E-solar (Idealab)	Pasadena, CA
FPL Energy	Mojave, CA
Industrial Solar Technology Corp	Golden, CO
Inland Energy	Upland, CA
Sky Fuel	Albuquerque, NM
Solel, Inc. (*Subsidiary of Solel Solar Systems Ltd*)	Henderson, NV
Solargenix Energy	Sanford, NC
Stirling Energy Systems	Phoenix, AZ
International	
ACCIONA Energia	Spain
Abengoa - Abengoa Solar	Spain
Albiasa Solar	Spain
Ener-T Global	Israel
Epuron	Germany
Eskom	South Africa
Grupo Enhol	Spain
Luz II *(BrightSource subsidiary)*	Israel
Novatec BioSol AG	Germany
Samca	Spain
Sener Group	Spain
Solar Millennium AG	Germany
Solar Power Group	Germany
Solel Solar Systems Ltd	Israel

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

The solar thermal industry appears to be significantly integrated across the value chain. Many developers conduct their own R&D to create unique, patented concentrating solar technologies. Concurrently, CSP developers often manufacture the patented components, build the power plant, and operate it. The planned Ivanpah Solar Power Complex is a good example. BrightSource Energy owns Luz II, one of the early CSP technology design and manufacturing companies, and Luz II will manufacture the CSP technology while BrightSource oversees the development, operation, and management of the plant. BrightSource will then sell the power produced to Pacific Gas & Electric. The U.S. Department of Energy also partners with a number of power plant owners and operators to help improve plant operation and management and develop better plant technology (Blair, 2008).

CSP plant construction requires commodity type materials (steel and concrete), and many companies contract out the manufacturing of non-patented components. Even when the developer of a U.S.-based CSP plant is an international company, the United States can expect significant job growth from plant construction and ongoing operations. There are two assembly sites: the first, which can be anywhere in the world, produces easily transportable components. The second, where larger components are assembled, must be near the plant to minimize transportation costs. This implies U.S. job growth potential in both component manufacturing and plant assembly.

The National Renewable Energy Laboratory (NREL) estimates that approximately 455 construction jobs are created for every 100 megawatts (MW) of installed CSP (Stoddard et al., 2006). The 280 MW Solana Generating Station scheduled for construction this year is expected to have an even greater impact, generating 1,500 to 2,000 construction jobs during the two-year construction period (Abengoa Solar, 2008). According to an analysis by *Black & Veatch*, a 100 MW CSP plant would produce 4,000 direct and indirect job-years in construction compared to approximately 500 and 330 job-years for combined cycle and simple cycle fossil fuel plants of the same production capacity, respectively (Stoddard et al., 2006).

During the operation phase of the power plant, permanent jobs are created in areas such as administration, operation, maintenance, service contracting, water maintenance, spare parts and equipment, and solar field parts replenishment. CSP plants generate an estimated 94 operation and management jobs per 100 MW, whereas conventional coal and natural gas plants of the same size generate between 10 and 60 permanent jobs. Despite the greater job creation, the total operation and maintenance cost for a CSP plant is approximately 30% lower than for a natural gas plant, even before the cost of natural gas is included (Stoddard et al., 2006).

The NREL estimates that an investment of $13 billion dollars in the installation of 4,000 MW of CSP, as expected based on the current and planned CSP plant development across the United States, will create 145,000 jobs in construction and 3,000 direct permanent jobs (Stoddard et al., 2006). Although the majority of the construction and operation and management jobs would be located in the Southwest, there will also be significant gains in manufacturing jobs, which would likely be more widely distributed across the country.

Government support also plays a vital role in the development of new solar technologies. The National Renewable Energy Laboratory in Golden, Colorado, receives federal funding to partner with private companies to improve the quality and cost-competitiveness of many renewable energy products, including CSP, and to perform high-risk research on new fluids, mirrors, and systems for CSP plants (Blair, 2008).

Concentrating Solar Market

Current penetration rates of CSP in the United States are near zero because existing large scale plants account for just 419 MW of power compared to a total U.S. installed electricity generating capacity of 1,758,346 GWh in 2007 (National Renewable Energy Laboratory, 2008 and Edison Electric Institute, 2008). Just 9% of the electricity generated in the United States came from renewable energy sources (6.4% hydroelectric and 2.5% other) and 91% was produced by other sources (50.5% coal, 18.3% natural gas, 3.3% oil, and 19% nuclear) (World Bank, 2008). Therefore just 2.5% of U.S. electricity was produced by a combination of geothermal, wind, photovoltaic, and CSP technologies. In fact, in 2006, only 1% of the nation's energy supply was generated from solar power (Energy Information Administration, 2008a).

Technological developments, the evolution of the regulatory environment on carbon emissions, and the volatility and accelerated increase in fossil fuel prices have created the perfect environment for commercial delivery of CSP. Between 2002 and 2007 the price of natural gas for electric power use more than doubled (Energy Information Administration, 2008b). Therefore, although current CSP costs are approximately 18 cents per kWh (Pernick & Wilder, 2008) compared to 6 cents per kWh for coal and 9 cents per kWh for natural gas (Rosenbloom, 2008), the volatility of and long-term increases in fossil fuel costs will make CSP costs more competitive (Pernick & Wilder, 2008). Furthermore, research suggests that increasing the CSP electricity production to 4 GW and incorporating new technological improvements could bring the cost of CSP down to 10 cents per kWh, which would be more competitive with natural gas and coal (Western Governors' Association, 2006). Other research from Clean Edge, Inc. and Co-op America estimates that by 2025, the cost of CSP will decline to 5 cents per kWh (Pernick & Wilder, 2008).

In 2006, total solar collector shipments for all types of solar collectors in the United States increased 29% from the previous year (Energy Information Administration, 2007). The largest market share gain was seen in shipments for high temperature collectors like those used in utility-scale CSP plants, which accounted for 18.5% of all solar collector shipments in 2006, compared to less than 1% in 2005. The Nevada Solar One solar thermal power plant that began generating power in 2007 is credited for this increase. Shipments of high temperature collectors are expected to further increase as additional U.S. CSP plants are developed.

The Sun Belt region has 5,203 million acres suitable to the implementation of CSP plants (Leitner, 2002) and almost all of the existing and planned CSP plants in the United States will be located in that region. Currently, four parabolic trough plants are operating with a combined capacity of 419 MW, two in California and one each in Arizona and Nevada. Another three parabolic troughs, two linear Fresnel reflectors, and two tower plants are expected to be in operation by 2011, and two dish engine plants also are planned (see Table 4-3). Once in operation, these will account for more than 3,000 MW combined. Figure 4-4 illustrates the distribution of existing CSP developers and component manufacturers across the United States. As manufacturing for the nine planned CSP plants gets underway, it is expected that the number of U.S. component manufacturers will increase, as indicated by Abengoa, which expects to open a mirror manufacturing plant at a later stage of development for the Solana Generating Station (Barron, 2008).

Table 4-3. Existing and Planned U.S. Concentrating Solar Power Plants

Project Name	Location	Capacity (MW)	Operation Year
Antelope Valley plant	Southern CA	245	2011
APS Saguaro	Saguaro, AZ	1	Operating
Beacon Solar Energy Project	Kern County, CA	250	2011
Corrizo Energy Solar Farm	San Louis Obispo, CA	177	2010
FPL plant	Florida	300	2011
Ivanpah Solar Power Complex	Ivanpah, CA & Broadwell, CA	400	2011
Mojave Solar Park 1	Mojave Desert	553	2011
Nevada Solar One	Boulder City, NV	64	Operating
SEGS I & II	Daggett, CA	44	Operating
SEGS III-IX	Kramer Junction, CA	310	Operating
Solana Generating Station	Gila Bend, AZ	280	2011
Solar One	Victorville, CA	500	TBA
Solar Two	Imperial County, CA	300	TBA

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

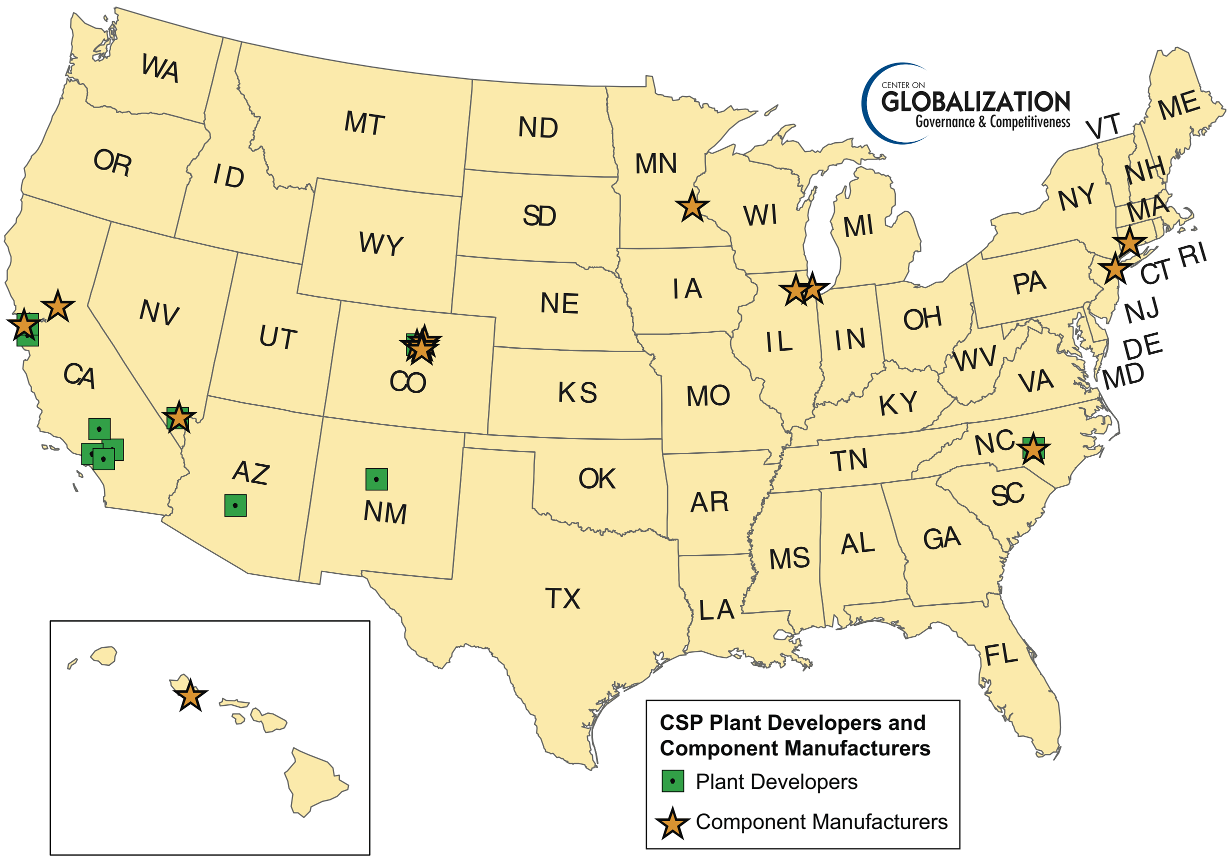
Case Study: Solar Manufacturing Can Replace Lost Auto Jobs

Infinia Corporation recognizes the market potential for CSP and the need for U.S. job growth in manufacturing. With these ideas in mind, the company developed a concentrating solar dish system, called the Infinia Solar System, which is the only CSP technology specifically designed to be mass manufactured by Tier 1 and Tier 2 auto manufacturers in the United States. Infinia included U.S. auto suppliers from the very beginning in product development, design, and manufacturing layout decisions. CEO J.D. Sitton explains that Infinia developed a solar technology product that can be "stamped out like a Chevy and installed like a Maytag." The product can be manufactured on existing auto production lines and shipped as a kit that can be installed by the most basic construction crew (Sitton, 2008).

There appears to be great potential for this approach. U.S. auto production has the capacity to produce over 19 million vehicles, but only about 15 million of the current capacity is being used. Infinia estimates each unit of auto production capacity can be retooled to produce 10 units of the Infinia Solar Power System. Therefore, the idle auto production capacity could produce 40 million units of this new technology per year. This would equate to 120,000 MW of solar capacity and as many as 500,000 manufacturing jobs in Washington, Michigan, and the upper Midwest (Sitton, 2008).

Production of the Infinia Solar System will be launched in January 2009. Infinia initially planned for nearly 100% of manufacturing to be in the United States. However, factors such as Congressional delay in extending the renewable energy investment tax credits and the U.S. government's lack of an effective renewable energy policy have created uncertainty regarding the near-term viability of the U.S. market. Thus, Infinia is investing some of its manufacturing abroad, where the markets are more economically attractive. The initial manufacturing distribution will be 60% U.S. and 40% international (Sitton, 2008).

Figure 4-4: Geographic Distribution of U.S.-Based Concentrating Solar Power Plant Developers and Component Manufacturing Companies



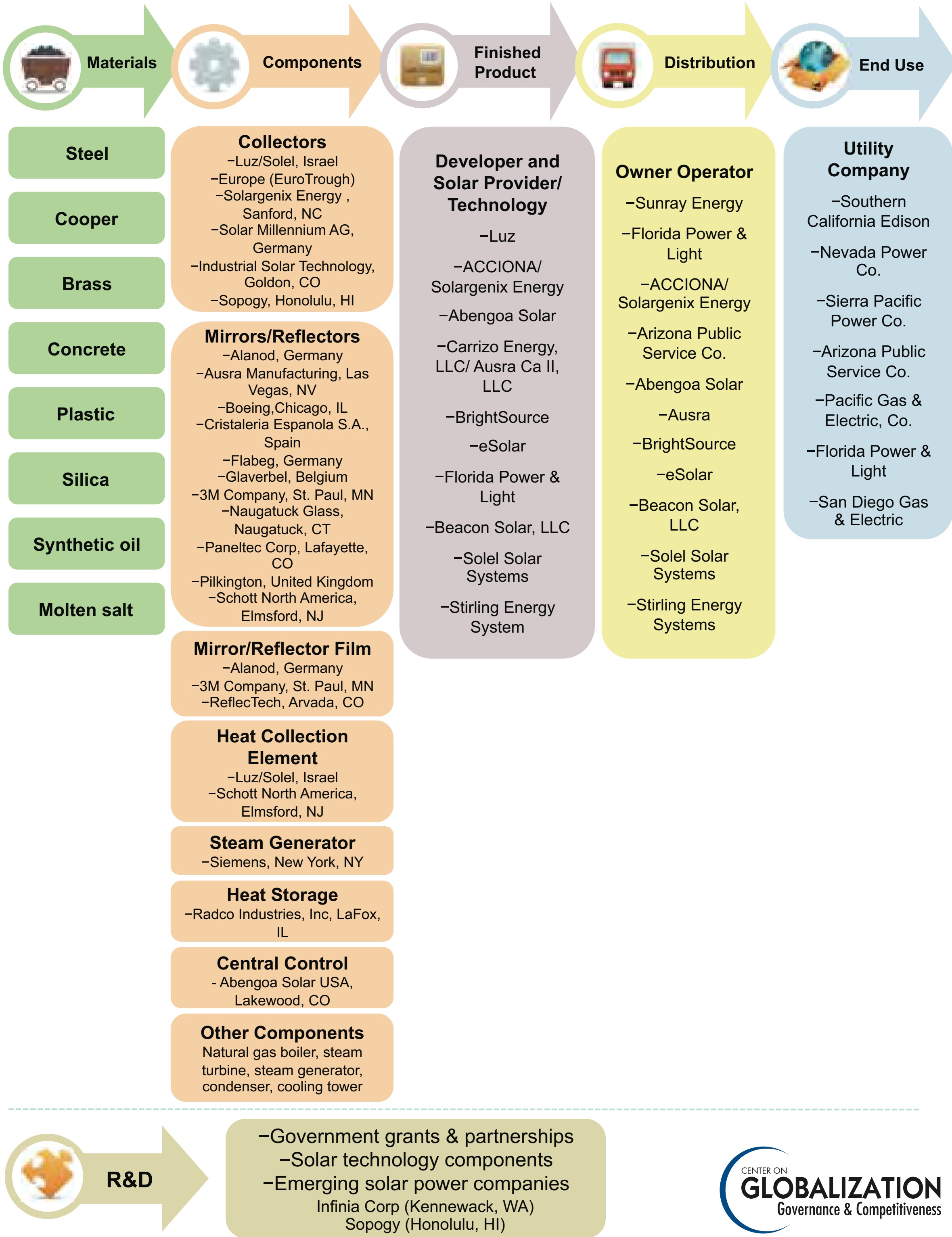
Source: CGGC, based on company annual reports, individual interviews, and company websites.

In addition to its potential to provide new production capacity for ailing auto manufacturing plants, Infinia believes its solar system is twice as efficient as photovoltaic products and has broader potential than other CSP technologies because it does not need flat ground or cooling water. This means it can be deployed in and around towns, making new transmission lines unnecessary. New business agreements to install this technology will be announced in the fall of this year (Sitton, 2008).

Conclusion

The example of Infinia Corporation illustrates the extensive manufacturing and technology innovation opportunities for CSP development in the United States. Furthermore, technological developments and the volatility and increase in fossil fuel prices are reducing the disparities in cost between renewable and non-renewable energy sources. Worldwide concern about carbon emissions also is strengthening the market. CSP has the potential to reduce carbon emissions while positively impacting job growth, if it is able to benefit from government tax incentives and more extensive technology deployment.

Figure 4-5. Concentrating Solar Power Value Chain, with Illustrative Companies



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

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CHAPTER 5

Super Soil Systems

A New Solution for Managing Hog Wastes

by

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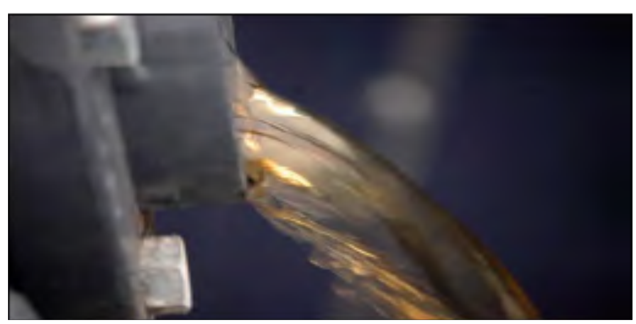
Summary
Over the past two decades the U.S. swine industry has evolved from small, traditional farms to large, industrial farms in which thousands of swine are confined in intensive feeding conditions. These large, specialized operations create great quantities of highly concentrated hog wastes. The dominant method of handling these wastes is to keep them in open lagoons and to spray them onto nearby fields, which, particularly in case of heavy rains, can contaminate surface water and groundwater. Air pollutants from industrial hog farms cause odors and contribute to health risks. Perhaps less well known is the swine industry's contribution to greenhouse gas emissions. When these emissions are calculated to include deforestation for feed crops, the global livestock sector, including swine production, is estimated to cause 18% of global greenhouse gas emissions measured in CO_2 equivalent. This is an even higher share than transport.

North Carolina, the nation's second largest hog producer, has made significant strides toward a viable alternative to open waste lagoons. The state's Lagoon Conversion Program has provided support for a particularly promising new technology, Super Soil Systems. This technology has met all the state's environmental performance standards, treating the entire waste stream from the farm. Super Soil also reduced greenhouse gas emissions by a remarkable 97%.

Super Soil is not yet commercially available, yet it is an example of a technology that could potentially be widely adopted. The adoption of this or similar technologies would involve manufacturing jobs producing large tanks—ranging, in the demonstration facility, from 11 feet to 36 feet in diameter—and pipes, which total some 2,000 feet. Additional manufacturing jobs would be needed to make the equipment, along with the associated requirements for steel, glass, concrete, and other materials, and construction jobs to build the facility. By addressing critical environmental problems caused by large animal farms, Super Soil and related technologies could help hog-producing states protect existing jobs and keep the door open to future job expansion. This dynamic is evident in North Carolina, where finding an alternative to open hog waste lagoons serves the best interest of many closely affiliated jobs in the meat processing industry. Because Super Soil technology is also applicable to large beef operations, it is an opportunity for the United States to become a world leader in solving serious environmental problems associated with livestock farming, problems that will only become more acute as the demand for meat steadily rises among consumers in developing countries.

Figure 5-1. On-Farm Super Soil System

Source: Vanotti & Szogi, 2007



Source: Vanotti & Szogi, 2007

Introduction

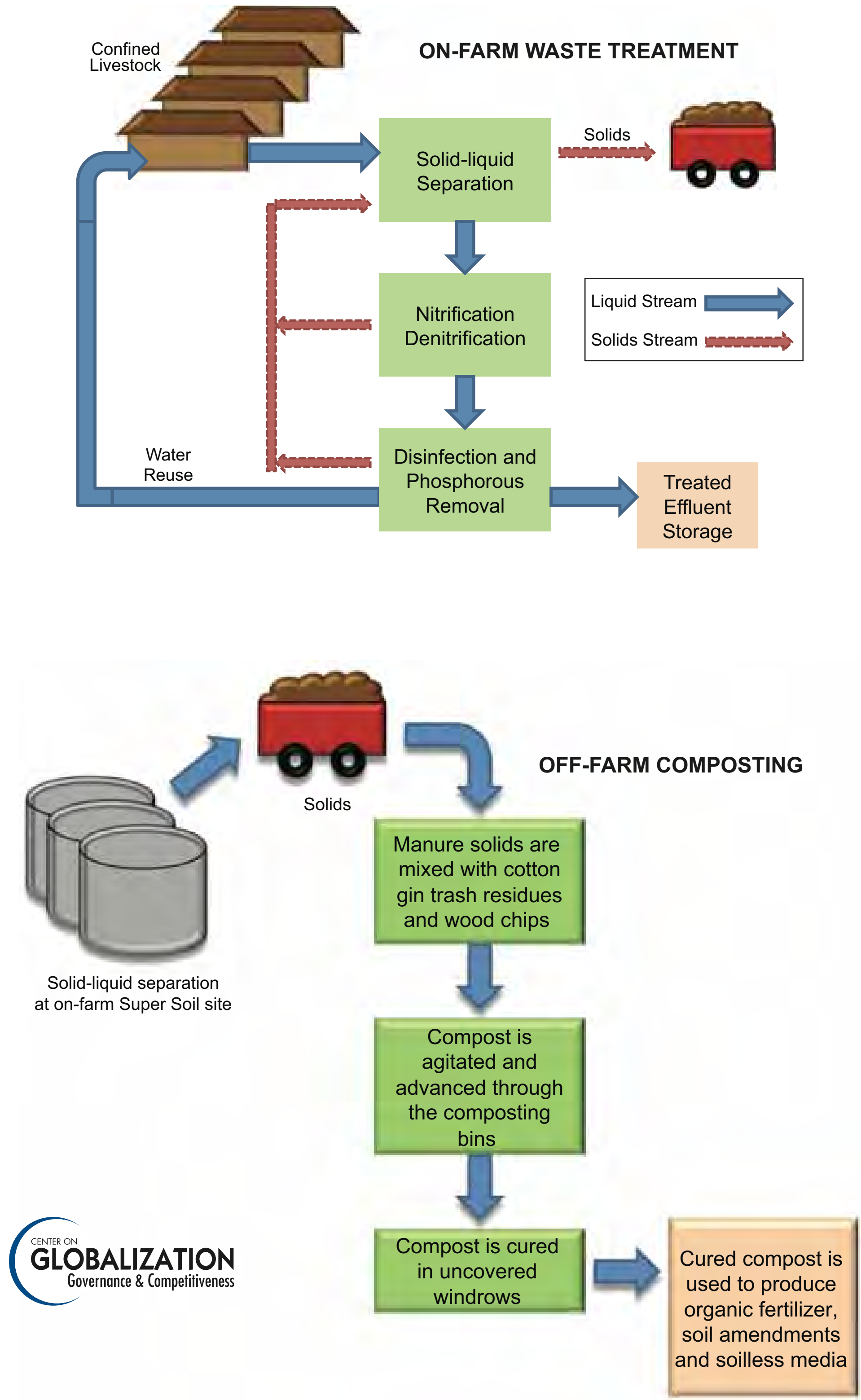
The United States is leading the international trend toward consolidation of animal farming into extremely large, integrated industrial operations (Key & McBride, 2007). These large, specialized operations create great quantities of highly concentrated hog feces and urine. Federal and state regulations allow hog farms to keep these wastes in open lagoons and to spray them onto nearby fields; however, both of these methods pose several environmental problems. The lagoon pits sometimes rupture after heavy rains, and this runoff, along with that from the fields on which waste is sprayed, can contaminate surface water and groundwater. Air pollutants from industrial hog farms cause odors and contribute to fine particulate matter, diminishing quality of life and increasing health risks for nearby residents (Wing et al., 2008).

The swine industry also generates significant greenhouse gas emissions. The three major greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Agriculture is responsible for roughly 30% of total U.S. methane emissions, and manure management accounts for about 25% of methane released by the agricultural sector. Manure management is also responsible for some 5% of all U.S. nitrous oxide emissions. These emissions are particularly significant because they are potent heat-trapping gases. On a per-molecule basis, methane and nitrous oxide have 21 times and 270 times the global warming potential of CO_2, respectively (U.S. EPA, 2006). When emissions are calculated to include deforestation for feed crops, the global livestock sector including swine production is estimated to be responsible for 18% of greenhouse gas emissions measured in CO_2 equivalent—an even higher share than transport (Gerber et al., 2007).

North Carolina, the nation's second largest hog producer, has undertaken substantial measures to deal with the growing hog waste problem. The state has more than 10 million hogs, 97% of which are on farms with 2,000 or more head (USDA, 2008). In 1997, responding to environmental concerns, the state government placed a 10-year moratorium on new and expanded swine operations. When this moratorium expired in 2007, it was replaced by a permanent ban on new lagoons and spraying fields, along with a Lagoon Conversion Program that offers grants to help farmers pay for adopting alternatives to waste lagoons (Rawlins, 2007).

A particularly promising new alternative that has received support from North Carolina's Lagoon Conversion Program is called Super Soil System. This technology was thoroughly evaluated in conjunction with an agreement between the state's Attorney General and Smithfield Foods, the world's largest hog producer and pork processor. Under the Smithfield Agreement, 18 different hog waste technologies were tested against five environmental performance standards. Those standards included the substantial elimination of ammonia emissions, odor, pathogens, soil contamination by nutrients and heavy metals, and elimination of hog waste discharge and runoff. Only five technologies met all the standards. Of all technologies tested, only one, Super Soil Systems, treated the entire waste stream from the farm. Super Soil not only met all of the performance criteria, it also reduced greenhouse gas emissions by 97% (Vanotti et al., 2007).

Figure 5-2. Super Soil Waste Treatment Process



Sources: On-farm process adapted from figure in Vanotti & Szogi, 2007; off-farm process based on description in Vanotti, 2005.

The second generation Super Soil System is made up of two elements: a liquid treatment system consisting of a series of large steel tanks located at the hog farm, and a solids processing facility, which is located offsite (see Figure 5-2). Liquid treatment involves separating the solids out of the hog waste stream. The solids are then transported to an offsite location where, in a proprietary process, they are composted and blended with other materials to make a value-added product, commercial fertilizer (Vanotti & Szogi, 2007).

In addition to Super Soil, several technologies offer promise for handling hog waste in different combinations that best meet the needs of a particular farm. Methane capture is one such technology. When animal wastes are kept in a digester or anaerobic lagoon, the decomposition process produces “off-gases,” which consist of about 70% methane. This methane can either be simply flared off, which converts methane to CO_2, or it can be fed into a combustion device to generate electricity, thus providing a renewable energy alternative to coal-based electric generation. These systems, also called biogas digesters, have been used extensively in small-scale settings in developing countries and are also feasible on a much larger scale. For example, one of the technologies tested along with Super Soil Systems in North Carolina was a methane digester in use on a 4,000 head sow farm.[6] Approximately 100 digesters are operational or under construction on farms across the United States; however, this represents merely 1% of the 7,000 candidate dairy and hog farms (Resource Strategies, Inc., 2006). While anaerobic digesters provide some air quality benefits (methane capture and odor reduction), they can only provide sufficient water quality benefits to meet environmental performance standards if combined with technologies that treat the digester effluent or other liquids left on the farm.

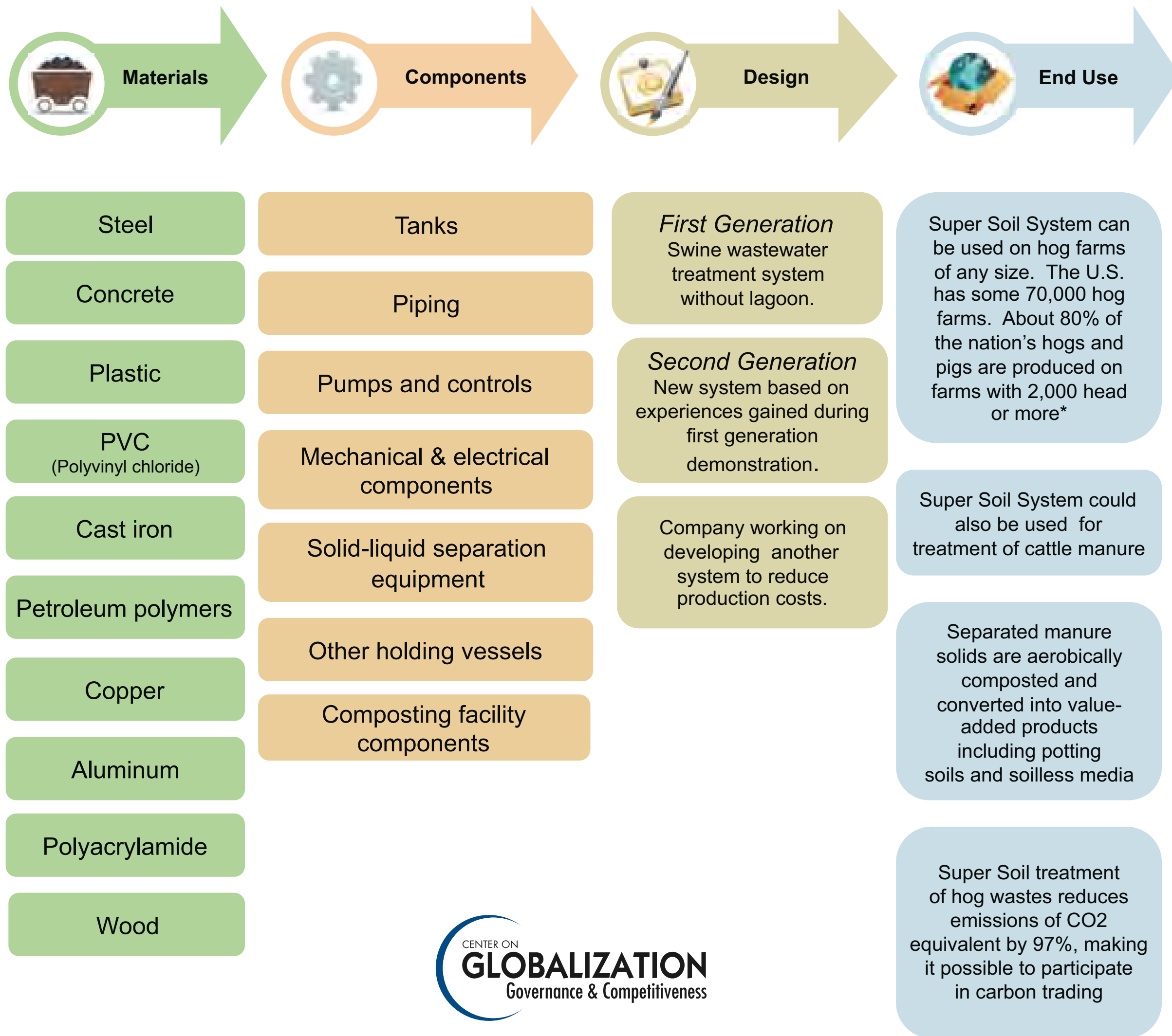
Several possible combinations of collectors, tanks, digesters, and mixing areas could make up a methane recovery system. When implemented on a large scale, these systems may use large tanks and piping similar to those that make up the Super Soil System. Thus, although the analysis that follows will focus specifically on Super Soil technology, portions of the analysis are potentially relevant to the materials and components required for both systems.

Super Soil System Value Chain

Super Soil technology will soon be operating on the equivalent of six North Carolina farms with the potential to treat 70,000 hogs (Rudek, 2008), but since it is still under development, its value chain looks quite different from those of established industries. For this report we have divided the Super Soil System value chain into four segments: materials, components, design, and end use (see Figure 5-3). The left side of the value chain, including materials and components, applies to the equipment that makes up the second generation demonstration facility in eastern North Carolina. The design segment describes the two generations of Super Soil technology that have been developed to date, and the company’s future plans for a third generation. The end use segment highlights the potential for implementing the technology on large hog farms across the United States, as well as for managing other wastes from large animal operations, such as cattle manure.

[6] Sows live to reach a weight roughly three times that of “finishing” pigs—which are typically slaughtered by the age of six months—and so they produce a greater amount of waste. A 4,000 head sow farm produces wastes equivalent to a 12,800 head finishing farm (Rudek, 2008).

Figure 5-3. Super Soil Systems, Simplified Value Chain



*Key & McBride, 2007
Source: CGGC, based on interviews and Vanotti & Szogi 2007.

The main material in the current demonstration facility, the second generation Super Soil, is steel, which is used for a series of large tanks and other holding vessels. A major focus of an upcoming third generation project, now in the design stage, is to reduce installation costs, and alternatives to steel will be an important possibility. The third generation system will be implemented at several sites in North Carolina and, while emphasizing reduced costs for materials, will use largely the same components. One option under consideration is to build the treatment infrastructure, including tanks, with concrete or glass-lined steel (Campbell, 2008).

Installation costs of Super Soil technology are higher than those for the anaerobic waste lagoons now widely used in the swine industry, although there are at least two ways in which these costs can be partly offset. First, the solids are separated out of the waste stream and composted into a value-added soil "container mix," which can be sold in bulk to nurseries and large retail outlets such as Lowe's or Home Depot. Second, the considerable reductions in greenhouse gas emissions could bring value under a carbon trading system, in which farmers earn money based on the amount of carbon-dioxide equivalent they prevent from entering the atmosphere.

According to a report by USDA researcher Matias Vanotti and colleagues, replacing the traditional hog lagoon with this cleaner, aerobic waste treatment technology nearly eliminated greenhouse gas emissions; in a 4,360-head swine operation, the new lagoon process reduced total greenhouse gas emissions 97%, from 4,972 tons of carbon dioxide equivalent to 153 tons of CO_2 equivalent per year. Including the entire Super Soil process, the project reduced greenhouse gas emissions by 1.1 tons of CO_2-equivalent per hog per year (Vanotti et al., 2007). According to an analysis of Super Soil using Chicago Climate Exchange trading values of $4 per ton of CO_2, the return to the hog farmer was $1.80 per finished pig (Vanotti et al., 2007).

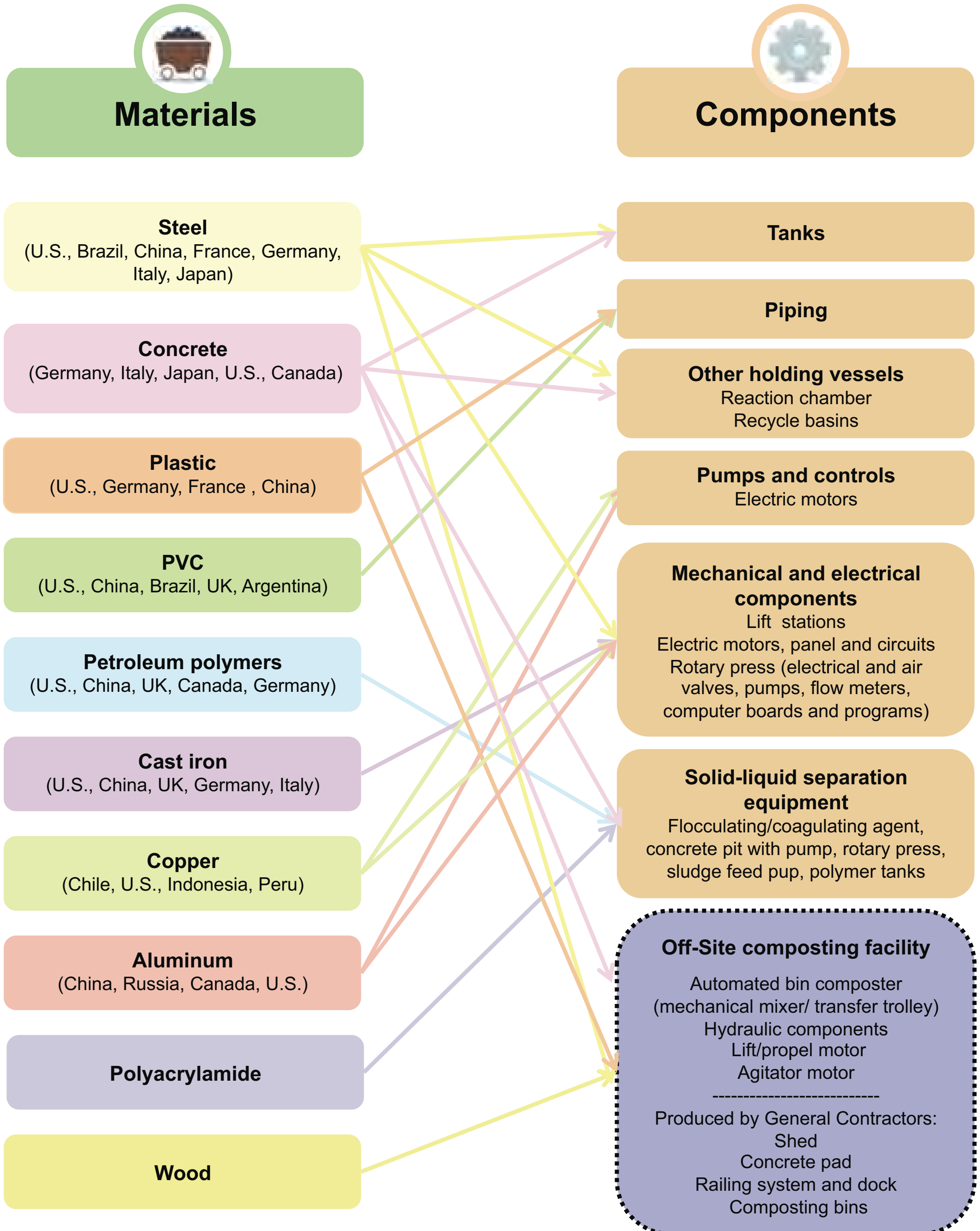
The on-farm system also removed more than 97% of suspended solids from wastewater. It eliminated 95% of total phosphorous, 99% of ammonia, 98% of copper, and more than 99% of biochemical oxygen demand and odor-causing components, producing a disinfected effluent. In addition, the old wastewater lagoon at the demonstration site became clean and aerated, with substantially lower ammonia emissions (Vanotti et al., 2007).

Materials and Components

The main materials used in the Super Soil System are steel, concrete, and polyvinyl chloride (PVC). The system's tanks and other holding vessels use large amounts of steel, including stainless steel, epoxy-coated steel, glass-lined steel and galvanized steel. Of the seven tanks in the system, two consist of epoxy-coated steel, and five consist of glass-lined steel. These tanks and other vessels range in size from 11 feet to 36 feet in diameter, and all have concrete bases. The system uses approximately 2,000 feet of piping, which can be made of steel, PVC or other plastic. Other materials include cast iron, copper, aluminum, polyacrylamide (a flocculating/ coagulating agent), and petroleum polymers. The United States is one of the leading producers of all the major materials used in the system (see Figure 5-4).

The components that make up the on-farm Super Soil System (where solids are removed and the liquid wastes are treated) can be grouped into six main categories: tanks; piping; pumps and controls; mechanical and electrical components; solid-liquid separation equipment; and other holding vessels (see Table 5-1). Steel tanks are the largest component. Mechanical and electrical components include lift stations, electric motors, panels and circuits, and a rotary press. The solid-liquid separation process includes a rotary press; sludge feed pump; polymer tanks; a concrete pit with a pump; and a flocculating agent.

Figure 5-4. Super Soil Components and Major Materials with Top Producing Countries



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Source: CGGC, based on OneSource industry market research, individual interviews, company websites, Vanotti and Szogi 2007, and Vanotti 2005.

The offsite Super Soil composting facility treats solids using an in-vessel composting method (one of many suitable methods for composting animal manure). With in-vessel composting, the material to be composted is confined within a building, vessel, or container, and the composting process is accelerated via forced aeration and mechanical turning of the materials. The Super Soil composting facility on the Hickory Grove Farm in Sampson County, North Carolina, first mixes the manure solids with cotton gin trash residues and wood chips, then agitates the material and advances it through composting bins in an enclosed shed. The main components in this composting facility are an automated bin composter (mechanical mixer), which moves over the composting bins on a railing system, and a dock. The mixer uses hydraulic components as well as propel motors and agitator motors. The main materials used for the construction and installation of the automated machinery in the composting facility are steel and concrete. The shed enclosure is constructed from wood, plastic, and standard roofing material.

Table 5-1. Description of Major Super Soil System Components

Category	Subcomponent	Picture
Tanks	Aeration tank	
	Clean water tank	
	De-nitrification tank	
	Homogenization tank	
	Large settling tank	
	Nitrification tank	
	Phosphorous removal tank	
	Phosphorous removal tank	
	Polymer preparation tank	
	Scum tank	
	Storage tank	Source: Vanotti & Szogi, 2007
Piping	Diffuser piping network Piping throughout entire system Various materials possible	
Solid-Liquid Separation Equipment	Polyacrylamide	
	Concrete pit with one pump for lifting	
	Rotary press separator	
	Polymer preparation tanks	
	Polymer metering tank	
	Sludge feed pump	
	Dual, 48” rotary press	Source: Vanotti & Szogi, 2007

Category	Subcomponent	Picture
Mechanical and Electrical Components	Submergible mixer	
	Lift stations	
	Electric motors, panel and circuits	
	Rotary press (electrical and air valves, pumps, flow meters, computer boards and programs, electrical parts)	
Pumps and Controls	Concrete pit with one pump for lifting	
	Polymer metering pump	
	Sludge feed pump	
	250gpm capacity pump	
	Lime injection pump	
Other Holding Vessels	Recycle basins	
	.3 m^3 reaction chamber	
Trickle Irrigation System	Note: This is an optional feature. Excess water can also be applied using an overhead irrigation system.	
Automated Composting System	Mechanical mixer/ transfer trolley	 Source: Vanotti, 2005
	Railing system and dock	
	Composting bins	
	Lift/propel motor	
	Agitator motor	
	Hydraulic components	
	Concrete pad	
	Shed	
	Front end loader (tractor with shovel)	

Source: CGGC, based on company websites, Vanotti and Szogi 2007, and Vanotti 2005.

Selected Component Suppliers

The types of firms associated with the major components in Super Soil Systems include those that supply tanks, pumps, piping, mixers, and controls to wastewater treatment and irrigation systems. For proprietary reasons, names are not available for the companies that provided the actual components used in the Super Soil demonstration facility in Clinton, North Carolina. However, a list of representative companies in the relevant component categories is found in Table 5-2.

Widespread adoption of Super Soil System technology would involve manufacturing jobs producing large tanks—ranging, in the demonstration facility, from 11 feet to 36 feet in diameter—and pipes, which totaled some 2,000 feet. Additional manufacturing jobs would be needed to produce the other components listed in detail above, along with the associated requirements for steel, glass, concrete, and other materials. Construction jobs would be involved in building the facility, including large equipment, housings, and freestanding structures. Installation jobs would be associated with the piping, with steel pipes necessitating skilled labor, and PVC and other plastics requiring less specific labor skills. Although the operation of the system is fully automated, some labor would be required to perform maintenance and part replacement. Certain components of Super Soil equipment, including mixers, pumps, and blowers, have a limited life span, and replacement can be expected after 10 years of operation (Rudek & Shao, 2007).

Super Soil and related technologies could help hog-producing states protect existing jobs and keep the door open to future job expansion. By addressing critical environmental problems caused by large animal farms, these technologies serve the best interest of a large number of closely associated jobs in the meat processing industry. This dynamic is evident in North Carolina, home of the world's largest pork processing facility, where the state government has combined environmental laws with support for innovation in the development of Super Soil and other hog waste solutions.

Table 5-2. Component Manufacturing Companies Relevant to Super Soil Technology*

Component	Company Name	Location	Total Sales (USD mil)	Total Employees
Coated Steel and Stainless Steel Tanks	Fisher Tank Company	Lexington, SC	$34.0	45
	Columbian-TecTank	Parsons, KS	$32.8	140
	Baker Tanks, Inc. (BakerCorp)	Seal Beach, CA	$28.5	400
	Pittsburgh Tank Corporation	Monongahela, PA	$28.5	50
	Highland Tank & Manufacturing Company	Stoystown, PA	$25.0	160
	Western Tank and Lining Ltd.	Canada	$24.4	27
Ductile Iron, Copper and Metal Pipes; Plastic and FRP Pipes	Ameron International	Pasadena, CA	$631.0	2,600
	Future Pipe Industries	United Arab Emirates	$556.4	3,500
	Reinforced Plastic Systems Inc.	Canada	$208.0	150
	Oxford Plastics, Inc.	Canada	$41.4	30
Coagulants, Flocculants and Precipitants	SNF Floerger SAS	France	World's top producer	n/a
	Ciba Specialty Chemicals Holding Inc.	Switzerland	$5,211.8	14,130
	HaloSource, Inc.	Bothell, WA	$76.2	80
	Kemira Water Solutions, Inc.	Lakeland, FL	$41.4	200
	Bentonite Performance Minerals	Lovell, WY	$20.9	70
Pumps, Motors, Pumps and Controls, Pump Drivers	Rockwell Automation, Inc.	Milwaukee, WI	$5,003.9	20,000
	Kavlico Corporation	Moorpark, CA	$156.1	1,400
	Weir Pumps Ltd.	Salt Lake City, UT	$54.4	800
	Armstrong Pumps, Inc.	North Tonawanda, NY	$33.7	110

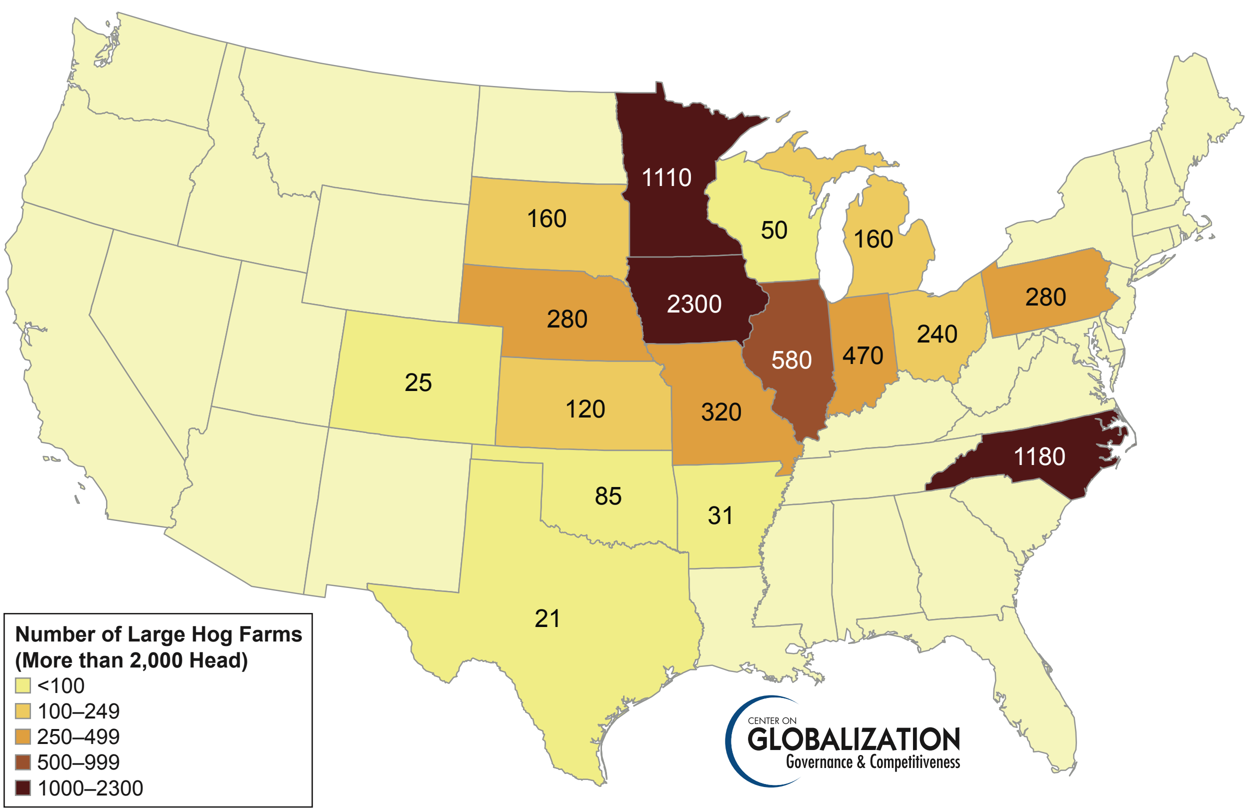
Component	Company Name	Location	Total Sales (USD mil)	Total Employees
Lift Stations and Vertical Pumps	Sulzer Pumps Ltd.	Switzerland	$2,296.8	10,000
	Gorman-Rupp Company	Mansfield, OH	$305.6	1,065
	Topp Industries, Inc.	Rochester, IN	$29.3	125
	Holland Pump	Brunswick, GA	$9.2	30
In-Vessel Automated Composter Systems	Farmer Automatic of America	Rochester, IN	$4.2	10
	Engineered Compost Systems	Seattle, WA	$3.1	17
	Green Mountain Technologies, Inc.	Whittingham, VT	n/a	n/a

*With the exception of Farmer Automatic of America, this list refers to relevant companies, not actual suppliers to Super Soil Systems
Source: CGGC, based on company websites and industry sources.

Markets

The United States accounts for 10% of global pork production, making it the world's third largest pork producer, behind China (46%) and the European Union (24%) (USDA, 2008). The U.S. swine industry is dominated by large farms; some 80% of the nation's hogs and pigs are produced on farms with 2,000 head or more (see Figure 5-5).

Figure 5-5. Number of Large Hog Farms, by State, 2007



Source: CGGC, based on USDA/NASS 2008

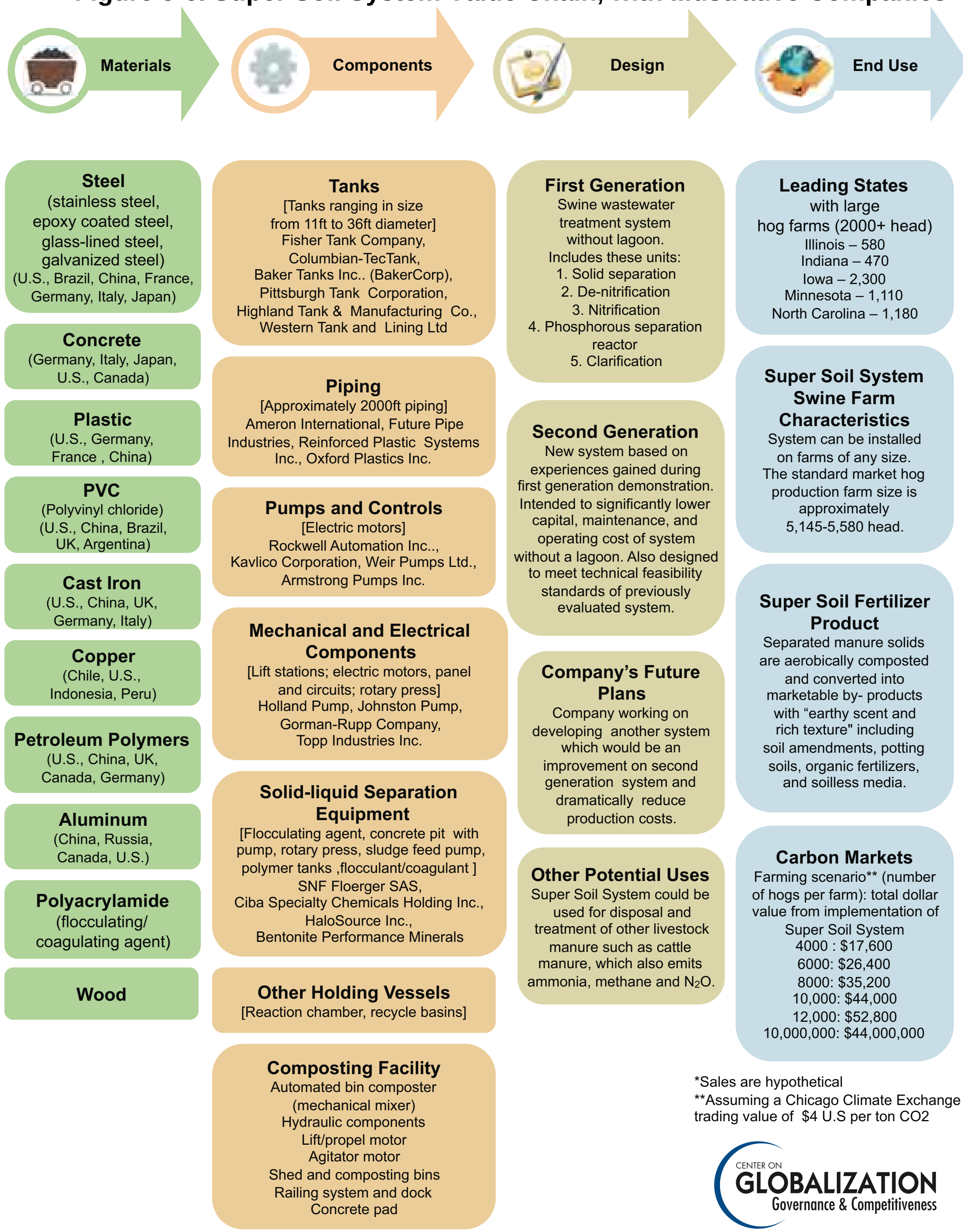
Nationwide, more than 7,700 farms fall in this size category. Farms of this size are the most likely to receive pressure from citizens and governments to mitigate the environmental impacts of hog farming operations. Environmental groups are stepping up the pressure on governments to regulate factory farms to clean up their waste as other industries are required to do. The Sierra Club, for instance, is targeting factory farms as one of its national priority campaigns (Sierra Club, 2008). In 2007 the organization joined a local Iowa group, Iowa Citizens for Community Improvement, and the Washington, D.C.-based Environmental Integrity Project, in filing a formal legal petition urging the U.S. EPA to strip the Iowa Department of Natural Resources of its authority to issue factory farm operating permits to the state's growing number of concentrated animal feeding operations, because of continuing violations of the Clean Water Act (Environmental Integrity Project, 2007). Since open pit lagoons are the main focus of these efforts, a proven technology such as Super Soil Systems would likely have a large potential market as an environmental solution—one that could help states avoid having to take more drastic measures, such as banning new and expanded hog operations.

Conclusion

Animal farming is marked by a growing international trend toward consolidation into exceptionally large operations, which pose serious environmental hazards, including greenhouse gas emissions and pollution of rivers, lakes, and streams. Super Soil Systems are one promising alternative to the dominant method of handling hog wastes: storing them in open lagoons. Super Soil fully treats all liquid and solid wastes from the hog farm, nearly eliminating greenhouse gas emissions and passing all environmental performance standards in North Carolina, the state with the nation’s strictest environmental restrictions for hog farms.

As the hog industry grows in other states, state governments will likely need to follow North Carolina’s lead and require effective waste management, which means providing an alternative to open lagoons. Replacing existing lagoons and building new systems such as Super Soil would create U.S. manufacturing jobs in large tanks and piping, other wastewater treatment equipment, and in construction and installation. Because the technology is also applicable to large beef operations, it is an opportunity for the United States to become a world leader in solving serious environmental problems associated with animal factory farming, problems that will only become more acute as the demand for meat steadily rises among consumers in developing countries.

Figure 5-6. Super Soil System Value Chain, with Illustrative Companies



Source: CGGC, based on Campbell, 2008; Rudek, 2008; Vanotti, 2005; Vanotti & Szogi,2007; and Vanotti et al., 2007.

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