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Countries are jockeying for leadership. They know that investing in clean energy can renew manufacturing bases, and create export opportunities, jobs and businesses.

– Phyllis Cuttino, Pew Campaign on Global Warming

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## Keeping Manufacturing in the United States

The U.S. solid-state lighting (SSL) industry sits on the cusp of major technology advances that will revolutionize the industry and greatly accelerate energy efficiency here and around the world. In 2007, lighting manufacturers employed almost 60,000 people nationwide and shipped products valued at \$13.5 billion.

Solid-state lighting is an exciting new technology that has tremendous economic upsides for the lighting industry, which has essentially been reduced to selling commodity products in recent years. Large and small manufacturers, as well as technology start-ups, are well aware of the worldwide regulatory trend toward more energy-efficient lighting. In 2009 alone, U.S. companies, many of them start-ups, raised about \$300 million in venture capital for advanced lighting products.

However, as in the semi-conductor and information technology sectors before, U.S. solid-state lighting companies are faced with economic factors that have led to the globalization of those industries, including lost jobs, a dispersal of the technology infrastructure largely built in this country, and ultimately a U.S. trade deficit.

Over the last eight years, the U.S. Department of Energy (DOE) has directly worked to accelerate the growth of the emerging solid-state lighting industry, primarily through research, development and demonstration efforts. This support has led to numerous technological and market advancements that have supported the growth of U.S. industry and a distinct international lead in the production of quality products.

This lead is predicated on technological advancements and a strong U.S. market. The industry's major concern is that it will not be able to maintain this lead if a substantial portion of volume manufacturing is outsourced. Therefore, using funding from the American Recovery and Reinvestment Act of 2009, DOE added a manufacturing research and development component to its support for core research and product development. DOE aims to help improve U.S. manufacturing efficiency and avoid the loss of technological expertise, intellectual property and manufacturing jobs to other countries.

### US DOE SSL Manufacturing Roadmap

#### GOALS

- Improve product consistency and quality
- Accelerate cost reduction
- Encourage U.S.-based manufacturing for job creation and maximum benefit to the U.S. taxpayer

In April 2010, at DOE's annual SSL Manufacturing R&D Workshop in San Jose, California, plenary speakers and a special panel on U.S. manufacturing addressed these challenges.<sup>1</sup> While many speakers and participants noted that the industry is truly global, and that some of the technology and manufacturing will inevitably migrate out of the United States, there are several specific actions we can take that will help the country retain a strong position in significant portions of the SSL industry.

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1 Please see presentations at [www.ssl.energy.gov/sanjose2010\\_materials.html](http://www.ssl.energy.gov/sanjose2010_materials.html)

This paper reports the findings of the workshop. It outlines the current state of the solid-state lighting industry; highlights the importance of continued government/private sector collaboration in retaining manufacturing strength in the United States; and summarizes the recommendations of the lighting industry for the roles both sectors could play in this important endeavor.

## The Opportunity

The U.S. lighting industry has lost most, if not all, of its incandescent and compact fluorescent lamp (CFL) manufacturing to Asian countries in the last two decades, as well a substantial share of finished luminaire product and sub-system manufacturing, because it could not match production costs. U.S. companies have made significant financial investments in SSL technology and would like to retain a larger share of this next generation of lighting. The more industry has to outsource, the less control it has over component development, manufacture and quality. Also, future development becomes more focused in the countries that manufacture the products. As the work is outsourced, the United States loses its status

Reversing the trend of off-shore SSL manufacturing would have a significant impact on the U.S. economy through the retention of tens of thousands of jobs and of technical expertise and capability, and the creation of new jobs. It could boost the sales of value-added exports, while reducing the level of value-added imports. Perhaps of most value would be maintaining U.S. leadership in the solid-state lighting industry as product advancements are made over the coming years.

as a center of expertise, intelligence and jobs. Short-term profit gains are offset by the long-term loss of leadership.

While solid-state lighting components are already being sourced internationally, research and development remains most intense in the United States and Europe, as does manufacturing of higher quality products. Although China and other Asian countries are catching up, the United States still maintains the innovation competitive edge. However, according to a recent study published in the *Harvard Business Review*, as manufacturing is outsourced, there is strong evidence that research, development and innovation are following<sup>2</sup>.

It is important to understand how the manufacturing industry will change to meet the complexities of this

advanced technology. The current lighting industry is primarily divided between the manufacture of light bulbs and the manufacture of light fixtures. While recent acquisitions have resulted in a somewhat more vertically integrated industry structure, these two activities remain almost completely separate.

This separation is not feasible for solid-state lighting. The ultimate value of SSL, including its energy efficiency potential, is not in the production of replacements for incandescents or CFLs, but in the development of integrated luminaires that serve a particular function. Fixtures and even replacement lamps must be specifically designed to accommodate light-emitting diode (LED) light sources properly; failure to do so will result in poorly performing, unreliable products. Because of this design requirement, fixture manufacturing must develop greater technological expertise. Some LED manufacturers have already acquired fixture manufacturing capabilities, and some of the larger independent luminaire makers have acquired additional technological skills, but many manufacturers have yet to come on board.

2 “Restoring American Competitiveness”, Gary P. Pisano and Willy C. Shih, *Harvard Business Review*, July-August 2009

The higher-tech nature of solid-state lighting was seen by many workshop participants as an important opportunity for the U.S. lighting industry to gain more strength in the global market. However, this will not be automatic. To ensure that the monetary benefits are not lost to foreign manufacturers, the U.S. lighting industry must establish more efficient and cost-effective manufacturing processes.

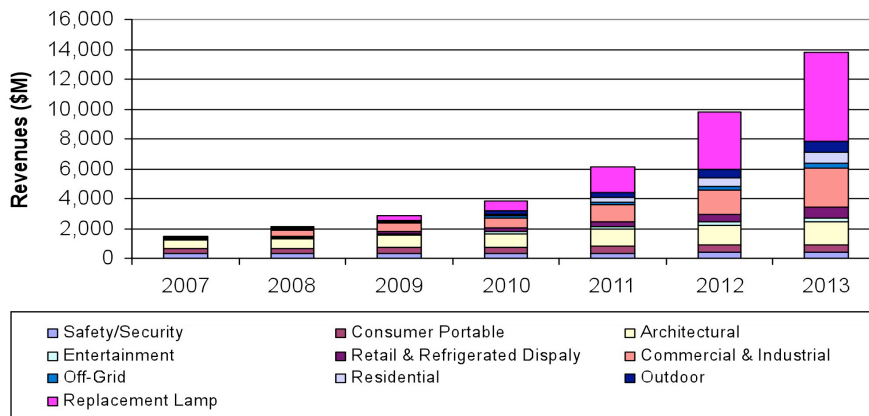
Our best opportunity to preserve and build the U.S. industry is to get closer to the customer—getting close to the end application. [The United States] is still one of the very largest markets in the world and it’s a primary driver in the solid-state lighting arena.

– Chuck Berghoff, President and CEO of OptoElectronix

## An Industry in Transition

The United States has led the evolution of LEDs for use in general purpose lighting. While the use of high-brightness LEDs has been quite common in everyday products, such as cell phones, TVs, and street signs, widespread use in the world’s lighting market is just beginning. After years of intense investment by several multi-national and U.S. companies, LED technology has advanced so far that the production of highly efficient “white light” products is feasible and becoming more cost-effective.

**APPLICATION SEGMENTS  
2008 – 2013**



Source: Strategies Unlimited

According to Vrinda Bhandarkar of Strategies Unlimited, an industry market research firm, the LED slice of the worldwide market has more than doubled in value from under \$2 billion in shipments in 2007 to a projected value of about \$4 billion in 2010. The projection of almost \$14 billion in 2013 is more than 7 times the value of the 2007 market. The majority of the LED product market is in fixtures, with replacement lamps growing in market size to about 43 percent in 2013. Because solid-state lighting applications are better suited to integrated fixtures, purpose-designed fixtures, and modular sources, the focus on replacement lamps will ebb as the technology matures and much more energy-efficient lighting replaces incandescent sockets. However, all of these product designs share the same technological challenge of integrating thermal management, sophisticated electronics, and semiconductor sources into the product.

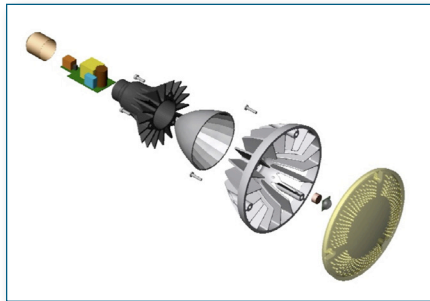
### Energy Savings Potential of LEDs

With the promise of being 10 times more efficient than incandescent lighting, LEDs will change the way Americans light their homes and businesses. With superior durability, flexibility, and longevity, LEDs have the potential to reduce lighting energy use by 25 percent by 2030, which is the annual equivalent to saving:

- \$15 billion (today's dollars)
- 190 terawatt-hours
- Output of 24 1,000-MW power plants

While the worldwide lighting market declined by approximately 15 percent<sup>3</sup> in 2009, the LED lighting lamp and luminaire market grew robustly by 32 percent. Manufacturing is expanding to hundreds of companies worldwide, with more than 500 outside China, which is the current manufacturing leader with thousands of companies. The United States remains the world's market leader in purchasing such products.

Major LED lighting improvements are being made not only in chip efficiency, but in the quality of luminaires and lamps. Major markets are emerging in outdoor area lighting and commercial retrofit products. DOE's L Prize is a technology competition designed to spur lighting manufacturers to develop high-quality solid-state lighting products to replace the common light bulb. The competition is stimulating the development of LED lamps that are much more efficient than incandescents and CFLs. The 2007 Energy Independence Security Act (EISA), which becomes effective in 2012, will lead to the phaseout of inefficient light bulbs and an even broader market for solid-state lighting.



Components of a typical solid-state lighting luminaire  
Source: Philips Color Kinetics

One of the most worrisome lighting industry trends of the last 20 years has been the loss of U.S. jobs and economic stature, not to mention intellectual property foundation, to Asian countries. This is reflected in the huge disparity in U.S. imports versus exports. Many observers attribute this to the lower-wage structure in these countries, but several workshop participants commented that labor cost is not the main reason U.S. companies outsource high-tech manufacturing. The lighting manufacturers highlighted the following reasons for migration to China and other Far East countries:

- Proximity to the world's highest population and economic growth markets
- Proximity to the supply chain
- Incentives offered for foreign investment in manufacturing and R&D
  - Availability of infrastructure, space in industrial parks, a trained workforce, and low-cost loans
  - Generous government subsidies for energy and water
  - Export incentives, tax breaks, and refunds of the value-added tax
  - Tariff protections from foreign competition

3 According to the National Electrical Manufacturer's Association (NEMA)

- Local rules and regulations
- Funding for research and development
- Lower wages

Because semiconductors are an important component of solid-state lighting, a direct parallel exists. According to the Semiconductor Industry Association, semiconductors have been the number-one export product for the United States over the last five years. The U.S. industry generated \$115 billion in revenue in 2009, representing 51 percent of worldwide revenue. The industry directly employs about 200,000 people in the United States and supports an additional 5.9 million U.S. high-tech workers. However, of the 16 new semi-conductor fabrication plants under construction worldwide in 2009, seven of which were devoted to producing LEDs, only one was being built in the United States and it was not an LED plant. The U.S. Department of Labor also predicts that the semiconductor industry will lose one-third of its jobs in the next 10 years as companies find that a continued U.S. manufacturing presence does not meet competitive needs.<sup>4</sup>

The panelists at the DOE workshop felt strongly that a substantial number of high-tech and aligned industry jobs could be established by making the investment needed to grow the U.S. industry. Such an investment would include building LED plants and supporting industries on U.S. soil. Workshop participants agreed that in addition to investments from manufacturers, it will take federal and local government subsidies in the form of capital grants to lower utility and logistics costs, corporate tax reductions or rebates, and site infrastructure investment to reduce the flow of outsourcing.

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So how are we going to support the objectives of manufacturing in the United States for solid-state lighting? We believe it is the equipment and materials suppliers that [need] to support manufacturing worldwide, support these trends, this industry and employment in this country.

- Tom Morrow, Vice President of Marketing at SEMI, the global association for the micro-electronics supply chain

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## **Growing the U.S. Lighting Industry**

U.S.-based or multinational companies have invested millions, if not billions, of dollars in research and developing solid-state lighting technology, as well as the other components crucial to producing quality products. The economic progress gained from these R&D efforts stands to be negated if the trend of outsourcing manufacturing continues unabated without an effort to retain the value-added functions of the industry in the U.S.

Philips Lighting is a large multinational company whose parent company is based in the Netherlands. In the last decade, it has acquired two U.S. start-up companies that have helped it transition to LEDs. In 2008 and 2009, Philips invested \$630 million in the past two years in projects aimed at taking full advantage of the LED-driven future opportunities in the lighting industry. Philips has made a number

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4 <http://www.bls.gov/opub/mlr/2009/11/art4full.pdf>

of acquisitions in lighting, including one of the largest U.S. fixture manufacturers. In addition, Philips recently downsized its number of worldwide incandescent lamp factories from 20 to seven, including two of three in North America.

Jim Anderson of Philips Color Kinetics explained what it would take to establish a larger domestic manufacturing presence:

- A location where labor is only 3 to 5 percent of the end cost of producing a high-power solid-state light engine
- Highly automated and flexible factories to allow for lower cost ‘just-in-time’ manufacturing. If they are done right they can also improve quality and statistical process controls. Strong local infrastructure industries that provide materials and component parts and the other building blocks necessary for market success
- Government incentives and tax credits
- A strong local market for products

Even though this is the view of only one large company, it is not atypical of the lighting industry. Many of the major players who attended the workshop said the same.

## A Way Forward

Reversing the trend toward outsourcing is the responsibility of the lighting industry and government working together to establish the foundation for a strong U.S.-based industry. The United States government and industry must act quickly to bolster the advances that have already been made through the growth of small business in this field. It must also continue to support chip technology improvements, and advancements in component technology and quality standards.

The participants at the April workshop agreed that the outsourcing tide could be stemmed, but it would take a concerted public/private effort. Jim Anderson of Philips Color Kinetics made the bold statement that to promote a competitive edge, a leadership position, and a sustainable advantage in the U.S., “I believe we need to establish a bold, common goal like putting a man on the moon.” While not as costly or intense, the focus of such an effort is clear and the stakes are very high. A sizable portion of the SSL industry, including U.S.-owned and based firms, are already moving production to Asia. Anderson and other lighting representatives agree that it is extremely important for industry and government to work together to develop cost-effective U.S. manufacturing strategies immediately.

The following recommendations came from industry representatives and stakeholders who attended the April workshop:

- **Increase basic and applied research**—While a great deal of attention and funding has been directed at LED chip development, both government and industry should increase technology research and development aimed at reducing chip production costs.
- **Increase LED fabrication capacity**—Industry must find ways to build cost-effective fabrication facilities in the United States.

- **Provide government incentives to defray capital costs of SSL manufacturing**—Industry would like federal and local governments to provide financial incentives similar to the ones Asian countries provide, as described above.
- **Build U.S. capacity for supplying manufacturing equipment, non-chip lighting components, and source materials**—Since much of the U.S. industry supply chain is outside the country, the supply industry must be grown at home to keep domestic SSL manufacturing strong.
- **Establish standards for product specifications and compliance**—Both industry and government should concentrate on establishing product standards to assure marketability of solid-state lighting products.
- **Facilitate responsible product performance claims and labeling**—Through the Lighting Facts<sup>CM</sup> voluntary labeling program and CALiPER testing program, DOE has established an internationally recognized program that should be continued and improved.
- **Increase consumer education and awareness efforts**—U.S. manufacturing will be enhanced by a strong national buyer market. Therefore, DOE should continue to work with the market chain to enhance consumer interest in more energy-efficient products.
- **Build industry, market-chain and utility partnerships**—While basic relationships have been established, it is important they be strengthened because the U.S. is still the strongest market for SSL products.
- **Open government markets to SSL products**—A natural market for SSLs is federal, state and local governments, which have a history of setting an example by increasing efficiency in their building stock. Procurement policies like “Buy American” could be used.
- **Establish industry- and government-supported university programs**—A move to more automated equipment and more complex integrated luminaire design and manufacturing will require a more highly educated workforce to design and build such equipment.
- **Focus resources on solving technological problems**—Continue and add competitions to improve manufacturing efficiency, like the Congressionally-mandated L Prize program, which provide the stimulus for innovation.

With its huge energy savings potential, it is clear that solid-state lighting will eventually transform the industry. It could revitalize what has become a commodity, rather than value-added, industry. It is also evident that the U.S. will not realize long-term economic benefits unless immediate action is taken to reduce outsourcing. Workshop participants recommended that the U.S.-based lighting industry and the federal government move quickly to institute measures that will preserve the U.S. lead in the production of quality products. The DOE research and development program, along with the nascent Manufacturing Initiative, were noted as important elements of this growing industry. However, if economic incentives do not materialize over the next couple of years, the trend to outsource manufacturing will continue. Industry can, and must, play a major role in its own resurgence. The federal government can play an even larger role by enacting legislation that will assist in the growth of state-side manufacturing plants, and stabilize and increase the number of industry jobs.