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NANOTECHNOLOGY AND THE BUILT ENVIRONMENT: INVESTING IN GREEN INFRASTRUCTURE

Green building is a growing priority amid global efforts to reduce energy consumption and use resources more efficiently. Innovative nanotechnology companies, such as those highlighted in this report, are likely to prove essential for growth in the built environment as their technologies enable more sustainable development in each of the following sectors: ***3D Printing***, ***Cementitious Materials***, ***Insulation***, ***Lighting/LEDs***, ***Photovoltaics***, ***Smart Grid Technologies***, ***Steel***, ***Water Treatment***, *and* ***Windows***.

See inside for applicable disclosures.

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Introduction

Construction projects today are increasingly required to meet stringent building codes and energy regulations, which is helping to fuel an industry transition to the use of next-generation **nanomaterials†** that offer enhanced performance, often with fewer negative environmental impacts. Further, consumers and governments alike are demanding more energy-efficient and ecofriendly infrastructure, which is also driving adoption of sustainable building materials. This report examines the future for U.S. infrastructure, specifically as it relates to the widespread **green building** movement, which has been characterized by the use of energy-efficient, recyclable, and sustainable building materials—initiatives greatly enabled through advancements in nanoscience.

This report examines a future for U.S. infrastructure as it relates to advancements in green building being driven by nanoscience investment.

As of 2012, the global market for nanotechnology was estimated at over $20 billion, composed of nanomaterials, tools, and devices used in a number of industries worldwide (Source: BCC Research's *Nanotechnology: A Realistic Market Assessment,* September 2012). Driven by a rapid expansion of nanotechnologies in the energy storage/generation and construction sectors through 2016, the market for nanotechnology-derived products and processes could exceed $48.9 billion as early as 2017 (Sources: *Nanotechnology: A Realistic Market Assessment*; and Freedonia Group Inc.'s *World Nanomaterials,* May 2012).

Investments in nanotechnology across industries such as construction, electronics, chemicals, healthcare, and more have enabled its transition from a laboratory application into a proven science, which have created more efficient, better-performing commercial products. Within the **built environment**, industry is increasingly turning to innovative nanomaterials to upgrade, expand, and rebuild crumbling infrastructure. Such innovations are particularly important, for example, as the northeastern U.S. rebuilds following the devastating effects of Super Storm Sandy in late October 2012, which caused up to an estimated $50 billion in property damage, lost business, and other costs in the region (Source: *Forbes*, November 5, 2012).

While the resources needed for rebuilding affected areas are considerable and reconstruction may take years, there is an underlying opportunity to replace ruined infrastructure with higher-quality, nano-enabled structures that offer improved durability in the face of massive storms. To this end, in a November 2012 interview with CNN regarding Super Storm Sandy, New York Governor Andrew Cuomo stated that he was hopeful that not only would the city and metropolitan area be rebuilt, but that the U.S. would "use this as an opportunity to build it back smarter" (Source: CNN's "Hurricane Sandy Strikes U.S. East Coast; Is Global Warming Bringing Stronger Storms?," November 2, 2012).

A number of organizations, such as Architecture for Humanity and Global Green USA, have presented plans for rebuilding that emphasize "smarter" designs, including replacing outdated building systems with smart grid technologies and employing green building principles that can often double as disaster preparedness measures. The ability to generate clean energy with solar panels, process waste and water, and maintain thermal insulation without relying on power for heating and cooling could have benefited people during Sandy and reduced disruption in the aftermath. As well, smart grid technology may have allowed power companies to detect and isolate problems faster, potentially reducing fires and other hazards, decreasing outages, and increasing response times.

This report, *Nanotechnology and the Built Environment: Investing in Green Infrastructure*, is the second edition of Crystal Research Associates' and Livingston Securities' *Nanotechnology and the Built Environment* series. The first report, *Nanotechnology and the Built Environment: The Transition to Green Infrastructure*, was published on November 17, 2011, and is available at www.crystalra.com.

†**Bold** words are defined in the Glossary on pages 73-75.

How Nanotechnology Enables Green Building

The greatest environmental impact of nanotechnology on infrastructure in the near term will likely occur in the areas of energy savings and resource conservation.

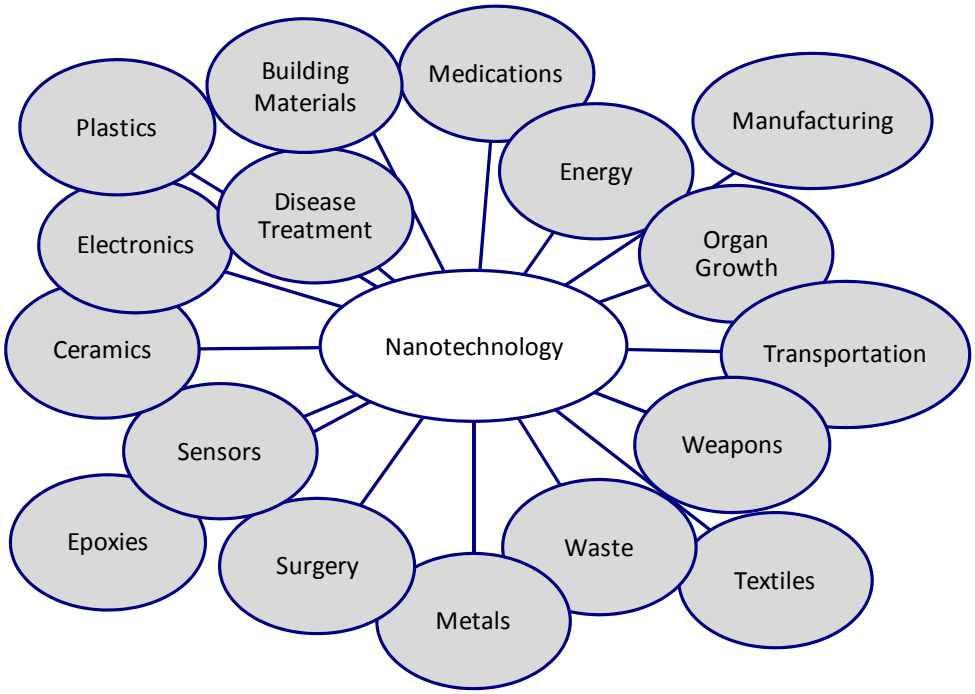
The term "nanotechnology" is often used as an all-encompassing term for science, engineering, and technology conducted at the **nanoscale** level—which involves the understanding and control of matter at dimensions between approximately 1 and 100 nanometers (nm). For reference, a single nanometer is one millionth of a millimeter. It would take roughly 50,000 nanometers to span the diameter of an average human hair.

As extraordinary advances take place in the field of nanoscience today, researchers are able to individually manipulate minute pieces of material smaller than atoms, yielding the ability to study the world at an ever smaller and smaller scale. The outcomes of this research have been revolutionary.

Creating Next-generation Products

At the nanometer scale, physics gives way to **quantum mechanics**, through which scientists can substantially change the physical, chemical, and biological properties of matter in ways not previously possible at the atomic or molecular level. By engineering materials at the **nanoparticle** level, scientists have been able to create new products that offer vast improvements in efficiency, strength, weight, heat transfer, and so on. For instance, nanostructured opaque substances can be made transparent; inert materials can attain catalytic properties; stable materials can turn combustible; and insulators can become conductors. Thus, nanotechnology R&D is not just about making products smaller, it is also intended to make products perform *better.* Figure 1 provides a selection of categories where applications for nanotechnology are being explored.

Figure 1
A SELECTION OF FIELDS WHERE NANOTECHNOLOGY APPLICATIONS ARE BEING EXPLORED



Source: New Building Materials & Construction World (NBM&CW), August 2011.

Specifically for the built environment, nanoscience has set the stage for a host of innovations. The most commonly employed materials in modern construction to date have been concrete, steel, glass, and timber. As an enabling technology, nanotechnology allows for the development of these materials with enhanced and/or completely new properties, such as stronger, lighter-weight steel, waterproof concrete, or **electrochromic** glass that changes tint in response to outside temperature and light.

Nanotechnology has also led to the development of thinner forms of building insulation; transparent insulation for windows and skylights; materials that are inherently fire-resistant; solar panels; more efficient lighting technologies; nanoporous membranes and filters that can improve water treatment and purification; glass, paints, and other coatings that prevent dirt from accumulating and can eliminate bacteria on walls/surfaces; and methods to prevent the cracks, corrosion, and stress that eventually cause structural failure in bridges and buildings (such as is shown in Figure 2). One of the more recent developments has been **3D printing**, an advanced form of manufacturing that rarely produces any waste material.

Figure 2
I-35 BRIDGE COLLAPSE:
MINNEAPOLIS, MN (AUGUST 2007)

Source: AP.

Creating Next-generation, Green Products

Though not every nanotechnology-enabled product can be considered a sustainable product, nanoparticle research has greatly contributed to the introduction of building materials that offer environmental improvements, such as the conservation of raw materials, energy, and water, combined with a reduction of greenhouse gas emissions and elimination of hazardous waste. Occasionally, these benefits are achieved in the use of the product itself, such as using better insulation in the building envelope, which in turn reduces the energy required to heat or cool the building. As another example, nanostructured paints can be applied in thinner coats, which has the potential to reduce emissions of **volatile organic compounds (VOCs)** by as much as 65% (Source: the Insitute of Technology Assessment of the Austrian Academy of Sciences, March 2012). Alternatively, benefits may occur during production of nanomaterials, such as by reducing the amount of CO_2 that is emitted during manufacturing as a result of replacing environmentally damaging ingredients and chemicals with new substances.

According to the U.S. Green Building Council (USGBC), the market for green building could range from $120 billion to $145 billion by 2015.

The nanoscale titanium dioxide (TiO_2) compound exemplifies how nanotechnology can be used to improve construction. The novel compound has the ability to help break down organic material, such as dirt. Its application to concrete or other surfaces enables "self-cleaning building materials," where dirt cannot accumulate as it is broken down by the nano-TiO_2 and easily washed off the surface by rain. Accordingly, these surfaces do not need to be cleaned as often, thereby conserving water, and lasting much longer. Rome's Jubilee Church built in a white, self-cleaning concrete is expected to remain clean and bright white for 1,000 years (as shown in Figure 3).

Figure 3
JUBILEE CHURCH (ITALY)

Source: Concrete Décor®.

Nano-TiO_2's ability to decompose organic matter also means that building products made with nano-TiO_2 can help improve air quality in traffic-congested areas, as the substance removes the harmful nitrogen oxides emitted in vehicle exhaust from the air by converting them into nitrates. Using nano-TiO_2 on bricks and **pavers** along roads may therefore help offset the negative environmental impact of vehicles. *Concrete Decor®* magazine has reported that a study of such paving demonstrated the potential to decompose 15% of the **nitrous oxide** released by cars. Nano-TiO_2's anti-bacterial growth properties have also been used for their health benefits. Hong Kong, for example, sprayed a nano-TiO_2 coating on the interiors of its subway cars to kill airborne bacteria and viruses.

Figure 4 overviews a selection of ways in which nanotechnologies are able to benefit the environment, and accordingly, green building efforts. Among nanotechnology's range of environmental impacts in the built environment, the greatest benefits in the near term are likely to be in the areas of *energy savings* and *resource conservation* (conserving raw materials, energy, and water).

Figure 4

A SELECTION OF ENVIRONMENTAL BENEFITS POSSIBLE WITH NANOTECHNOLOGY

Miniaturized or thinner products use fewer raw materials	LEDs and other new lighting technologies can convert energy to light more efficiently than traditional lights
Nanotechnology-based dirt- and water-resistant coatings reduce cleaning efforts and water usage	Nanoporous filters used in water treatment may soon also be used to reduce emissions in vehicles
Nanoporous insulation applied in walls, to roofs, and to windows greatly reduces the energy needed to heat and cool buildings	Using nanoparticles in a material can reduce weight and fuel consumption during transport, or increase energy yields in equipment such as wind turbines
Nanomaterials replace environmentally problematic substances, including toxic heavy metals (chromium, nickel), VOCs, non-recyclable coatings/plastics used for waterproofing, hazardous biocides in preservatives or paints, and bromine in flame retardants, among others	Nanomaterials that protect against wear and corrosion improve the durability and extend the useful life of structures—contributing to energy savings and resource conservation by reducing how often infrastructure needs to be repaired or replaced

Sources: the Institute of Technology Assessment of the Austrian Academy of Sciences' NanoTrust Dossiers' "Nano and the Environment – Part I: Potential Environmental Benefits and Sustainability Effects" (March 2012) and "Nano in the Construction Industry" (August 2012); and Crystal Research Associates, LLC.

Large-scale Green Building Profile: NYC's World Trade Center Complex

One of the largest construction projects in the U.S. to adhere to green building practices and standards is the rebuilding of the World Trade Center (WTC) complex ongoing in New York City.

One of the largest construction projects in the U.S. to adhere to green building practices and standards is the rebuilding of the World Trade Center (WTC) complex currently ongoing in New York City. Each building in the complex (a rendering of which is pictured in Figure 5) is designed to achieve **Leadership in Energy and Environmental Design (LEED)** certification and be at least 20% more energy efficient than is required by New York energy codes. Ongoing construction of the new WTC complex is pictured in Figure 6 (page 8).

The first completed WTC building, an office tower located at 7 World Trade Center, has already achieved **LEED Gold** certification and received awards from the U.S. Environmental Protection Agency (EPA), the Municipal Arts Society of New York, and the American Institute of Architects' New York Chapter. The 7 WTC building is also a model for the energy-saving technologies to be deployed in the remaining WTC buildings.

Figure 5
WTC COMPLEX

Source: Alliance to Save Energy®.

Seven WTC includes highly efficient heating and cooling systems, steam-to-electricity generators, plumbing designed to reduce water use by 30% or more, daylighting (capitalizing on sunlight as opposed to artificial light), high-tech windows that let in light but keep out heat and cold (which contributes to a significant decrease in building energy consumption), smart sensors within the building to automatically dim lighting when there is sufficient sunlight, and a preferred parking program for fuel-efficient vehicles.

Like the other buildings planned for the WTC complex, the main WTC structure under construction—One World Trade Center, previously known as the Freedom Tower—also includes a number of sustainable features. Many of the building's structural materials contain, at a minimum, 75% **post-industrial recycled content**. For example, the concrete foundation through the building's first 40 floors is composed of a high-strength, sustainable concrete mixture supplied by Eastern Concrete Materials, Inc. and BASF Construction Chemicals (part of BASF SE, profiled on page 18). The Green Sense® concrete uses recycled materials in its formulation to reduce the amount of CO_2-producing **Portland cement** needed in the concrete. Portland cement is the leading type of cement in use worldwide, and its energy-intensive manufacturing process accounts for nearly 5% of global CO_2 emissions (Source: *Time*, December 6, 2010).

The Green Sense concrete also included next-generation **admixtures** from BASF that exceed the performance targets specified by the One WTC project stakeholders and the Port Authority of New York/New Jersey (Source: *Building Design + Construction's* "One World Trade Center goes to new height of sustainability," May 15, 2012). An eco-efficiency analysis of the Green Sense concrete found that it created fresh water savings of over 30,000 gallons, energy savings of over 8 million kilowatt hours, air emissions savings of 12 million pounds of CO_2, solid emissions savings of over 400,000 pounds, and fossil fuel savings of 750,000 pounds (Source: *Building Design + Construction*).

The One WTC tower is to be partially powered by 12 hydrogen fuel cells, which are expected to provide 4.8 million watts/hour of electricity. To meet further energy requirements, the design calls for the installation of solar panels as well as off-site hydroelectric and wind power. Furthermore, a rainwater collection and recycling scheme is planned for the building's cooling systems (Source: The Alliance to Save Energy's "New World Trade Center Serves as Model for Urban Energy Efficiency," April 2012). One WTC is scheduled for completion in 2013, making it the tallest sustainable building in the U.S.

Figure 6

WTC COMPLEX

Source: The Port Authority of New York & New Jersey.

Building with "Smarter" Technologies Can Drive Energy Savings

Green building is more than just the use of environmentally preferable materials. It also entails outfitting structures (both new construction and retrofits) with a layer of intelligence—smart sensors and controls that can accurately determine building performance in real time and even make adjustments to certain controls, such as lighting or heating, ventilation, and air conditioning (HVAC) systems, in order to optimize energy use. For example, to drive efficiencies and reduce costs, the U.S. Air Force is automating facilities management and infrastructure maintenance across its 170 locations worldwide (Source: IBM's *Buildings can be smarter, but are we up to the challenge?*, November 12, 2012).

Likewise, New York City's Empire State Building was recently retrofitted with an array of next-generation technologies designed to improve the iconic structure's greenhouse gas emissions and energy efficiencies. Renovations included using smart sensors and digital controls to adjust the amount of outside air needed in the building, providing tenants with a web-based dashboard to monitor their own energy use, and upgrading the building's energy controls, among many other features.

Benefits of using intelligent technologies in the Empire State Building retrofit have included the following:

- reducing cooling/heating demand;
- being able to monitor indoor air quality;
- increasing occupant comfort;
- reducing energy bills; and
- drastically improving the building's carbon footprint—preventing over 4,000 tonnes of CO_2 emissions.

In the first year after completing core stages of a major retrofit, energy-efficient upgrades at the Empire State Building saved $2.4 million and exceeded energy efficiency guarantees by 5%.

However, the greatest benefit of the Empire State Building's green overhaul has been to demonstrate that commercial green retrofit projects can be economically viable (Source: the Rocky Mountain Institute, a Colorado thinktank participating in the Empire State Building's renovation, May 31, 2012). In its first year since completing the core retrofit (individual tenants' spaces are still being optimized), the Empire State Building saved $2.4 million and exceeded its Year One energy efficiency guarantee by 5% (as of May 2012). Once upgrades of tenants' spaces are completed in 2013, the building is expected to save $4.4 million a year as a result of a 38% reduction in energy use (Source: Johnson Controls, Inc.'s** May 31, 2012, press release). The Empire State Building received a LEED Gold certification in September 2011.

Figure 7
EMPIRE STATE BUILDING'S DYNAMIC LED LIGHTS

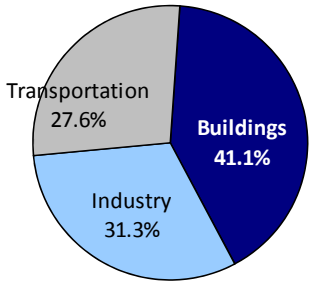
Source: PCMag.

Figure 7 illustrates the new LED lighting system installed on top of the Empire State Building in summer 2012 by Philips Color Kinetics. The custom-built, dynamic system enables changes in light scenes in real time. It was used to display CNN's election results as they were announced on November 6, 2012, as well as during other high-profile events and concerts.

Market Opportunities for Green Building

As illustrated in Figure 8, commercial and residential buildings are responsible for roughly 41% of primary energy consumption in the U.S., and are one of the heaviest consumers of natural resources (Source: the U.S. Department of Energy [DOE]). The built environment is also responsible for producing a significant share of the harmful greenhouse gas emissions affecting climate change, including up to an estimated 52% of all CO_2 emissions. As conflict in oil-producing regions, volatile energy prices, heightened concerns of climate change, and global population growth fuel demands for more energy-efficient products, "greening up" the U.S.'s buildings, roads, and other infrastructure represents a big challenge and yet a substantial opportunity going forward.

Figure 8
U.S. PRIMARY ENERGY USE



Source: DOE, Buildings Energy Data Book, Table 1.1.3, March 2012.

*** See disclosures on page 77.*

As of June 2012, two billion square feet of building space was LEED certified.

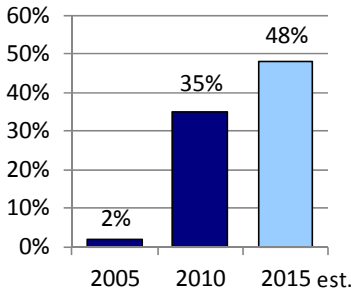
According to the U.S. Green Building Council (USGBC), the green building market is likely to range from $120 billion to $145 billion by 2015, driven by sustainable initiatives in non-residential construction. As of 2010, up to 35% of non-residential construction starts were green projects—a share that is anticipated to expand to as high as 48% by 2015. To illustrate the momentum of sustainable development in the built environment, as of 2005, only 2% of non-residential construction starts were "green."

Among high-value building projects, desire to meet green standards is particularly high. The USGBC reported in August 2012 that its LEED rating system was referenced in specifications for approximately 71% of projects valued at over $50 million. A LEED-certified building adheres to specific standards relating to energy savings, water efficiencies, greenhouse gas emissions reductions, waste reductions, and indoor environmental quality, with a special emphasis on the materials used during construction. Moreover, demand for green certifications is not limited to the U.S. Roughly 40% of all projects pursuing a LEED designation today are located internationally.

There are several factors contributing to the rise of green construction materials, which relate to the following:

- increased global awareness of environmental concerns over high energy costs;
- government legislation and incentives, more stringent energy and building codes, and an increasing presence of voluntary standards organizations; and
- technological advancements leading to more competitive pricing for sustainable materials as well as highly competitive performance attributes.

Figure 9
GROWTH IN GREEN CONSTRUCTION PROJECTS



Sources: McGraw Hill Construction (2010) and USGBC (August 2012).

On average, a LEED Gold building will consume 25% less energy and 11% less water as well as have 19% lower maintenance costs, 27% higher occupant satisfaction, and 34% lower greenhouse gas emissions than the typical commercial building (Sources: DOE and USGBC). The DOE's *Buildings Energy Data Book* (last updated March 2012) describes relevant laws, energy codes, and standards that have influenced building energy consumption. This reference source includes details of key national legislation, federal tax incentives, and efficiency standards for residential and commercial HVAC, residential appliances, lighting, and water use, as well as state by state energy codes. The publication is available at http://buildingsdatabook.eren.doe.gov.

2012 Venture Capital Funding Targeted to Nanotechnology Companies

The flexibility of nanotechnology allows for its application in many different industries. In the U.S. alone, it is estimated that government and private industry together invest more than $3 billion per year in nanotechnology R&D (Source: Georgia Tech's Enterprise Innovation Institute, April 2012). Globally, as of 2010, investments in nanotechnology by governments, corporations, and venture capitalists totaled an estimated $17.8 billion (Source: Lux Research's *Nanotechnology Funding: Corporate Grabs the Reins*, April 2011). Despite the recent economic recession, total nanotechnology funding exhibited a compound annual growth rate (CAGR) of 1% from 2008 to 2012, with future investments expected to grow at a faster rate as the technology finds applications in new areas (Source: RNCOS' *Nanotechnology Market Forecast to 2014,* October 2012).

It is estimated that U.S. government and private industry together invest more than $3 billion annually in nanotechnology R&D.

From a venture capital (VC) perspective, the investment focus is on nanotechnology as an enabling technology. As nanotechnology matures, it is transitioning from basic R&D to innovation and specific new product development and commercialization. The interest of the investment community in nanotechnology does not rely on the technology itself, but on its capability to drive the development, implementation, and commercialization of new processes and products across a vast array of industries, such as construction, energy, manufacturing, healthcare, and environmental protection (Source: Spinverse Capital and Consulting's *Venture Capital in Nanotechnology*, April 2010).

Globally, investments in nanotechnology by governments, corporations, and venture capitalists total an estimated $17.8 billion.

Governments worldwide have recognized the potential of nanotechnology. Globally, there are over 130 government organizations and programs aimed at conducting nanotechnology-related research. In the U.S. alone, the government has invested approximately $15.6 billion in nanotechnology through the U.S. National Nanotechnology Initiative (NNI), with an additional request for $1.8 billion in NNI funding for FY 2013. However, approximately 90% of total NNI funding supports academic research and R&D at government laboratories, while only 10% supports industry R&D (Source: Congressional Research Service's *The National Nanotechnology Initiative: Overview, Reauthorization, and Appropriations Issues*, May 2012).

The private sector is also continuing to shape development of nanotechnology into attractive uses and commercial applications, with a growing number of early stage companies seeking to launch new nanotech-based products and processes (Source: MedCity News' *Nanotechnology Investing: What VCs, Angels, and Strategic Investors Look For,* April 2012). As the time to commercialization for many applications decreases, and the actual economic activity of nanotechnology products increases, VCs may profit in this expanding industry by filling the funding gaps created by the government's focus on academic research.

The ability of nanotechnology to not only bring commercially viable products to market but also to have a positive impact on social issues, such as energy conservation, the need for better biotechnology products, and green initiatives, has attracted venture funds from a variety of arenas. Google Inc.'s (GOOG-NASDAQ) Venture Fund, for example, is planning to invest $1 billion in a wide range of start-ups over the next five years, with a special focus in biotech, **cryogenics**, and nanotechnology (Source: CNBC, September 20, 2012). In addition, multinational corporations are a continuing source of investment funds, as they seek to partner with smaller companies that have developed critical nanotechnology expertise.

Pages 12-15 highlight 32 nanotechnology companies that received significant VC funding during 2012. This list is not intended to be an exhaustive list of VC funding over the past year, but is believed to be representative of the types of investments currently being conducted by VC firms and corporations supporting nanotech firms.

- **Albeo Technologies, Inc.**—On March 20, 2012, Albeo Technologies, a manufacturer of LED lighting systems for the industrial and commercial sectors, announced that it secured $8 million in new VC debt and equity financing. Braemar Energy Ventures led the round, which also included Green Spark Ventures and Silicon Valley Bank. Albeo Technologies was founded in 2004 and is based in Boulder, Colorado.

- **Ambri Inc.** (formerly Liquid Metal Battery Corporation)—On May 24, 2012, Ambri, an MIT spinoff backed by Bill Gates that produces cheap liquid metal batteries and electrical storage solutions, announced that it secured an additional $15 million in Series B financing in a funding round led by Khosla Ventures. Ambri is headquartered in Cambridge, Massachusetts, and was founded in 2010.

- **Bioformix, Inc**.—On March 12, 2012, Bioformix, a developer of energy-efficient and environmentally friendly adhesives and plastic alternatives in the form of monomer and polymer platforms, announced that it raised $13.6 million from Braemar Energy Ventures, Arsenal Venture Partners, Mitsui Global Investment, and other strategic investors. The company is based in Blue Ash, Ohio.

- **Bridgelux, Inc.** (profiled on page 43)—On February 13, 2012, Bridgelux, a developer and manufacturer of LED lighting technologies and solutions, raised $25 million in funding from Chinese lighting company Kaistar Lighting. Bridgelux was founded in 2002 and is headquartered in Livermore, California.

- **C3Nano Inc.**—On February 15, 2012, C3Nano, a developer of transparent electrode material for applications such as flexible displays, touchscreens, **organic light-emitting diodes (OLEDs)**, solar cells, and smart windows, announced it raised $6.7 million in Series B financing led by Phoenix Venture Partners, with participation from existing investor, GSR Ventures. C3Nano was founded in 2010 and is headquartered in Hayward, California.

- **Calxeda Inc.**—On October 8, 2012, Calxeda, a manufacturer of ultra-low-power server chips that use ARM-based processors, closed a $55 million round with new investments from Austin Ventures and Vulcan Capital. The new round brings Calxeda's total funding to $100 million. Calxeda, based in Austin, Texas, was founded in 2008.

- **Cambrios Technologies Corp.**—On January 30, 2012, Cambrios Technologies announced that it raised $5 million in a fourth round of funding from strategic investor Samsung Venture Investment Corp. Cambrios, a provider of solutions that enable the development of electronic devices with transparent conductors for the display industry, was founded in 2002 and is based in Sunnyvale, California.

- **Coulomb Technologies, Inc.**—On May 7, 2012, Coulomb Technologies, an electric vehicle infrastructure company, raised $47.5 million in fourth-round funding led by Energy Ventures and Kleiner Perkins Caufield & Byers, with participation by Toyota Tsusho Corporation and existing investor Rho Ventures. Coulomb develops and operates a global charging network that connects electric vehicle drivers to charging stations. Coulomb was founded in 2007 and is based in Campbell, California.

- **EMCORE Corporation** (EMKR-NASDAQ)—On October 3, 2012, EMCORE, a provider of compound semiconductor-based products for the broadband, fiber optics, satellite, and solar power markets, announced the closing of its underwritten public offering of Common Stock, resulting in approximately $9.5 million in net proceeds for general corporate purposes. EMCORE was founded in 1984 and is headquartered in Albuquerque, New Mexico.

- **EnerVault Corporation**—On February 23, 2012, EnerVault, a developer of large-scale energy storage systems for large commercial and industrial facilities and utility grids, announced the completion of a $15.5 million Series B financing. The investment complements the company's grant awards totaling $5.5 million from the DOE and other state organizations. EnerVault was founded in 2008 and is based in Sunnyvale, California.

- **Hydronovation, Inc.**—On January 23, 2012, Hydronovation, a developer of next-generation water conditioning systems, announced that 3M New Ventures, the corporate venture organization of 3M Co. (MMM-NYSE), invested in its Series B financing. The financing also included a second investment by Clean Pacific Ventures. Terms of the transaction were not disclosed. Hydronovation develops, manufactures, and distributes electro deionization modules and components for commercial and residential water treatment applications. The company was incorporated in 2005 and is based in San Francisco, California.

- **Intematix Corporation**—On March 13, 2012, Intematix, a developer of phosphor products for LED lighting technologies, announced that it raised $16.2 million in funding from current investors Draper Fisher Jurvetson and Crosslink Capital as well as a new financial investor. In addition, on July 17, 2012, Intematix announced plans to conduct a registered initial public offering (IPO) of its Common Stock, following the U.S. Securities and Exchange Commission (SEC) review process initiated on July 13, 2012. Intematix was founded in 2000 and is based in Fremont, California.

- **IO Data Centers, LLC**—On October 10, 2012, IO Data Centers, a provider of digital energy technology for large enterprises, governments, and service providers, announced that it raised $90 million in new venture capital funding. New World Ventures led the round, and was joined by existing shareholders, including Sterling Partners. This brings the total equity funding to over $250 million. IO Data Centers, which is on track for an IPO in 2013, was founded in 2006 and is based in Phoenix, Arizona.

- **LED Engin, Inc**.—On April 23, 2012, LED Engin, a solid-state lighting company specializing in high lumen density LED lighting components and optics, announced the successful completion of its Series E financing. GVT Fund led the round. The company was founded in 2004 and is based in San Jose, California.

- **Lehigh Technologies, Inc.**—On August 21, 2012, Lehigh Technologies announced the closing of $16 million in financing led by Leaf Clean Energy and including Kleiner Perkins Caufield & Byers, Index Ventures, and NGP Energy Technology Partners. Lehigh Technology turns end-of-life tire materials and other post-industrial rubber into micronized rubber powders that are used in a range of industrial and consumer applications. Lehigh Technology was founded in 2003 and is based in Tucker, Georgia.

- **Lighting Science Group Corporation** (LSCG-OTC)—On September 25, 2012, Lighting Science Group, a developer of LED general illumination products, announced that it closed $49 million in a Preferred Stock financing, representing the final tranche of a $168 million equity financing first announced by the company on May 29, 2012. Lighting Science Group is headquartered in Satellite Beach, Florida.

- **LightSail Energy**—On November 5, 2012, LightSail Energy, a startup building a compressed air energy storage system, announced that it raised $37.3 million in funding. The Series D round was led by PayPal cofounder Peter Thiel and included the leader of LightSail's last investment round, Khosla Ventures, as well as Microsoft founder Bill Gates. The Berkeley, California, company was founded in 2009.

- **Lumenergi, Inc**.—On March 13, 2012, Lumenergi, a provider of network-controlled lighting energy management solutions, announced that it secured $6.2 million as an initial closing to an extension of its Series B financing to support commercial growth and expansion plans, with participation by Braemar Energy Ventures, Noventi Ventures, and Low Carbon Accelerator Ltd. Lumenergi was founded in 2008 and is based in Newark, California.

- **Luxtera, Inc.**—On February 27, 2012, Luxtera, a semiconductor company that provides silicon complementary metal-oxide semiconductor (CMOS) photonics to make lightning-fast optical chips, announced that it raised $21.7 million in a third round of funding. Participants included existing investors as well as new investment from Tokyo Electron Ltd. Luxtera was founded in 2001 and is headquartered in Carlsbad, California.

- **NanoH_2O, Inc.** (profiled on page 65)—On April 30, 2012, NanoH_2O, a provider of nanotechnology-enabled reverse osmosis membranes that lower costs of desalination and water purification, announced that it closed a $40 million equity round and $20.5 million in credit facilities. Investors included BASF Venture Capital GmbH, Total Energy Ventures International, and Keytone Ventures as well as existing investors, including Khosla Ventures. The company, founded in 2005, is based in El Segundo, California.

- **NovaLED AG**—On March 19, 2012, NovaLED, a German company seeking to improve OLED performance, filed with U.S. regulators for an IPO of up to $200 million. The company expects to list on the NASDAQ National Market under the ticker symbol "NVLD." The Dresden-based company, founded in 2001, reported to the SEC in a preliminary prospectus that Goldman Sachs and Deutsche Bank Securities were the lead underwriters to the IPO.

- **Omni Water Solutions, Inc.** (profiled on page 66)—On February 28, 2012, Omni Water Solutions, which develops water treatment technology for use in **fracking** operations, announced it raised $7.9 million from Austin Ventures and other investors. The company was founded in 2010 and is based in Austin, Texas.

- **Picarro Inc.**—On July 25, 2012, Picarro, a manufacturer of instruments for carbon and water cycle measurements, announced that it secured $7 million in Series D equity financing from Focus Ventures, DAG Ventures, NTT Finance, and Mingxin China Growth Fund. The company was founded in 1998 and is based in Santa Clara, California.

- **Relume Technologies, Inc.**—On January 30, 2012, Relume Technologies, a manufacturer of LED products and smart grid control systems for outdoor lighting, announced it closed its $7 million Series D financing round. Investors include Beringea LLC, which led the round, as well as Western Technology Investment and other existing investors. Relume is based in Oxford, Michigan.

- **Roka Bioscience, Inc**.—On January 6, 2012, Roka Bioscience, a developer of molecular assays and portable diagnostic instruments for biopharmaceutical production, water and food safety testing, and various industrial applications, announced that it secured $47.5 million in Series D financing from new investor Aisling Capital and existing investors, OrbiMed Advisors, New Enterprise Associates, Inc., and TPG Biotech. The company was incorporated in 2009 and is based in San Diego, California.

- **Sefaira Ltd**—On April 10, 2012, Sefaira, a developer of web-based software for the design, build, maintenance, and retrofit of green building, announced that it secured a $10.8 million funding round, led by Braemar Energy Ventures in partnership with Chrysalix SET and Hermes GPE. Sefaira was founded in 2009 and is based in London, with offices in New York.

- **Segetis, Inc.**—On August 15, 2012, Segetis, a developer of plant-based green chemical building blocks and resins that supplant the petroleum used in cleaning solutions, plastics, and synthetics, announced that it raised $25.5 million in its Series C financing. Saudi Basic Industries Corporation (SABIC) Ventures B.V. led the investment with participation by current Segetis investors including Khosla Ventures, Malaysia Life Science Capital Fund (MLSCF), and Royal DSM. Segetis was founded in 2006 and is based in Golden Valley, Minnesota.

- **SmartSynch, Inc**.—On May 1, 2012, smart grid and meter company Itron, Inc. (ITRI-NASDAQ) completed its previously announced strategic acquisition of privately held SmartSynch in a transaction valued at $100 million. Mississippi-based SmartSynch provides point-to-point smart grid solutions that use a cellular network for communications.

- **Solidia Technologies, Inc.** (profiled on page 33)—On February 1, 2012, Solidia, a provider of proprietary processes for the creation of sustainable building and construction materials, announced that BASF Venture Capital invested $5 million in the company, as part of a $27 million financing round. The current round also included Kleiner Perkins Caufield & Byers, BP Ventures, and Bright Capital. Solidia was founded in 2008 and is based in Piscataway, New Jersey.

- **TerraLUX Inc.**—On May 7, 2012, TerraLUX, a solid-state lighting company specializing in integrated LED solutions for original equipment manufacturers (OEMs) and retrofit applications, announced that it closed a Series B VC financing round of $18.3 million. The round was led by Generation Investment Management, with participation from existing investors Emerald Technology Ventures and Access Venture Partners. Terralux, founded in 2003, is headquartered in Longmont, Colorado.

- **UtiliData, Inc.**—On February 13, 2012, UtiliData, a supplier of voltage optimization products for the electric grid, announced that it completed a round of financing led by Braemar Energy Ventures. Terms of the transaction were not disclosed. The funds come less than a week after UtiliData announced that it was relocating its business to Providence, Rhode Island, and receiving $500,000 in state support from the Rhode Island Economic Development Corp. through a Renewable Energy Fund loan.

- **Vigilent Corporation**—On March 26, 2012, Vigilent, a provider of intelligent energy management systems for data centers, telecommunications facilities, and large buildings, announced that it raised $6.7 million in investments led by Accel Partners. Vigilent, headquartered in El Cerrito, California, was founded in 2004.

Companies and Sectors to Watch

Innovation is key to long-term corporate survival. In the built environment, this is likely to mean learning how to capitalize on developments in nanotechnology to provide a better, more efficient, and greener product.

Innovation is critical to future success in the built environment. Businesses that do not keep up with technology may risk losing market share to competitors that have learned how to supply an enhanced, more efficient, and greener product created at the nanoparticle level. Consequently, businesses of all sizes—ranging from small, venture-backed start-ups (such as those highlighted on pages 12-15) to well-established multinational corporations with decades of experience (such as those highlighted on pages 18-23)—are investing in nanotechnology to broaden product pipelines and stay ahead of emerging market trends. While some enterprises are developing these resources internally, many others seek to increase their foothold in the sustainable built environment through acquisitions and investments into synergistic technologies.

In today's environment, technology changes rapidly. Companies that cannot out-innovate their competition are less likely to be able to survive long-term. With the considerable impact that nanotechnologies are having on the built environment, companies that operate within this industry or that supply to this industry must be able to keep current on these advancements. Should they fail to do so, they risk losing market share to competitors that can supply a better-performing, more energy-efficient, and greener product.

To this extent, in late August 2012, the NanoBusiness Commercialization Association (NanoBCA), a national nonprofit trade association for nanotechnology-enabled business, announced the Top Nanotech Innovators of 2012, highlighting companies that it believes are creating novel and potentially disruptive technologies in the nanotech sector—many of which are specifically addressing aspects of the built environment. NanoBCA recognized 20 large corporations and 20 emerging enterprises, which are noted in Figure 10 (continued onto page 17).

Figure 10

NanoBCA'S TOP NANOTECH INNOVATORS OF 2012

Large Corporations			
Company	Area of Innovation	Company	Area of Innovation
Amgen, Inc.	Cancer vaccines	Hewlett-Packard Co.	Memristors
Apple Inc.	Computer chips	IBM Corp.	Quantum computing
BASF	Advanced materials	Intel Corporation	Microprocessors
Bayer AG	Targeted delivery therapeutics	LG Electronics	Advanced materials
		L'Oreal Group	Skin care
Behr GmbH & Co. KG	Advanced building materials	Lockheed Martin Corp.	EMI-ESD coatings
DMS Semiconductor Equipment GmbH	Semiconductor equipment	Mitsubishi Electric Corp.	Advanced materials
E. I. Du Pont De Nemours and Co.	Advanced materials, photovoltaics	Novartis AG	Reformulations and targeted delivery therapeutics
Evonik Industries AG	Advanced materials, photovoltaics	Pfizer Inc.	Reformulations and targeted delivery therapeutics
General Electric Co.	Advanced diagnostics	Samsung Group	High-performance computer chips
General Motors Co.	High-strength composites		

Source: the NanoBusiness Commercialization Association, August 2012.

Figure 10 (continued)

NanoBCA'S TOP NANOTECH INNOVATORS OF 2012

Emerging Enterprises			
Company	Area of Innovation	Company	Area of Innovation
ABSMaterials, Inc.	Pollutants removal	Molecular Imprints, Inc.	Next generation lithography
Bridgelux, Inc.	Solid-state lighting for general illumination	Nanofilm	Coatings
Cambrios Technologies Corp.	Transparent conductors	NanoInk, Inc.	Diagnostic testing
		NanoMech Inc.	Advanced materials
Cerulean Pharma Inc.	Targeted delivery cancer therapeutics	Nanosys	Solid-state lighting, energy storage
D-Wave Systems, Inc.	Quantum computing	Nantero, Inc.	Carbon nanotube flash memory
HzO, Inc.	Waterblock coatings for electronics	PWAbsorbents, Inc.	Water treatment
Kovio, Inc.	Near-field communication	Siluria Technologies Inc.	Natural gas to fuels and chemicals conversion catalysts
Kurion, Inc.	Advanced materials (nuclear waste cleanup)	SiOnyx, Inc.	Si-based photonic devices
Metabolon, Inc.	Advanced diagnostics	Solazyme, Inc.	Algae-derived biofuel, chemicals, nutraceuticals, and skin care
Mersana Therapeutics	Novel cancer therapies		

Source: the NanoBusiness Commercialization Association, August 2012.

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Pages 18-23 profile a selection of large-cap market leaders active in the built environment. These firms are a representation of the type of merger and acquisition (M&A) activity, internal development, and other forms of investment occurring in the field of nanoscience as it relates to creating better products designed to meet the needs of a sustainable America. Following, pages 24-72 describe major sectors within the built environment where rapid technological development is occurring, including profiles of several of the key technologies/producers in those sectors. Specific emphasis is given to entities with growth prospects stemming from an ability to capitalize on advancements in nanotechnology in order to create the next generation of building materials.

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Globally, BASF is a member of 11 green building councils.

With an expansive product portfolio that spans oil and gas, chemicals, plastics, performance products, agricultural products, and fine chemicals (among others), Germany-based BASF is among the world's leading chemical companies. BASF operates under sustainable development principles and is a member of 11 green building councils worldwide.

BASF has made nanotechnology a key to its future business practices, employing various nanoparticles and nanostructured surfaces and materials. In the building and construction space, the company offers a number of solutions ranging from flooring systems and concrete repair to corrosion protection and other protective coatings. For example, BASF's Micronal® phase change material (PCM) is designed to support an improved indoor climate and better energy efficiency. Composed of polymer capsules containing a special wax mixture, Micronal® PCM adjusts to the temperature of the home to absorb or emit heat as necessary. At temperatures above 23°C, the wax melts and the material absorbs heat. When the temperature drops, the wax solidifies and heat is released. The company's Elastopave® polyurethane can be used to form a durable, porous pavement for car parks, driveways, and other walking surfaces that allows surface water to drain away, preventing ice or puddles from forming. BASF's Mastertop® flooring is monolithically bonded to provide a durable, seamless, and wear-resistant surface that is flexible and reduces sound.

In October 2012, BASF announced that its products were used in the construction of Innovation Park in Ravenscraig, Lanarkshire, Scotland—a project headed by the Building Research Establishment (BRE) to show how future homes might look with a focus on energy, sustainability, and affordability. Part of the redevelopment of a former steel works site, Ravenscraig is Scotland's first new town in more than 50 years and one of the largest regeneration projects in Europe, covering 1,125 acres and featuring 10,000 homes. BASF's Micronal® PCM was used in ceiling tiles, while its Mastertop® flooring system was installed in the visitors' center. Elastopave® was used in select walkways as part of the site's surface water management strategy.

The company also employs nanotechnology in other areas. For textiles, a Mincor® coating keeps water drops and dirt at bay. BASF's Ultradur® High Speed engineering plastic can be used in electronics and cars to improve the flowability of plastic while preserving its mechanical properties. BASF has also developed "nanocubes"—structures with nanosized pores organized in the form of cubes—which have shown an ability to store large quantities of hydrogen and other high-energy gases. Thus, as a rechargeable storage medium for miniature fuel cells, they could replace conventional rechargeable batteries in mobile electronic equipment, such as laptops or cell phones. BASF is also developing nanoporous foams, which offer enhanced insulating properties versus established insulating fabrics, potentially improving energy efficiency and sustainability.

BASF is also jointly developing materials for next-generation illuminants, including OLEDs, with strategic partners. The company's organic **photovoltaics** could enable solar cells in which the current solar cells' silicon is replaced by organic semiconducting materials, potentially creating more cost-efficient production processes as well as new applications.

BASF employs roughly 111,000 individuals and reported sales of approximately €73.5 billion (~$93.8 billion) in 2011. The company's shares are traded on stock exchanges in Frankfurt (BAS), London (BFA), and Zurich (AN).

General Electric Company (GE-NYSE)

General Electric (GE) is a global technology and financial services company providing energy, healthcare, home and business, aviation, transportation, and capital/finance solutions. Technology development for all of GE's businesses occurs at GE Global Research. Through this division, the company employs 2,800 researchers specializing in chemistry, biosciences, computing, metallurgy, fluid mechanics, materials, and imaging, among other areas. The researchers focus on achieving new performance levels for GE's products in part by capitalizing on material properties at the nanoscale level. GE Global Research has five facilities, which are located in New York, India, China, Germany, and Brazil.

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GE scientists are engineering novel surfaces and coatings for various applications. Inspired by a nanotextured wax surface that repels water on the leaves of Lotus plants, GE is developing nanocoatings to control moisture on electricity-generating turbine blades, thus creating anti-icing surfaces for wind turbines and jets. GE's anti-icing surfaces have been shown to significantly reduce ice adhesion and delay ice formation under simulated conditions (Source: GE's March 6, 2012, press release). GE researchers are also exploring coatings to improve moisture control in steam turbines and to reduce fouling (the accumulation of unwanted material on solid surfaces) in gas turbines.

GE is investing $10 billion by 2015 in "ecomagination" research—the company's program for identifying and developing innovative solutions to today's environmental challenges while driving economic growth.

In October 2012, GE entered into a two-year, $1.2 million joint venture with the DOE to explore the possibility of storing CO_2 emissions in underground wells as an alternative to releasing harmful quantities of CO_2 into the atmosphere. GE is creating a fiber optic cable and sensing system to monitor pressure and temperature to support long-term stability of stored CO_2. GE reports that these sensors could also be used for jet engine and turbine development.

Through its GE Lighting Solution subsidiary, the company offers high-performance LED product solutions that lower costs and improve performance without relying on mercury, lead, or glass. More than 25 million linear feet of GE's LED lighting had been installed as of June 2012. In a recent example, Public Storage (PSA-NYSE) has announced plans to replace existing fluorescent lamps in its exterior signage with GE's Tetra® PowerStrip LED sign lighting in over 2,000 locations, which could lower Public Storage's annual energy and maintenance costs by up to $1.9 million and reduce energy consumption by roughly 73%.

GE's ecomagination initiative seeks to identify cleaner energy sources, reduce emissions, and enable more clean water. In 2011, the company reported $21 billion in revenues for ecomagination products and services and had invested over $2 billion in research and development. GE is in the process of investing $10 billion in ecomagination research by 2015 (Source: GE's June 28, 2012, press release). Ecomagination added 34 new products in 2011, including the FlexEfficiency 50 Combined Cycle Power Plant, which enables the integration of power from a variety of sources, including solar and wind. To view GE's complete ecomagination portfolio, visit www.ecomagination.com/portfolio.

GE operates in 150 countries and had roughly 301,000 employees globally as of December 2011. The company reported revenues of roughly $147.3 billion in 2011.

Honeywell International Inc. (HON-NYSE)

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Honeywell International is a Fortune 100 entity that invents and manufactures technologies for safety, security, and energy. The company is separated into the following businesses: (1) aerospace products and services; (2) automation and control technologies for buildings, homes, and industry; (3) automotive products; (4) performance materials and technologies; and (5) transportation systems. More than 50% of the company's portfolio provides energy efficiency benefits, including in the form of air traffic modernization; reduced emissions; biofuels; green buildings; fuel efficiencies; industrial process efficiencies; and smart grid technologies. Honeywell's various nanotechnology applications further include nanolaminate coatings for aerospace applications and nanoparticles in plastics formulations.

Honeywell's aerospace business is developing innovative safety products that are driving the modernization of global air traffic management, revolutionizing combat technology, and improving operational efficiencies. The company's automation and control solutions' (ACS) environmental controls, life safety, security, sensing, scanning and mobility products, and building and process solutions are at work in 150 million homes, 10 million buildings, 5,000 industrial facilities, and hundreds of gas and electric utilities worldwide. Honeywell's portfolio of products and solutions give customers the ability to capture increased and improved data faster and across a wireless landscape, advancing productivity, safety, and security; driving better decision-making; and reducing costs.

Honeywell has partnered with energy information software company, Opower, Inc. (profiled on page 54) to develop Wi-Fi - enabled, cloud-based smart thermostats currently being tested in thousands of homes.

The company is, as well, a worldwide leader in developing and manufacturing advanced materials and process technologies. These materials and technologies are used by people every day in a range of industries and applications—from petroleum refining to environmentally friendlier refrigerants to bullet-resistant vests. Its transportation systems include fuel-saving and emission-reducing turbochargers, as well as safety-enhancing brake materials, which provide solutions to automakers, their suppliers, and consumers. Honeywell's technologies improve the performance, safety, and efficiency of passenger and commercial vehicles worldwide.

Honeywell recently released a suite of professional services—the Attune™ Advisory Services—for building managers and owners who are working to optimize their energy use and costs. Attune™ incorporates cloud-based analytics and a global network of operations centers, with the objective of reducing utility bills and operating expenses by up to 20%. As well, the company announced an agreement to acquire Saia-Burgess Controls, a provider of intelligent building controls, from Hong Kong-based Johnson Electric for $130 million.

Honeywell introduced a third-generation durable laminate film, PowerShield® 3W, applied to solar panels to protect the panels from harsh environments. The company also announced that its Spectra Shield® ballistic material would be used to improve armor protection on U.S. Army UH-60 Black Hawk and CH-47 Chinook helicopters, reducing armor weight by as much as 40% compared with current systems. Honeywell furthermore announced the development of fuel-efficient turbochargers that help automakers achieve Corporate Average Fuel Economy (CAFE) targets while meeting consumer demand for improved fuel economy without compromising engine performance. The Obama administration announced CAFE, a new fuel standard for cars and light-duty trucks, on August 28, 2012, which seeks an equivalent of 54.5 miles/gallon by 2025.

Honeywell employs approximately 132,000 individuals globally, who work at close to 1,300 sites in more than 70 countries, including more than 21,000 engineers and scientists at 97 research and engineering facilities. In 2011, Honeywell reported $36.5 billion in revenues, with about 55% of sales derived outside of the U.S.

*Johnson Controls, Inc. (JCI-NYSE)***

Johnson Controls is a global diversified technology and industrial company focused on: (1) building efficiency, as the company is a leading provider of equipment, controls and services for heating, ventilating, air conditioning, refrigeration, and security systems; (2) automotive experience, as Johnson Controls is a global leader in automotive seating, overhead systems, door and instrument panels, and interior electronics; and (3) power solutions, as the company is focused on lead-acid automotive batteries and advanced batteries for **start-stop vehicles**, hybrids (as one of the only companies in the world mass producing lithium-ion batteries for hybrids), and electric vehicles. Johnson Controls has been committed to sustainability since 1885, when it invented the first electric room thermostat.

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Johnson Controls delivers innovative energy efficiency and infrastructure improvements that support the bottom line for its clients by balancing economic, environmental, and social outcomes. The company is combining renewable technologies, such as biomass, geothermal, solar, and wind power, with innovative energy efficiency strategies. Using its expertise and experience in renewable energy solutions, Johnson Controls provides environmentally friendly and economical energy supply options for customers—designing, engineering, installing, commissioning, operating, and maintaining renewable energy sources.

Johnson Controls' website states that the company has saved its private and public sector customers more than $7.5 billion in energy and operating costs since 2000, and that its projects have cut CO_2 emissions by 13.6 million metric tons. Johnson Controls recently introduced the Panoptix software development community, providing building data, tools, and support to developers to create and market new applications that address energy efficiency, sustainability, and operations.

Johnson Controls—a primary partner in the Empire State Building retrofit (described on pages 8-9)—states that its building efficiency solutions have cut CO_2 emissions by 13.6 million metric tons since 2000.

Johnson Controls is one of the primary partners responsible for the ongoing retrofit of the Empire State Building (described on pages 11-12 of the first edition of *Nanotechnology and the Built Environment*, published on November 17, 2011). One year after the retrofit project, the company announced that it is ahead of plan and has exceeded its year one energy efficiency guarantee by 5%, saving $2.4 million and establishing a commercial real estate model for reducing costs, maximizing return on investment, increasing real estate value, and protecting the environment.

As well, the DOE announced that it expects to save more than $264 million and reduce fossil fuel use by 72% at its Oak Ridge National Laboratory (ORNL) through energy and operational efficiency measures over a 25-year performance period—specifically through an energy savings performance contract with Johnson Controls—where ORNL's greenhouse gas emissions are expected to be reduced annually by almost 50,000 metric tons of CO_2.

With customers in more than 150 countries, the company reported nearly $42 billion in revenues in fiscal year 2012 (ended September 30)—roughly $21.3 billion from its automotive sector, $14.7 billion from building efficiency, and $5.9 billion from power solutions. Johnson Controls employs more than 162,000 individuals.

*** See disclosures on page 77.*

*The Sherwin-Williams Company (SHW-NYSE)***

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Sherwin-Williams is a global leader in the manufacture and sale of coatings and related products. The Sherwin-Williams Global Finishes Group distributes products in over 70 countries worldwide. The company has developed innovative ways to make coatings that are compliant with today's most stringent regulatory requirements, offering a wide selection of products that meet new VOC guidelines for industrial and architectural applications and offering products qualified for LEED projects.

For instance, in July 2012, the company introduced new, zero-VOC Emerald™ Interior and Exterior paints and ColorCast Ecotoner® colorants as the latest additions to its zero-VOC products. The Emerald paints are engineered to be self-priming (thus requiring fewer coats of paint) and offer improved durability. The Ecotoner has been deployed at all Sherwin-Williams locations, and as such, the company's entire line of water-based paints and colors is now tinted with zero-VOC colorants.

To Sherwin-Williams' knowledge, it offers more green coatings than anyone in the industry. The company uses a GreenSure™ symbol to help customers identify which products meet green coating standards—offering maximum performance and long-term durability—and are designed for reduced environmental impact and rigorous regulatory requirements. In 2011, Sherwin-Williams was awarded the EPA Presidential Green Chemistry Challenge Award in recognition of its innovative paint formulation and manufacturing technologies.

Sherwin-Williams, which has seen its stock price double over the past year, is in the process of acquiring North America's 4th largest paints and coatings manufacturer, Mexico's Comex Group.

In November 2012, Sherwin-Williams entered into a definitive agreement to acquire Consorcio Comex, S.A. de C.V., believed to be the fourth largest architectural paint manufacturer in North America, for approximately $2.34 billion. Comex, headquartered in Mexico City, reported 2011 sales of $1.4 billion. Like many other paints and coatings companies, Comex has capitalized on nanotechnology for development of innovative products, such as the Deletum 3000 brand, which is a unique nanocoating to combat graffiti that was originally developed by a nanotech researcher at Mexico's Universidad Nacional Autónoma de México (UNAM) (Source: *Coatings World*, November 1, 2010). As part of Comex's portfolio, Deletum 3000 incorporates an acrylic urethane base, nanoparticles, oil and water-proof molecules, and a cross-linking agent in order to last through multiple solvent cleanings aimed at removing graffiti.

Sherwin-Williams® branded products are sold exclusively through a chain of roughly 3,500 company-operated stores and facilities, while the company's other brands are sold through leading mass merchandisers, home centers, independent paint dealers, hardware stores, automotive retailers, and industrial distributors. Founded in 1866, the company is headquartered in Cleveland, Ohio. In 2011, Sherwin-Williams reported net sales of approximately $8.8 billion. Over the past year, the company's stock price has nearly doubled, up from a share price of $83.98 when the first edition of *Nanotechnology and the Built Environment* was issued on November 17, 2011, to close at $151.57 on Friday, November 16, 2012.

** See disclosures on page 77.

Siemens AG (SI-NYSE)

Siemens is a global electronics and electrical engineering company operating in the industry, energy, healthcare, and now, infrastructure sectors. In 2012, Siemens won Frost & Sullivan's Global Award for Company of the Year in the "City as a Customer" category. The award recognized Siemens' 2011 creation of a new business sector called "Infrastructure & Cities," which is focused on identifying megatrends and their impacts and offering a relevant portfolio of urban infrastructure solutions. The company emphasizes sustainable, environmentally friendly, and energy-efficient technologies and products that are built upon advanced sciences, such as nanotechnology principles. Siemens' Infrastructure & Cities sector offers products in the following areas:

- Building Technologies;
- Mobility;
- Power Distribution;
- Smart Grid;
- Lighting; and
- Consumer Products.

In addition to the above product areas, the company's industry sector is the world's leading supplier of manufacturing, transportation, building, and lighting systems. Its energy-efficient products and solutions are focused on making an important contribution to environmental protection. In the energy sector, Siemens provides solutions for the generation, transmission, and distribution of power, and the extraction, conversion, and transport of oil and gas. In the healthcare sector, Siemens develops, manufactures, and markets diagnostic and therapeutic systems, devices, and consumables and offers information technology (IT) systems for clinical and administrative purposes. The company also provides technical maintenance, professional, consulting, and financing services.

In September 2012, Siemens opened a center for sustainable urban development in London, called the Crystal, designed to facilitate sustainability expositions, urban dialogue, and technology and innovation development. The company has invested roughly €35 million into this project, where experts from Siemens can collaborate on R&D of technologies and innovations for the urban infrastructure of the future. Additional centers are expected to be built in Shanghai and Washington over the next several years.

Siemens was founded in 1847 and is headquartered in Munich, Germany. The company reported fiscal 2012 revenues of €78.3 billion, and has stated that it generates more than 40% of its revenue from ecofriendly products.

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Siemens recently added an "Infrastructure & Cities" business unit to its multinational operations, which led to the company being selected as Frost & Sullivan's 2012 Company of the Year in the "City as a Customer" category.

3D Printing (Additive Manufacturing)

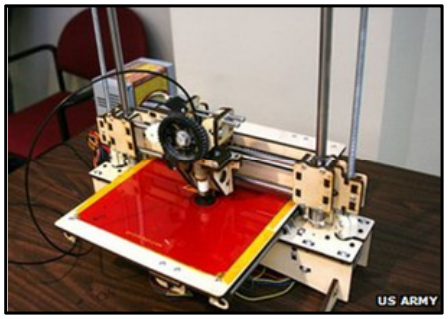
The 3D printing market is forecast to reach $3.5 billion by 2017, up from $1.8 billion in 2012.

Market Snapshot

In addition to providing millions of jobs, manufacturing enables innovation. The U.S. manufacturing industry added approximately 500,000 jobs between February 2010 and July 2012, and represented 70% of R&D spending in the private sector (Source: The White House, www.whitehouse.gov, July 17, 2012). Additive manufacturing (or "3D printing") is an advanced manufacturing technique whereby a physical object is formed—based on a computer model—by depositing together successive layers of powdered metal, tiny droplets of heated plastic, or other materials. 3D printers can create complex, functioning parts without tools or fixtures, and rarely produce waste. Moreover, these machines produce parts at a fraction of the cost of traditional manufacturing methods. 3D printers vary in size and purpose from desktop to industrial.

Figure 11

3D PRINTING

Used by the U.S. Army to Produce Spare Parts for Sensitive Instruments	"Urbee" Car Prototype Built Entirely with 3D Printers by Stratasys Inc.
	

Sources: BBC News' "US army builds its own 3D printer," November 9, 2012; and Stratasys Inc.

3D printing was originally developed as a technique to create prototypes, but is now used to produce a range of objects, including mechanical devices, furniture, electronics cases, medical devices, jewelry, and clothing, among others, with an ever-expanding potential for creating more complex objects, such as building materials, electronics, organ replacements, and car parts. Aerospace companies are also using the technique to create lighter, improved versions of airplane parts without needing a manufacturing line or inventory (Source: *Forbes'* "3D Printing, Shapeways, and the Future of Personal Products," June 19, 2012).

Materials used for 3D printing can include polymers, metal alloys, ceramics, and even food. Furthering the potential of advanced manufacturing, a number of nanomaterials have been developed for 3D printing, including carbon nanotubes, ceramic-matrix nanocomposites, and carbon fibers, which offer improved strength, lighter weight, greater energy efficiency, and better durability versus existing materials (Source: *IndustryWeek's* "New Technologies Offer Hope for American Manufacturing," August 22, 2012).

Such advances in 3D printing are expected to benefit domestic manufacturing in coming years. As the ability to perform small-scale production of previously labor-intensive products becomes a reality, the cost of manufacturing in the U.S. may decrease, enabling the country to better compete with China while adding critical manufacturing jobs to the U.S. workforce (Source: *Foreign Policy's* "The Future of Manufacturing Is in America, Not China," July 17, 2012).

Outlook

- The 3D printing market is forecast to reach $3.5 billion by 2017, up from $1.8 billion in 2012 (Source: MarketsandMarkets' *Global Additive Manufacturing Market [2012-2017]*, October 2012).
- Fueled by the discovery and diversity of novel printing materials, there are an expanding number of applications for which 3D printing can be used.
- The cost of 3D printers is decreasing for both industrial and consumer use models. Lower costs, as well as the availability of simple, web-based applications for print designs, are making 3D printing more accessible to end users.
- Companies are scaling up 3D printers for increasingly large applications.
- Continued market consolidation, as well as new market entrants, is anticipated as 3D printing transitions from the research and prototype stage to a reality.

Key Developments During 2012

- A number of industry events were held during 2012 that furthered innovation and collaboration in the advanced manufacturing space, including the Nanomanufacturing Conference, the Workshop on Building the National Network for Manufacturing Innovation, and the Nanomanufacturing Summit 2012, among others.
- A group of public and private organizations created "Manufacturing Day" to highlight the importance of manufacturing in the U.S. economy as well as to promote high-skill manufacturing jobs. The inaugural event was held on October 5, 2012.
- In March 2012, President Obama announced plans to invest over $1 billion in the formation of a National Network of Manufacturing Innovation (NNMI), which may include up to 15 institutes for developing new manufacturing technologies—potentially making U.S. manufacturers more competitive and encouraging investment in the U.S.
- The first institute to be established under the NNMI initiative—the National Additive Manufacturing Innovation Institute (NAMII)—has been awarded $30 million in federal funding, with an additional $40 million committed by a private industry consortium (Source: *USA Today*, "Obama announces new manufacturing institute in Ohio," August 16, 2012).
- The proposed U.S. budget for FY 2013 included $2.2 billion for advanced manufacturing R&D (a 19% increase over FY 2012), with a goal of strengthening the competitiveness of the U.S. manufacturing sector (Source: The White House's "FACT SHEET: White House Advanced Manufacturing Initiatives to Drive Innovation and Encourage Companies to Invest in the United States," July 17, 2012).

The Obama administration has allocated over $1 billion for development of advanced manufacturing technologies, such as 3D printing, with an additional $2.2 billion for manufacturing requested in the FY 2013 budget.

3D Systems, Inc. (DDD-NYSE)

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www.3dsystems.com

Founded in 1986, 3D Systems and its subsidiaries develop, manufacture, and market 3D printers and related products, print materials, and services for custom parts. More than 25 years ago, 3D Systems invented stereolithography, a manufacturing technology in which layers are formed by using a laser to cure the surface of a bath of photosensitive polymer resin in the desired shape. Since then, the company has expanded its 3D printing capabilities with the development of **selective laser sintering**, multi-jet modeling, and film transfer imaging technologies. These technologies serve as the engines supporting 3D Systems' portfolio of 3D printers (overviewed in Figure 12), which includes personal 3D printers for students, hobbyists, and other consumers. The company's Cube® desktop printer (priced $1,299 and up) requires no assembly and can produce up to 25 objects. 3D Systems received *Popular Mechanics*' 2012 Breakthrough Award for the Cube® printer.

In 2012, Fortune magazine recognized 3D Systems' rapid growth—the company was ranked fifth in tech, top six in profit growth, and 12th overall out of a list of 100 of the "fastest-growing companies."

Figure 12
3D SYSTEMS' PRODUCT PORTFOLIO OVERVIEW

Source: 3D Systems, Inc.'s Investor Presentation, November 2012.

For professional users, 3D Systems offers the ProJet™ and ZPrinter series, which have various models to accommodate customers' needs. 3D Systems also offers solutions for production-level users, where machines are stated to deliver high throughput, up to 1,524 mm build size, and high part resolution (build accuracy).

3D Systems has over 100 performance print materials. The company's printers and materials are used in the automotive, aerospace, computer, electronic, defense, education, consumer, energy, and healthcare sectors, as well as by OEMs, government agencies, universities, and independent service bureaus.

The company is focused on acquiring new products and technologies for its portfolio. In October 2012, 3D Systems acquired South Korea-based Rapidform, a provider of 3D scan-to-CAD and inspection software tools in a $35 million agreement, as well as TIM: The Innovative Modelmakers B.V., a full-service provider of on-demand custom parts services. The company is also a partner in the National Additive Manufacturing Innovation Institute (NAMII).

3D Systems is headquartered in Rock Hill, South Carolina. The company was named to *Fortune's* 2012 list of the fastest-growing companies, ranking fifth in tech, top six in profit growth, and 12th overall out of 100 firms listed. 3D Systems' consolidated revenues were approximately $230.4 million in fiscal 2011.

Objet Ltd.

Founded in 1998, Objet is a global provider of inkjet-based 3D printing systems and materials for consumer goods and electronics; aerospace, defense, and automotive applications; education; dental and medical devices; architecture; industrial machinery; sporting goods, toys, and footwear; and service bureaus. Objet enables manufacturers and product design professionals to create accurate prototypes in-house within hours.

Objet's 3D printing technology is designed to build prototypes that mimic the appearance, feel, and function of an end-product, including complex, assembled goods. Currently, the company's 3D printers are compatible with over 100 materials ranging from rigid to rubber-like, transparent to opaque, and standard to ABS-grade engineering plastics, with a large number of in-between grades and shades. To print a 3D product, Objet's synchronized printing heads or "jets" spray the material in ultra-thin layers onto a build tray. A UV light is used to cure each layer before more material is applied. This process is repeated layer by layer until the part is completed. Additionally, a gel-like support material can be used to create complex geometries.

The company offers several lines of 3D printers, from cost-effective desktop printers for entry-level professionals to industrial-scale multi-material machines for designers and manufacturers. Created for designers and engineers, the Objet Connex™ line employs the world's only technology to simultaneously jet two materials, enabling users to print various mixed parts on the same build tray (Source: Objet). Figure 13 illustrates an Objet260™ Connex printer as well as a GPS device prototype created by Objet's printer.

Figure 13

OBJET260™ CONNEX 3D PRINTER (left) AND A PRINTED GPS DEVICE PROTOTYPE (right)

Source: Objet Ltd.

In April 2012, Objet entered into a $1.4 billion merger agreement with Stratasys Inc. (SSYS-NASDAQ) (profiled on page 28). The merger has been approved under the Hart-Scott-Rodino (HSR) Antitrust Improvements Act of 1976 and by Stratasys stockholders, and is expected to close by year-end 2012 (Source: Stratasys' November 2, 2012, press release). It is hoped to support the companies' ability to grow the 3D printing market and enable cross-selling opportunities for the combined product portfolio.

Objet is headquartered in Rehovot, Israel, and has offices in North America, Europe, Japan, China, Hong Kong, and India. The company reports that it has thousands of customers worldwide, many of which are Fortune 100 or Fortune 500. Its technologies have been recently showcased at the 2012 ASME Congress, EuroMold 2012, the 3D Printshow 2012, AfriMold 2012, and SIGGRAPH 2012, among other venues. Objet reported $121.1 million in revenues during fiscal 2011.

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Objet and Stratasys (profiled on page 28) are in the process of merging, which the companies believe will greatly improve their ability to grow the 3D printing market. With over 40% market share, Stratasys reports that it is the unit market leader.

Stratasys Inc. (SSYS-NASDAQ)

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Stratasys and its subsidiaries develop, manufacture, and market 3D printers, rapid prototyping systems, and related consumables. The company's products are used in the aerospace, defense, automotive, medical, business and industrial equipment, education, architecture, and consumer-product industries.

Stratasys' patented Fused Deposition Modeling (FDM®) technology is able to create functional prototypes and manufactured goods using high-performance industrial thermoplastics based on a 3D CAD model. The company has employed this technology in its 3D printing product lines. Stratasys' top selling 3D printer is its Dimension brand, which enables users to create large 3D models with precise detail. Dimension 3D printers are used by 3M, Honeywell, Sony Corp. (SNE-NYSE), Honda Motor Company, Ltd. (HMC-NYSE), Hewlett-Packard Co. (HPQ-NYSE), Johnson & Johnson (JNJ-NYSE), Northrop Grumman Corp. (NOC-NYSE), General Motors Co. (GM-NYSE), and many others, including a Delaware hospital that used a Dimension 3D printer to create a mobile plastic exoskeleton for a young girl who needed medical help using her arms (due to a rare congenital disorder).

Stratasys reports that it held a 41.5% market share in 2011 and has been the unit market leader for a decade (Source: Stratasys' November 2, 2012, press release). Figure 14 highlights features of Stratasys' 3D printing and production systems, which include multiple product lines beyond the aforementioned Dimension brand.

Figure 14

FEATURES OF STRATASYS' 3D PRODUCTION SYSTEMS AND MATERIALS

Source: Stratasys, Inc.'s Investor Presentation, April 2012.

The company also offers a digital manufacturing service called RedEye On Demand. Through this service, consumers can obtain prototypes and production parts without owning a 3D printer. RedEye operates over 125 FDM® systems worldwide.

In April 2012, Stratasys entered into a $1.4 billion merger agreement with 3D printing company Objet (profiled on page 27) that is expected to close by year-end 2012. Prior to that, in 2011, Stratasys acquired Solidscape Inc., a manufacturer of 3D wax printers for medical, consumer, and industrial markets.

In mid-2012, Stratasys was selected as part of a team to develop the National Additive Manufacturing Innovation Institute (NAMII). The company, founded in 1989, holds 380 approved or pending additive manufacturing patents and operates a global network of value-added resellers and distributors. As of March 1, 2012, Stratasys had approximately 530 employees and contractors worldwide. The company reported fiscal 2011 revenues of nearly $156 million.

Cementitious Materials

Market Snapshot

Targeting a potentially $330 billion worldwide cement market, nanoscience is driving adoption of new forms of cement that offer a considerably lower carbon footprint as well as stronger concrete products that are less susceptible to corrosion.

The production and sale of concrete—one of the world's most common building materials—represents a $200 billion industry that is critical to the built environment in the U.S. and internationally. However, despite the necessity of concrete in construction, this material is also one of the world's worst greenhouse gas polluters. Its manufacture and use is associated with up to 10% of all CO_2 emissions globally (Source: *R&D Magazine*, August 30, 2011). Consequently, many businesses and research institutions have begun commercializing greener methods for producing concrete or concrete alternatives.

Research has focused not only on ecofriendly concrete manufacture but also on improving structural performance. Concrete is inherently porous; thus, water and salt seep in over time, causing concrete to crack and its steel reinforcements ("rebar") to corrode (as shown in Figure 15). Concrete exposed to the environment (rain, ground water, freezing temperatures) over time will most always show structural damage, corrosion, and leaking. Rather than applying an exterior coating or a rubber, plastic, or asphalt membrane to concrete as a way of waterproofing (which are typically not recyclable and can be difficult to remove after the concrete's useful life), companies specializing in nanotechnology have developed next-generation solutions to keep waterproofed concrete "green" and recyclable while also reducing its carbon footprint.

Figure 15

CONCRETE CORRODED DOWN TO THE STEEL REINFORCEMENTS

Source: Matco Services, Inc.

Similar approaches are also being developed to improve the performance and environmental impact of bricks and other cementitious (cement-like) materials. Cement is the active component of concrete, and in itself, entails a very energy-intensive manufacturing process that accounts for roughly 5% of CO_2 emissions worldwide. Thus, several companies looking to make inroads in the green building sector are using nanotechnology concepts to develop viable alternatives to traditional Portland cement, the leading type of cement in use worldwide.

Outlook

- First Research, a division of Hoover's, expects the value of global cement demand to top $330 billion by 2015, representing a 5.3% annual growth rate (Source: First Research's *Cement & Concrete Product Manufacturing Industry Profile*, October 1, 2012).
- Growth factors include recovering construction markets, technological advances, and green construction initiatives that require the use of construction materials with enhanced cost, performance, and environmental impact profiles.
- Greater collaboration between industry, academia, and other institutions is likely to drive R&D of new, more efficient, more durable cement technologies.

- The largest market for concrete, brick, and cementitious materials continues to be the construction industry. This industry is forecast to expand at a CAGR of 7.3% over the next five years, to reach a global market value of over $8.9 billion by 2017 (Source: *Concrete Construction*, September 18, 2012). Major events, such as the 2014 FIFA World Cup, 2014 Winter Olympic Games, 2016 Olympic Games, and 2018 FIFA World Cup, are expected to significantly influence demand for construction materials.

- As a result of favorable weather and gains in construction activity in the first half of 2012, the Portland Cement Association (PCA) revised its forecasts for cement consumption upward in August 2012. The PCA forecasts a 6.9% increase in 2012 from 2011 levels, a 5.8% increase in 2013, and a 10.9% increase in 2014.

Key Developments in 2012

- In the wake of Super Storm Sandy, professors from the New Jersey Institute of Technology (NJIT) have begun advocating for the use of **autoclave aerated concrete (AAC)** in rebuilding projects (Source: NJIT, November 7, 2012). AAC is a lightweight, manufactured stone believed to be strong enough to withstand earthquakes and hurricanes when reinforced with steel. It has been used the most in Russia, with limited but increasing adoption in the U.S. Its principal manufacturer in the U.S. is Florida-based Aercon Florida LLC.

- Swiss engineers from *Ecole Polytechnique Federale de Lausanne* (EPFL) developed a new imaging technique to see inside concrete bridges. Similar to a sonogram, the technique assesses the health of bridges and diagnoses corrosion in the steel rebar skeleton. Previously, structural diagnostics entailed drilling samples from the bridge, which is not very precise for determining the magnitude of corrosion and in itself can be a time consuming and costly process. With the EPFL's georadar device, it may be possible to scan an entire 100-meter bridge in a few hours (Source: EPFL, April 18, 2012).

- Researchers from George Washington University have developed a device to capture solar energy and used it to power a new chemical process to make lime—the key ingredient in Portland cement—without releasing CO_2. The proof-of-concept technology converts the CO_2 into useful substances instead, such as oxygen or carbon (Source: *MIT Technology Review*, May 11, 2012).

- In September 2012, U.S. producer of Portland cement, concrete, and other aggregates, Eagle Materials Inc. (EXP-NYSE), acquired two cement plants from Lafarge North America Inc. (Lafarge S.A. [LG-EPA]) for $466 million, thereby expanding production capacity by 60%.

- Central Concrete Supply Co., part of U.S. Concrete, Inc. (USCR-NASDAQ), joined Architecture 2030's "2030 Challenge for Products"—an initiative to reduce greenhouse gas emissions by developing low-carbon building products—and achieved the first Challenge target by delivering concrete mixes with a carbon footprint more than 30% less than that of traditional Portland cement concrete. In October 2012, Central Concrete acquired Bode Gravel Co. and Bode Concrete LLC for $24.5 million.

- Spain's Basque Country Initiative for Cement and Concrete Research (Baskrete Initiative) is promoting the implementation of nanotechnologies in the cement and concrete industry. In a March 2012 conference, the Initiative brought together global participants, including MIT, the University of California at Berkeley, Spain's Donostia International Physics Center, the University of Basque Country, Tecnalia Research & Innovation, CEMEX S.A.B. de C.V. (CX-NYSE), Lafarge, Italcementi SpA (BIT-IT), and Italy's Bozzetto Group, to coordinate technology transfers and joint working programs in the field of cement nanoscience.

CalStar Products, Inc.

Founded in Silicon Valley in 2006, CalStar seeks to create effective, efficient, and environmentally friendly building materials, meeting an industry need for feasible green building products. The company developed a manufacturing process for bricks and pavers (brick for exterior walkways), whereby bricks and pavers are made with 40% post-industrial recycled content. In addition to a high recycled content, CalStar's manufacturing process requires up to 85% less energy and emits 85% less CO_2 than conventional masonry production, which uses high-temperature firing of clay brick and pavers.

To date, CalStar has produced several million bricks. To support adoption of its products, CalStar recently opened a manufacturing plant in Racine, Wisconsin, capable of producing 40 million brick equivalents a year. The company has since relocated operations to Wisconsin and built a network of independent distributors for its masonry products. In the past several years, CalStar's 40%-recycled-content bricks have received numerous recognitions for their value as green building products, including but not limited to those listed in Figure 16.

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CalStar uses recycled fly ash (a waste product of burning coal) in its bricks instead of Portland cement—reducing CO_2 emissions and turning a waste material into a functional green building product.

Figure 16
CALSTAR PRODUCTS: IMAGES AND AWARDS

(Above) 11,000 ft.^{2} Farmer's Market in Milwaukee, paved with CalStar permeable pavers

(Above) CalStar's Thru-Wall units combine the structural properties of concrete block with the aesthetics of brick.

(Right) Auburn Hills, Michigan, Hampton Inn using CalStar's natural utility bricks

Builder magazine	CalStar Holland Pavers ranked #33 of the top 50 products of 2012
Professional Remodeler, *Professional Builder*	101 Best New Products for 2012 (CalStar Thru-Wall Block Units); Top 101 Products in 2010
Architectural Products	Two Product Innovation Awards (Holland Pavers and Architectural Facing Bricks)
Building Products	2011 Most Valuable Product
San Francisco Business Times	2011 Cleantech and Sustainability Awards, Building Innovation winner
Architectural Record	Editor's Pick in the Concrete, Masonry, and Exterior Improvements category
AlwaysOn's GoingGreen 100	Top 100 GreenTech companies in Silicon Valley, 2010

Sources: CalStar Products, Inc., Masonry magazine (November 2011), and Professional Builder (August 2012).

To create its novel brick products, CalStar uses recycled fly ash, which is the fine ash waste expelled as a byproduct of burning coal. Fly ash, aggregates, mineral oxide pigments, and proprietary ingredients are mixed with water, vibrocompacted, and cured into a stable solid. Because the fly ash works as a binding agent, CalStar's bricks do not require kiln-firing to harden, thus avoiding the energy and CO_2 impact of the firing process. As well, incorporating recycled fly ash avoids the use of Portland cement in concrete pavers. Thus, CalStar is helping to turn a waste material into a functional green building product.

CalStar believes that its products are priced competitively with traditional clay products of equivalent quality. The company's commercial brick also meets or exceeds the same building standards of equivalent masonry products, thereby supporting green infrastructure projects without compromising building performance or budgets. As a private company, CalStar's sales figures are not publicly available.

Hycrete, Inc. (Subsidiary of Broadview Technologies Inc.)

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In April 2012, New Jersey chemical company Broadview Technologies acquired Hycrete, Inc., the maker of water-repellant molecules used to waterproof concrete and other cementitious materials (e.g., mortar and stucco). The acquisition strengthened Broadview's current product line, which centers on the sale of waterless compounds known as **anhydrides** used in the production of **epoxy** resins. Other materials sold by Broadview include non-halogen fire retardants as well as specialty substances known as **plasticizers** that are added to a wide array of materials to make them more pliable.

As a Broadview subsidiary, Hycrete adds intelligent moisture and corrosion control to the company's material science portfolio. Founded in 2002, Hycrete has developed water-based concrete admixtures that are mixed with sand, aggregate, cement, and water to create hydrophobic building materials (concrete, mortar, and stucco). When the concrete hardens, the admixtures turn from a liquid into a solid that is bonded to the concrete. As snow, rain, groundwater, and other environmental agents corrode the concrete over time, Hycrete's admixtures react with the metallic ions present in water, concrete, and steel reinforcements to form a water-repelling, oil-like precipitate that fills the capillaries of the concrete. This action stops capillary absorption of water and salts and increases concrete durability. This compares to some traditional waterproofing, which may enhance density but not actively repel water. Importantly, Hycrete's admixtures also form a protective layer over the steel reinforcements often used in concrete, such as rebar, which is a common source of corrosion leading to the eventual deterioration of concrete structures.

Integrated waterproofing and corrosion protection, such as enabled by Hycrete's admixtures, help eliminate the need for external protection systems. Because the admixtures are built into the concrete mixture, which is batched at the plant not the jobsite, waterproofing occurs simultaneously to pouring the concrete—shortening construction time, reducing the containers and materials needed on the jobsite, and lowering project costs versus alternative membrane solutions. As well, Hycrete reports that its waterproofing solutions enhance the durability and longevity of cementitious materials, leading to a reduction in future repair and maintenance costs. Further, there is no need to periodically reapply a coating to the concrete, as is required in some waterproofing approaches.

Hycrete's nanoparticle molecules are recyclable, environmentally friendly, and hold **Cradle to Cradle®** Gold certification. Using this technology for waterproofing allows the concrete to remain a sustainable building material as it can be recycled and may allow builders to earn LEED credits. As a recent example, the Thomas Jefferson School of Law based in San Diego, California, used Hycrete concrete in the construction of a new school building, which allowed the school to bypass external waterproofing mechanisms thus saving an estimated four weeks of construction time and reducing construction costs by $187,000. It also led to the receipt of a LEED "Innovation in Design" credit and eliminated 36 tons of landfill debris that would have been otherwise incurred (Source: Hycrete's January 19, 2012, press release). As a result, the building was designated "Institutional Project of the Year" by *Concrete Producer's* annual GreenSite Awards program.

Broadview was founded in 1970 and today offers over a dozen different anhydrides for curing epoxy resins as well as plasticizers and fire-retardant compounds that have been successfully incorporated into epoxy, acrylic, vinyl acetate, urethane, polypropylene, and PVC resin materials. Broadview's new Hycrete subsidiary has integrated its water-repellant molecules into over five million square feet of concrete in more than 100 projects from green roofs and sidewalks to below-water-table basements and concrete traffic barriers. In addition, Hycrete has received numerous awards for sustainability and innovation, which are summarized at www.hycrete.com. As a private company, Broadview's sales figures are not publicly available.

Solidia Technologies, Inc.

Founded in 2008, Solidia, an advanced materials company based in New Jersey, has developed a technology platform allowing for the sustainable production of building and construction materials. The company's process produces cementitious materials that are believed to exhibit improved mechanical properties, lower life-cycle costs, and a reduced environmental footprint versus standard concrete, Portland cement, or stone. A competitive feature of Solidia's approach is that cement manufacturers can use their current equipment to produce Solidia's indoor and outdoor low-environmental-impact products, ranging from pavers to structural precast concrete.

Solidia Technologies

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The company's proprietary technology is based on Low Temperature Solidification (LTS), wherein natural minerals and waste products are bonded together through a low-energy process and infused with CO_2—known to Solidia as the densification of inorganic materials. Essentially, the technology involves speeding up the natural process of CO_2 combining with minerals to make solids, so that mineralization occurs in hours rather than years. Resulting products offer a durability and mechanical performance exceeding that of traditional concrete and natural stone. Building and construction materials produced via LTS have been found to offer high compressive strength and low permeability with no shrinkage (Source: *Concrete Products*, March 21, 2012). They are also impact and abrasion resistant with insulating and fire resistance properties (Source: BP p.l.c.'s "Ventures Case Studies" on Solidia). Additionally, because of Solidia's low-temperature processing, electronic components such as sensors or radiant heating can be inserted directly into the material.

The LTS technology was invented at Rutgers, The State University of New Jersey by the Riman Research Group. Its co-inventers now hold executive management positions at Solidia. Solidia's commercial launch of the new manufacturing process occurred at the 2011 Greenbuild® International Conference and Expo in Toronto, Canada.

Figure 17

SOLIDIA TECHNOLOGIES: Technology Overview

LTS technology enables Solidia to

- Manufacture concrete and stone at low temperatures and pressures without high-temperature kilns
- Mold and process concrete and stone-like plastics in simple, scalable manufacturing
- Use a variety of abundantly available recycled materials and waste products, including those that cannot be used in traditional concrete, to make infrastructure products
- Use CO_2 as a reactant at low temperatures, consuming this gas rather than generating it

Enhanced mechanical properties	*Aesthetics*	*Significant thermal properties*	*Environmentally friendly*	*Value-add*
High strength, impact resistance, abrasion resistance, and toughness	Broad palette of colors, textures, shapes, and sizes	Thermal shock resistance with high insulating and fire resistance properties	Energy-efficient manufacture; consumes little water; potential for carbon-negative products	Can incorporate sensors, photovoltaic cells, LEDs, and other electronics into materials

Source: Solidia Technologies, Inc.

The LTS manufacturing process is applicable to building products in both exterior and interior applications, including countertops, flooring, interior wall panels, façades, roofing, and other exterior surfaces, as well as for infrastructure applications (precast [used for walls, pipes, road overlays, bridge decks, and more] and cast-in-place [a concrete replacement cast onsite]) and refractory machinery such as furnaces, kilns, incinerators, and reactors. Going forward, ongoing R&D at the company is directed at developing carbon-negative concrete replacement materials.

Rather than building a manufacturing plant to produce its next-generation construction materials, Solidia has elected to bring its technology to market in a capital-efficient model based on licensing the process know-how to cement, concrete, and building products manufacturers that have established sales, marketing, and distribution channels. In this way, the company seeks to become a global technology solutions provider to the building and construction material industries.

Solidia has approximately 25 employees. The company is backed by BASF Venture Capital, Kleiner Perkins Caufield & Byers, BP Ventures, and Bright Capital. BASF, Kleiner, BP, and Bright contributed approximately $27 million to Solidia in February 2012, which brought its cumulative funding to $37 million. Solidia has won awards from the DOE and the State of New Jersey Commission on Science and Technology and is an active member of the U.S. Green Building Council. As a private company, Solidia's sales figures are not publicly available.

Insulation

Market Snapshot

The U.S. market for thermal insulation was valued at $6.1 billion in 2011, up from $5.2 billion in 2010 (Source: Freedonia Group's *Insulation to 2016-Demand and Sales Forecasts, Market Share, Market Size, Market Leaders*, March 2012). The $6 billion insulation market is based on insulation products used in both residential and commercial construction, as well as for industrial and HVAC equipment. Roughly 950 trillion BTUs (British Thermal Units) of heat energy is lost every year due to the poor insulation of industrial systems alone, representing a waste of nearly 165 million barrels of crude oil annually (Source: DOE, June 7, 2012).

Stricter energy regulations, such as the 2012 IECC®, combined with legislative incentives like the U.S.'s recently passed Enabling Energy Saving Innovation Act of 2012 are driving adoption of aerogels and other forms of advanced insulation.

Retrofitting existing buildings with newer, more advanced insulation materials (or using these in new construction) can considerably improve buildings' energy consumption—a benefit that has become more important in recent years due to rising oil and gas costs for heating and cooling. In addition to promoting an energy cost savings, advanced insulation technologies are often more environmentally friendly and have a smaller mass than conventional fiberglass batting, enabling their use in space-constrained projects where thick insulation is not possible. Traditionally, to increase the effectiveness of insulation, builders doubled the thickness of the insulating material. This is not necessary with today's new products, which include liquid nanocomposite coatings and aerogel insulation (capable of delivering improved thermal properties in a much thinner form factor), among others.

Figure 18
INSULATION THEN AND NOW

Fiberglass Batting	Aerogel Blankets
	

Sources: Minnesota Roofing llc and CNET.

Outlook

- U.S. demand for insulation is forecast to rise 7.8% annually to reach $8.9 billion in 2016, driven by an anticipated rebound in housing and construction markets (Source: the Freedonia Group, March 2012).

- Greater use of new types of insulation, such as aerogels, will likely be fueled by new legislation and incentives promoting zero-energy buildings as well as increased momentum in the adoption of sustainable building methods amid a global emphasis on energy conservation and efficiency.

- As regulations on the thermal building envelope become more stringent, builders, developers, architects, and the like will have to focus on employing new products and technologies capable of meeting these standards.

Key Developments During 2012

- The 2012 International Energy Conservation Code® (IECC) was released, which addresses energy efficiency on several fronts, including cost savings, reduced energy usage, conservation of natural resources, and the impact of energy usage on the environment. The new code has stricter insulation requirements than previously, representing a 30% increase in energy savings versus the 2006 version.

- In September 2012, the U.S. Congress approved the Enabling Energy Saving Innovation Act of 2012 (H.R. 4850), which promotes the research, development, and use of alternative, energy-efficient insulation technologies.

- France's Saint-Gobain S.A. (SGO-EPA) recently agreed to purchase U.K.-based Celotex Group Ltd, which makes insulating foam, and acquired 25.1% of Russian stone wool manufacturer ZAO Isoroc. Stone wool is used as fire-resistant insulation.

- In October 2012, SOPREMA, Inc. acquired 100% of the activities of Convoy Supply Ltd., a Canadian company specializing in insulation and roofing materials.

- In August 2012, Johns Manville, a Berkshire Hathaway company (BRK.A, BRK.B-NYSE), announced the purchase of Industrial Insulation Group, LLC, a manufacturer of insulation for industrial and commercial applications.

- In August 2012, Kingspan Group PLC (KGP-LON), a global manufacturer of sustainable products for the construction industry, announced the acquisition of ThyssenKrupp Construction Group for approximately €65 million and of Middle East firm Rigidal Industries LLC for approximately $38.6 million.

- In April 2012, the American Society for Testing and Materials (ASTM) issued a performance standard for aerogel insulation—representing the first ever such specification. "ASTM C1728-12, Standard Specification for Flexible Aerogel Insulation" establishes minimum performance standards for aerogel-based insulation materials. Its introduction may be indicative of a growing acceptance of aerogel technology among end users, engineers, distributors, and contractors.

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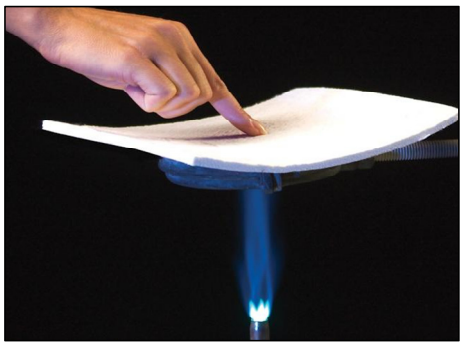
Since 2001, Aspen Aerogels® has capitalized on a patented nanoscience to create better and thinner insulation materials. Development ultimately led to the commercial introduction of an aerogel insulation, which is a low-density solid material produced when the liquid component is removed from a gel. In Aspen's aerogel composition, 97% of the insulation's volume is air trapped in nanopores between intertwined clusters of **amorphous** silica solids. The air in the nanopores is able to more effectively trap heat as a result of the very little room in which it has to move. Aspen Aerogels' flexible aerogel insulation (shown in Figure 19 reinforced with non-woven fiber batting) offers up to five times better performance than fiberglass, polyester microfiber, foam, or microporous silica insulation. For example, a relatively thin aerogel heated on one side by a flame torch can be safe to touch. Resting on dry ice at -78.5°C, it maintains room temperature of 22°C on the other side.

Figure 19
ASPEN AEROGELS' FLEXIBLE AEROGEL BLANKET WITHSTANDS EXTREME TEMPERATURES



Source: Aspen Aerogels, Inc.

Before Aspen Aerogels' aerogel was used in the built environment, it protected spacecraft from extreme temperatures during launch and in space. As a result of Aspen's work bringing this space technology into terrestrial applications, the company's vice president of R&D, Dr. George L. Gould, was inducted into the Space Foundation's Space Technology Hall of Fame® in April 2012, along with the induction of the low-density, lightweight aerogel material itself.

Aspen manufactures three aerogel lines—Cryogel®, Pyrogel®, and Spaceloft® (ranging from 5 mm to 10 mm in thickness)—that are sold primarily through distributors, contractors, and OEMs. The Spaceloft line is targeted to residential and commercial buildings for use insulating interior and exterior walls, framing, floors, and roofs. Additional applications include oil and gas, natural gas, industrial and refinery operations, defense and aerospace, appliances, and apparel industries, among others. Both of Aspen Aerogels' Cryogel and Pyrogel lines were initially developed with help from the DOE. The DOE's Advanced Manufacturing Office invested in Aspen Aerogels as part of the Obama administration's strategy for solving America's clean energy challenges (Source: DOE, June 7, 2012).

Aspen Aerogels is headquartered approximately 25 miles outside of Boston, Massachusetts, with manufacturing facilities in Rhode Island. The company reported 2010 revenues of approximately $43.2 million, although 2011 revenues have not been made publicly available. In both June and October 2012, Aspen Aerogels raised approximately $10 million in private debt financings, for a cumulative amount of $20.13 million according to an October 11, 2012, SEC Form D/A. As of October 11, 2012, the total offering amount was set at $35.13 million, leaving room for the sale of another $15 million. Aspen Aerogels previously filed a Form S-1 registration statement with the SEC for an IPO in mid-2011 but has not yet executed a public offering and has not issued guidance regarding the status of this initiative.

Cabot Corp. (CBT-NYSE)

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Cabot is a global performance materials company headquartered in Boston, Massachusetts. The company manufactures products for aerospace, defense, chemical processing, construction, electronics, energy, environmental protection, glasses, ceramics, life sciences, mineral processing, plastics, printing, textiles, and transportation, among other sectors. Within its portfolio, Cabot has developed several aerogel insulation products for use in the built environment. These aerogel technologies were commercialized under a cross license agreement with Aspen Aerogels (profiled on page 37), under which both entities have granted each other certain intellectual property rights.

Cabot has two primary aerogel product lines: (1) Enova® and (2) Lumira® aerogel (formerly Nanogel® aerogel). Enova® is a high-performance additive used in paints and coatings to provide moisture resistance, matting efficiency, coating clarity, a long shelf life, and thermal insulation. It is produced in a granular form, where each nanostructured granule is over 90% air, and can be used on its own or in conjunction with other materials. Enova® reduces temperatures by 60°C to 100°C on 200°C substrates and substantially inhibits heat transfer through the material. Lumira® aerogel entails high-performance insulation for daylighting, a technique of using windows and skylights to replace artificial light and reduce daytime electrical demand. Daylighting is employed by both architects and building owners as a way to create an aesthetic design while meeting strict energy and building code requirements.

Figure 20 illustrates the deployment of Lumira® aerogel windows in Advanced Glazings Ltd.'s Solera® **insulated glass units**, which were used in a luxury New York City apartment building, known as TEN23. The building, which opened in January 2012, has 111 units, and its owners specifically requested a design filled with natural daylight. Advanced Glazings' Solera® R18 glass units using Cabot's Lumira® are stated to have equivalent insulation to a solid wall, which enables the provision of both light and improved thermal performance. This project was the first large residential project to use Lumira® aerogel within its window system.

Figure 20
LUMIRA® AEROGEL USED TO INSULATE WINDOW GLASS ON NYC APARTMENT BUILDING

Source: Cabot Corp.'s March 28, 2012, Press Release.

Lumira® offers thermal efficiency, high light transmission (91% per cm), reduced solar heat gain, and sound reduction, and is believed to be resistant to color change, mold, mildew, and performance degradation. This aerogel has been used for an array of materials on the building envelope, such as structural composite panels, structural polycarbonate systems, U-channel glass, insulated glass units, unit skylights and smoke vents, and tensile structures/fabric roofing. Other uses of Cabot aerogel include oil and gas pipelines, industrial and cryogenic plants and vessels, outdoor gear, apparel, and personal care.

Cabot also produces aerogel as a Thermal Wrap (resembling a blanket) in a form factor similar to Aspen Aerogels' aerogel blanket shown in Figure 19 (page 37), and as loose-fill particles that are optimized for building retrofits where space for insulation is at a premium. The Thermal Wrap has been used to insulate façades, roofs, and walls. Its thickness ranges from 3.5 mm to 8 mm, with operating temperatures between -200°C and roughly 125°C (for continuous heat, 160°C for peaks). Cabot's aerogel holds Cradle to Cradle® certification.

Cabot's aerogel production occurs in Frankfurt, Germany. The company believes that it may be the only firm to have developed a commercial process for continuously producing aerogel under ambient conditions, whereby it can control porosity and nanostructured pore size and distribution without incurring the costs associated with supercritical drying. Founded in 1882, Cabot has approximately 4,300 employees. The company reported FY 2012 (ended September 30, 2012) net sales and other operating revenues of approximately $3.3 billion.

Industrial Nanotech, Inc. (INTK-OTC)

Industrial Nanotech is the manufacturer of Nansulate® thermal insulation products (www.nansulate.com). Developed out of a desire to create sustainable nanotechnology solutions, the first Nansulate products were introduced to the market in 2004, and have since been refined and expanded. Today, Nansulate is used in an array of residential and industrial projects, with customers ranging from government to small business and large corporations.

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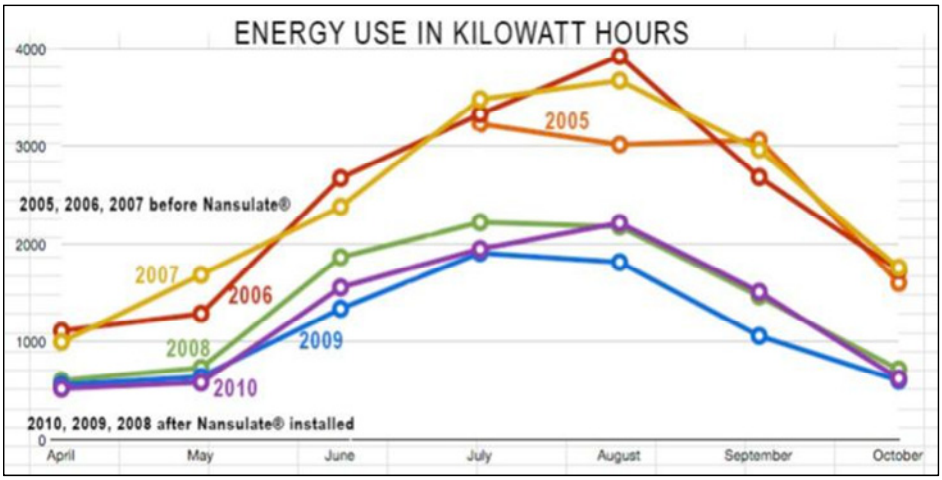
Nansulate entails a patented nanocomposite insulation made with 70% Hydro-NM-Oxide, a nanostructured material, and 30% acrylic resin and performance additive. It is applied as a clear liquid coating, that, when dried, insulates, protects against corrosion and rust, prevents mold, and builds resistance to adverse weather conditions including UV rays, moisture, and extreme temperatures. Industrial Nanotech states that Nansulate insulation has further been shown to lead to a reduction in energy consumption, lower carbon emissions, improved worker safety, decreased maintenance costs, and protection for plant assets. In testing performed by an accredited laboratory in Italy, applying a Nansulate thermal coating to a wall increased the wall's thermal resistance (a measure of the ability to prevent heat from passing through) by 28.98%, as presented in Industrial Nanotech's thermal insulation data. Figure 21 (page 40) illustrates the energy conservation benefits possible with Nansulate, according to the company's case study data of a residential application.

Figure 21

INDUSTRIAL NANOTECH: TULSA, OKLAHOMA, RESIDENTIAL CASE STUDY

25 gallons of Nansulate HomeProtect Clear Coat were applied via three coats with an airless sprayer to the underside of the home's roof deck (on roof of attic and ceilings of rooms where attic application was not applicable) on January 14-15, 2008.



Source: Industrial Nanotech's "Nansulate® HomeProtect Clear Coat - CASE STUDY - Updated with 2010 data."

Industrial Nanotech's Nansulate, a patented nanocomposite insulation applied as a clear liquid coating, has been shown to increase a wall's thermal resistance by nearly 30%.

The technology has led to the rise of many Nansulate products, such as for attic insulation, exterior and interior walls and ceilings, roof insulation for sloped tile and shingle roofs, insulation and corrosion prevention for industrial steam pipes, heat exchangers, valves, and boilers, as well as special uses such as a weather-resistant protective wood deck coating, an insulation coating for solar thermal systems, and a liquid heat shield coating for exhausts of motorcycles, ATVs, and motorbikes, among many other product variations.

In February 2012, the company announced the first sale of Nansulate coatings to a U.S. nuclear power facility. Among its beneficial characteristics, Nansulate technology facilitates the encapsulation of surfaces contaminated with lead—a key issue during the decommissioning of nuclear plants. Throughout 2012, Industrial Nanotech entered into several additional major sales agreements, which included installations with paper and textile manufacturers, roofing contractors, and energy companies, as well as an entrance into the Chinese market and expansion in India (along with the establishment of an Indian sales office). In October 2012, the company signed a distribution agreement with DuPont Powder Coatings Andina to serve as a distributor in Colombia and Venezuela for the Nansulate product line for the oil and gas industry.

Per its November 2012 corporate update, Industrial Nanotech expects continued expansion of markets for its Nansulate Crystal clear insulating and mold/algae/bacteria-resistant roof coating for building energy efficiency. The company also expects growth in the oil and gas market as a result of two successful energy projects in Portugal, heavy marketing to this sector, and ongoing field studies with large oil and gas companies in Asia. Milestones in 2013 could further include results of government-funded trials designed to evaluate Nansulate's effect at reducing energy costs in residential housing structures, and the launch of new non-coating-based products.

The company has headquarters in Florida with manufacturing sites in Colorado and New Jersey. Industrial Nanotech reported 2011 revenues of $772,532, according to financial data from S&P Capital IQ.

Lighting/LEDs

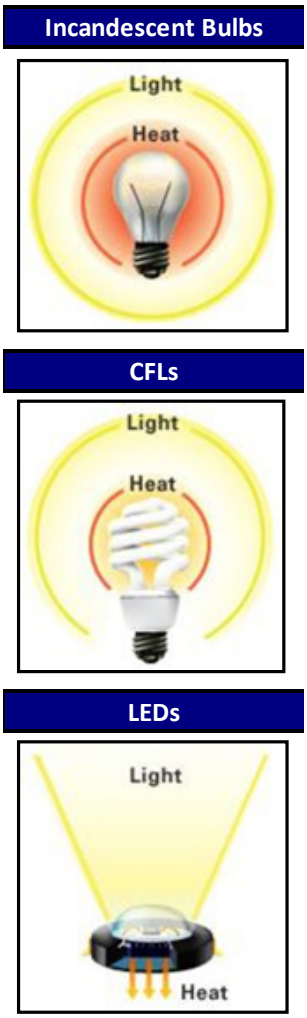
Market Snapshot

Using efficient lighting is a key component of energy efficiency, as lights are responsible for up to 17.5% of global electricity consumption. Within this market, the U.S. accounts for roughly 20% of all lighting electricity consumption. The greatest share of U.S. lighting electricity is due to commercial and public buildings, followed by residential, industrial, and outdoor/street lighting (Source: Pike Research's *Energy Efficient Lighting for Commercial Markets*, January 2011). Globally, the market for lighting products is estimated to range between $40 billion and $80 billion per year (Source: Bloomberg New Energy Finance).

For the first time since the fluorescent lamp was commercialized in the 1930s, the lighting industry is undergoing a radical transformation that could lead to greater strides over the next five years than in the past 50. The catalyst behind this conversion is the progression of light-emitting diode (LED) technologies, which have advanced considerably in the quality of light emitted and the variety of luminaires and fittings commercially available. As a result, LED technology is more efficient than compact fluorescent lamps (CFLs) and up to 95% more efficient than incandescent bulbs. Both CFLs and incandescents give off a greater portion of their energy as heat than as light. During 2012, the U.S. began phasing out standard incandescent bulbs in favor of CFLs or more efficient lights, such as LEDs, as part of the Energy Independence and Security Act of 2007, which seeks to eliminate incandescents in the U.S. by 2020 (Source: *Times Union*, November 20, 2012).

Today, LEDs can last for up to 80,000 hours versus the 1,000- to 2,000-hour lifetime of an incandescent bulb and the 6,000- to 10,000-hour lifetime of a CFL bulb (Sources: *Energy & Environmental Management*, August 25, 2011, and *Consumer Reports*, January 20, 2011). Performance improvements such as this have helped propel the LED market to revenues of $9.4 billion in 2011, up considerably from the $5.5 billion reported in 2010. Importantly, this growth—which has been fueled in large part by government mandates for phasing out incandescent lamps—has come despite downward revenue pressure due to price decreases. Moreover, new LED technologies can offer advantages and decreased costs in new and retrofit building projects as they have been outfitted specifically to meet the needs of lamp and luminaire manufacturers, facilitating adoption in the marketplace.

Figure 22
LIGHTING TECHNOLOGIES



Source: www.energystar.gov.

Outlook

- The global market for intelligent lighting controls is expected to see steady and robust growth over the rest of this decade, rising from $1.5 billion in 2012 to more than $4.3 billion in 2020, according to Pike Research. It is likely that office and educational buildings will be the most significant markets for intelligent lighting controls, with retrofits accounting for 73% of installations.

- Numerous countries including Japan, South Korea, and China have identified 2015 as a milestone in the development of lighting policies, such that 2013-2014 may experience a ramp-up of alternative, energy-efficient light sources that can replace traditional lighting by 2015 (Source: DIGITIMES Research's *Key Trends in the Development of LED Lighting Technology*, April 3, 2012). As a result, DIGITIMES Research forecast the LED lighting penetration rate at 25.8% in 2014.

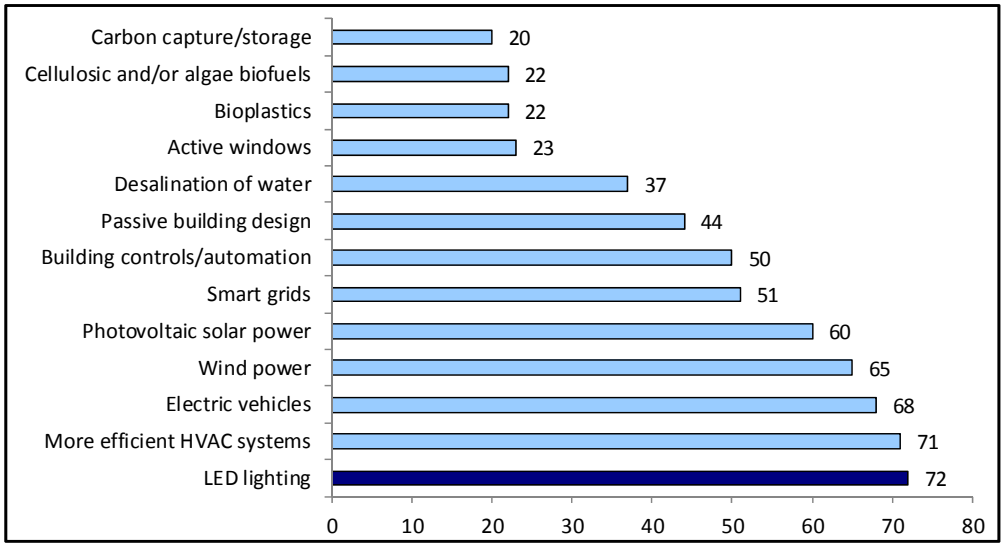
- High-tech lighting and control systems are likely to continue to be a key component to saving energy and boosting productivity in commercial and industrial applications, driven by incentives and legislation. The DOE expects that the U.S. could save more than $120 billion over the next 20 years if all public and domestic lighting sources were replaced with LEDs.

The U.S. could save $120 billion over the next 20 years if all public and domestic lighting sources were replaced with LEDs, according to the Department of Energy.

- Manufacturers will continue to pursue the goal of raising the luminous efficacy of LEDs. Cree, Inc. (CREE-NASDAQ), the largest U.S.-based LED manufacturer (as profiled on page 43), produced 2W LED products rated as high as 161 lm/W in 2011, which was higher than the maximum luminous efficacy of 133 lm/W for Nichia Corporation, the Japanese LED leader by market share, and the 146 lm/W achieved by Osram AG of Germany.

- LED technologies are viewed as the most promising technology in terms of commercial viability by 2020 (as illustrated in Figure 23), according to a recent market survey by McKinsey & Company.

Figure 23
LED LIGHTING IS EXPECTED TO BE THE MOST PROMISING TECHNOLOGY IN TERMS OF COMMERCIAL VIABILITY BY 2020 (% of respondents)*



* McKinsey surveyed over 4,000 management employees at a diverse set of companies across geographies, reportedly without any notable bias toward or against climate change or clean tech.

Source: McKinsey & Company's "Lighting the Way: Perspectives on the Global Lighting Market" (2012).

Key Developments During 2012

There were multiple financings directed at both end-product and component companies in the LED lighting market in 2012, including but not limited to the transactions listed below.

- Albeo Technologies, Inc., a manufacturer of LEDs for industrial and commercial buildings ($8 million)
- Bridgelux, Inc., an LED manufacturer profiled on page 43 ($25 million)
- Nuventix, Inc., developer of SynJet coolers that cool LED products ($10 million)
- CRS Electronics, Inc., a Canadian LED lighting manufacturer ($8.9 million)
- TerraLUX, Inc., a provider of integrated LED solutions for OEMs ($18.3 million)
- Pacific Light Technologies, a developer of high-efficiency LED lighting ($3 million)
- Lucibel SA, a France-based LED lighting company ($4.3 million)
- Nexxus Lighting, Inc., a maker of LED replacement lamps ($6 million)

Bridgelux, Inc.

Bridgelux is focused on providing high power, energy-efficient, cost-effective LED products. Founded in 2002, the company's customers employ its technology to replace traditional lamp and luminaire technologies (such as incandescent, halogen, and fluorescent lighting solutions) with solid-state lighting (SSL) products that provide high performance and energy-efficient white light for the fast-growing interior and exterior application areas—such as street lights, track, and downlights—and for use in commercial lighting and consumer applications. By reducing energy consumption in lighting, Bridgelux's products support clean energy projects and are considered to be ecofriendly solutions.

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The introduction of Bridgelux's LED arrays is expected to play an enabling role in breaking through existing cost barriers, which are currently slowing the adoption of SSL. The family of LED array products addresses the quantity of light, energy efficiency, color rendering, targeted lighting color temperatures, color consistency, beam uniformity, and cost. Such features enable lamp and luminaire manufacturers to easily integrate the light sources into their designs—resulting in high-performance, environmentally friendly, LED-based lighting products that may displace conventional products in commercial environments.

Bridgelux's LED arrays are built with a proprietary Metal Bond Technology (MBT) packaging technique that reduces thermal resistance by 30% to 50% that of current LEDs and reduces manufacturing costs. Lower thermal resistance indicates increased light output, and MBT eliminates redundant packaging and components to reduce design complexity and cost.

In 2011, Bridgelux launched its third-generation advanced LED arrays, which deliver up to 20% greater efficacy and reduce the cost per lumen by as much as 30% versus previous product generations. These arrays achieve **Energy Star** and other global energy efficiency standards and are configured to meet industry standards for new lamp and luminaire product development, potentially enabling accelerated time to market.

Bridgelux was ranked #128 on Deloitte's 2012 Technology Fast 500™ list of fastest-growing North American companies. As well, the company was nominated to the 2012 AlwaysOn GoingGreen Global 200, was included for the second consecutive year on the *Inc. 5000 list* (*Inc.* magazine's ranking of America's fastest-growing private companies), was named in the annual *San Francisco Business Times'* list of 100 Fastest Growing Private Companies in the Bay Area, and was included on the 2012 Global Cleantech 100, produced by the Cleantech Group. As a private company, Bridgelux's sales figures are not publicly available.

CREE, Inc. (CREE-NASDAQ)

CREE develops and manufactures semiconductor materials and devices primarily based on **silicon carbide (SiC)**, **gallium nitride (GaN)**, and related compounds. The company's expertise in SiC and GaN is concentrated on LED products. CREE operates in three segments: (1) LED products; (2) lighting products; and (3) power and radiofrequency products.

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The company's lighting products consist of both LED and traditional lighting systems, where CREE designs, manufactures, and sells lighting systems for indoor and outdoor applications, with a primary focus on LED lighting systems for the commercial and industrial markets. The company's LED products include LED chips, LED components, LED lighting, and SiC **wafers**. Its LED chip products include blue and green LED chips based on GaN and related materials. The blue and green LED chips can be employed in a variety of applications, including video

Seeking to increase consumer adoption of LED lighting, CREE is powering the Insignia LED bulb exclusively available at Best Buy.

screens, gaming displays, indicator lights, and automotive backlights. Some customers combine the blue LED chips with phosphors to create white LEDs, which are used in various applications for indoor and outdoor illumination and backlighting, full-color display screens, liquid crystal display (LCD) backlighting, white keypads, and the camera flash function.

The company's portfolio of lighting products is designed for use in office and retail spaces, restaurants and hospitality settings, schools and universities, manufacturing, healthcare settings, airports, municipal and residential uses, street lighting, and parking structures, among other applications.

In recent news, Best Buy Co., Inc. (BBY-NYSE) has debuted a new LED light bulb powered by CREE's LEDs. The new bulb is designed with improved features intended to make adoption of LED lighting easier for consumers. The Insignia LED bulb, which is exclusively available at Best Buy, offers advantages over existing LED bulbs on the market today, providing a more-ambient, omnidirectional light. As well, CREE announced the introduction of a range of new 50-V GaN high electron mobility transistor (HEMT) devices enabling a significant reduction in the energy necessary to power cellular networks.

The majority of CREE's products are manufactured at its production facilities in North Carolina, Wisconsin, and China. Employing roughly 5,550 individuals, the company reported annual revenues of $1.16 billion as of the 52-week period ended June 24, 2012.

Ephesus Technologies, LLC

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Closely held Ephesus Technologies designs, engineers, and manufactures next-generation LED lighting systems in Syracuse, New York. The company is composed of seven former Lockheed Martin Corp. (LMT-NYSE) employees with significant engineering experience. Ephesus is headquartered at the Syracuse Technology Garden with a manufacturing location at Ansen Corporation in Ogdensburg, New York, and plans to expand into a new facility in Baldwinsville, New York.

Ephesus' nanotechnology is integrated into products to create high-efficiency lighting systems of the future. The company has a wide range of products and is targeting the following markets: outdoor lighting (stadiums), street lighting, parking lot indoor lighting, high bay, medium bay, low bay, and fluorescent replacement. All of the company's LED lighting fixtures are waterproof and include a five-year company warranty.

Ephesus' products are stated to offer significant energy cost savings—both to the industrial markets as well as for residential users that employ the EG-4 LED chip, which consumes 95% less power than a conventional incandescent light bulb. Thus, the LED chip is intended to replace the 100-watt light bulb with only five watts of power, at a cost of under $8, and is designed to last for years longer than a traditional light bulb.

The company sources component parts from local suppliers although its lighting systems are intended for sale regionally and beyond. The company is also developing a nanotechnology education and technical skills curriculum at Onondaga Community College, an accredited college of the State University of New York system, located in Syracuse. The curriculum is intended to provide the skills base needed to continue to grow high-tech manufacturing positions in central New York state. As a private company, Ephesus' sales figures are not publicly available.

NTL-Lemnis Holding B.V.

In April 2012, closely held Lemnis Lighting, Inc. (the U.S. subsidiary of Dutch company, Lemnis Lighting B.V.) merged its LED activities with those of Indian lighting firm NTL Electronics into a new company, named NTL-Lemnis. The new company became fully operational in April 2012, with headquarters in the Netherlands. NTL-Lemnis is primarily serving the geographic markets of Europe, Africa, and India, where it is marketing complete LED lighting solutions.

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With low energy usage, the company's LED technology derived from Lemnis Lighting is estimated to be up to 90% more energy-efficient than conventional light sources. It is applicable to both indoor and outdoor lighting and is designed for a long service life and low maintenance costs—advantages of LEDs over fluorescent or incandescent bulbs. Lemnis Lighting achieved CO_2 reductions through both the energy-saving properties of LEDs as well as emphasizing efficient manufacturing.

Lemnis Lighting's chief product, the Pharox® LED brand, is among the best-selling household LED light globally. The company's newest addition to this line, the Pharox 400 (over 400 lumens in light output), became available as of September 2012. In February 2012, Lemnis Lighting unveiled a basic consumer LED bulb—200 lumens Pharox BLU bulb—at a price of $4.95. Further products from Lemnis Lighting include the Pharox Solar kit, a solar LED kit featuring a solar panel and a spherical LED lamp with a built-in USB port and charger. The USB functionality enables consumers to charge mobile devices wherever there is sunlight. Pharox Solar is also designed for off-grid uses in emerging economies. Lemnis Lighting anticipates that ecofriendly Pharox LED products, equipped with a five-year warranty, can last for up to 25 years and save on energy costs.

NTL-Lemnis' LEDs are 90% more energy efficient than incandescent lamps and 50% more energy efficient than fluorescent lamps.

In 2008, the World Bank selected Lemnis Lighting for the Lighting Africa award, which recognized innovative off-grid lighting products. In 2009, the company was named a Technology Pioneer by the World Economic Forum, and Google distributed 25,000 Pharox bulbs to staff members around the world as part of its Going Green at Google initiative. In 2010, Lemnis Lighting was ranked on *Fast Company's* list of Top 10 Consumer Products and the *Guardian's* (UK) Cleantech 100.

Outside of the U.S., the company's Pharox® LEDs are among the best-selling household LED lights.

India's NTL Electronics, which holds 50% of NTL-Lemnis, also has a history of providing LED solutions. The company states that, with annual product volumes near 180 million units, it may be one of the largest electronics-based lighting manufacturers in the world outside of China. NTL's competencies explicitly include LEDs, design validation, circuit design, product reliability, product life cycle management, and an ability to rapidly scale up manufacturing capacity.

As a private firm, NTL-Lemnis sales figures are not publicly available.

Veeco Instruments Inc. (VECO-NASDAQ)

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Veeco designs, manufactures, and markets equipment for LEDs and hard-disk drives, in addition to emerging applications such as concentrator photovoltaics, power semiconductors, wireless components, microelectromechanical systems (MEMS), and other next-generation devices. The company operates in two segments: (1) LED and solar; and (2) data storage.

In the LED and solar segment, Veeco designs and manufactures metal organic chemical vapor deposition (MOCVD) systems, molecular beam epitaxy (MBE) systems and components, wireless devices, power semiconductors, and concentrator photovoltaics for R&D applications. In the data storage segment, the company designs and manufactures the critical technologies used to create **thin-film** magnetic heads (TFMHs) that read and write data on hard disk drives. These technologies include ion beam etch (IBE), ion beam deposition (IBD), diamond-like carbon (DLC), physical vapor deposition (PVD), chemical vapor deposition (CVD), and slicing, dicing, and lapping systems. While these technologies are primarily sold to hard drive customers, they also have applications in optical coatings and other markets.

Veeco's manufacturing equipment specifically targets the LED manufacturing market, among others. The company maintains that its fully automated MOCVD systems (such as pictured in Figure 24) can produce high LED manufacturing yields and capital efficiencies—driving down the cost of LED manufacture, which may benefit companies looking to spread the technology into greater applications in the built environment.

Figure 24
MOCVD PRODUCTION PLATFORM: TURBODISC® MAXBRIGHT® M™ GAN SYSTEM

Source: LEDinside, June 7, 2012.

Founded in 1989, Veeco's approximately 900 employees support its customers through product and process development, training, manufacturing, and sales and service sites in the U.S., Korea, Taiwan, China, Singapore, Japan, Europe, and other locations. Veeco reported revenue in 2011 of $979 million.

Photovoltaics

Market Snapshot

The U.S. was forecast to be the largest contributor to global PV growth in 2012, accounting for 40% of new capacity.

Photovoltaic (PV) devices generate electricity from sunlight via an electronic process that occurs in certain types of materials called semiconductors. Electrons in semiconductors are released by solar energy and can be induced to travel through an electrical circuit, powering devices or sending electricity to the **power grid**. Most modern solar cells are made from either crystalline silicon or thin-film semiconductor material. Silicon cells are more efficient at converting sunlight to electricity but generally have higher manufacturing costs. Conversely, thin-film materials, which are flexible modules manufactured by applying very thin layers of semiconductor material to inexpensive substrates, such as glass, plastic, or metal, typically have lower efficiencies but are simpler and less costly to manufacture.

Following an unparalleled period of expansion, the number of installed PV systems in the U.S. reached 214,157 by the end of 2011—double the total at the end of 2009 (Source: the Congressional Research Service's *U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support*, June 2012). The U.S. was forecast to be the largest contributor to global PV growth in 2012, accounting for 40% of new capacity. Domestic demand is met by imports as well as roughly 100 U.S. manufacturing facilities employing an estimated 25,000 workers. U.S. manufacturing largely takes place within a few states, including California, Oregon, Texas, and Ohio.

In 2011, the global solar energy market was estimated at $39.6 billion. Within this market, applications for building-integrated photovoltaics (BIPV) have been expanding. BIPV entails using PV materials in place of conventional products on the building envelope, such as in a skylight or on a wall or roof.

Figure 25

BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV) INSTALLATIONS

Sources: Smarter Cities (a project of the Natural Resources Defense Council) and Better Energy AG.

Outlook

- The market for solar power is expected to have a solid outlook for the next five years, driven by government incentives that support revenue growth by providing tax credits for investing in solar. As well, renewable energy policies aimed at reducing CO_2 emissions may encourage solar deployment and an ongoing focus on green technology could spark greater interest in technologies that displace other types of energy sources; however, a reduction in EU solar subsidies could prove to be an obstacle to growth.

- As architects and building owners become more familiar with BIPV technologies and costs continue to decline, it is likely that solar projects in the built environment will continue to increase (Source: *Glass* magazine, October 3, 2011).

- Monetary incentives in certain areas of the world have supported concentration in the solar PV market. TechNavio (the market research platform of Infiniti Research Ltd) expects the global solar panel industry to post yearly growth in excess of 38% between 2010 and 2014, driven by technological innovation.

- The global PV market is forecast to top $75 billion in 2016, with North America the fastest-growing market at $14.8 billion by 2016 (bolstered by U.S. investments in both PV and concentrated solar thermal technologies) (Source: MarketsandMarkets' *Solar Power Market by PV, CSP Technologies by Installations, Price, Cost, Trade Trends & Global Forecasts [2011–2016]*, 2011).

Key Developments During 2012

- In November 2012, the U.S. Commerce Department imposed duty tariffs ranging from 24% to 36% on Chinese solar panels to combat alleged dumping and unfair competition.

- In September 2012, Hanergy Holdings Group, a Chinese renewable energy company, announced plans to buy MiaSolé, a producer of copper indium gallium (di) selenide (CIGS) PV modules, for $30 million. While MiaSolé has not disclosed how much venture capital the company raised since its inception in 2001, published reports estimate this figure in a range of $400 million to $500 million by the end of 2011, and in early 2012, the company raised $55 million. Terms of the acquisition agreement call for MiaSolé to become a subsidiary of Hanergy Holdings.

- In June 2012, Hanergy announced the acquisition of Solibro GmbH, a producer of CIGS PV modules, from parent company Q-Cells SE (under bankruptcy proceedings).

- As part of Wal-Mart Stores Inc.'s (WMT-NYSE) goal of becoming 100% powered by renewable energy, the retail giant unveiled its 100th store to rely on solar panels in mid-2012. The company seeks to expand renewable energy to 75% of stores in California (roughly 130 stores) by the end of 2013. California-based SolarCity Corp. is handling Wal-Mart's installation, management, and maintenance of solar panels. Wal-Mart estimates that its efforts across California could ultimately produce up to 70 million kilowatt (kW) hours of renewable energy annually, reducing the company's CO_2 emissions while supplying 10% to 30% of each facility's electricity requirements.

- In December 2011, Real Goods Solar, Inc. (RSO-NASDAQ) and Alteris Renewables, Inc. announced a merger, creating a company accounting for roughly 11% of all residential solar electric installations in the U.S.

Guardian Industries Corp.

Closely held Guardian Industries manufactures glass for the automotive and building industries, specifically, **float glass**, fabricated glass products, fiberglass insulation, and building materials for commercial, residential, and automotive markets.

The company's activity in solar involves providing mirrors for BrightSource Energy, Inc.'s 392-megawatt Ivanpah Solar Electric Generating System (ISEGS) in California's Mojave desert, where Guardian began shipping the first 160,000 of its Solar Boost mirrors to ISEGS in November 2011. The mirrors are able to withstand desert temperature swings and conditions while providing extreme reflectivity. They are a key component of the solar field, as they serve to focus the power of the sun on solar receivers atop power towers.

Figure 26 illustrates California's ISEGS, which is currently under construction. According to BrightSource Energy, this is the largest solar plant presently being developed worldwide. It is being constructed by Bechtel Corp., is funded by NRG Solar, Google, BrightSource, and others, and is expected to provide power to utility companies PG&E Corp. (PCG-NYSE) and Southern California Edison Co.

Figure 26

CONSTRUCTION OF THE ISEGS

Source: BrightSource Energy <http://www.brightsourceenergy.com/ivanpah-solar-project>.

As well, Guardian and Israel-based Pythagoras Solar (profiled on page 51) are collaborating to manufacture and sell a solar PV window, intended to replace standard vision and spandrel glass or skylights. Pythagoras is to provide production-ready units to Guardian, which is performing the final assembly.

Guardian is further providing float glass and patterned glass in a variety of options for a range of PV absorber materials: low-iron float glass to maximize solar transmission, molybdenum-coated glass to optimize the conductive characteristics of PV panels using copper indium sulfide (CIS) and CIGS solar cells, and coated glass designed to optimize the conductive characteristics of PV panels using cadmium telluride (CdTe) solar cells. Guardian is, as well, incorporating electrochromic glass for dynamic window shading as part of its portfolio, partnering with View Inc. (formerly Soladigm, as profiled on page 72), where Guardian incorporates View's Dynamic Glass product into its architectural glass offering—glass that can switch from clear to tinted on demand.

In 2011, Guardian ranked #62 on the *Forbes*' list of America's largest private companies, with $4.9 billion in revenues and 19,000 employees worldwide in more than 25 countries on five continents.

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Glass-maker Guardian Industries is providing "Solar Boost" mirrors for the largest solar plant under construction in the world.

In 2011, Guardian was the 62nd largest private company in the U.S.

HelioVolt Corporation

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Closely held HelioVolt manufactures thin-film solar CIGS PV modules. The company combines high-efficiency products with low-cost manufacturing capabilities intended to create a new generation of practical, efficient, and economical CIGS-based solar panels. HelioVolt's first line of products entails glass substrate solar panels developed for commercial rooftops, ground mount utility scales, and residential applications.

The company is also developing BIPV offerings that place the flexible solar cells onto a plastic substrate or directly onto conventional construction materials, which can be integrated into buildings. The glass laminate modules are compatible with existing industry installation tools and practices and do not require complex custom mounting solutions. The frameless modules further offer durability and positive weathering characteristics.

Working in collaboration with researchers at the National Renewable Energy Laboratory in Golden, Colorado, HelioVolt has developed an advanced manufacturing process for CIGS modules, called Field Assisted Simultaneous Synthesis and Transfer (FASST®). The combination of its product architecture and production process enables the company to generate materials that are more efficient, flexible, economical, and can provide better long-term product reliability than competing processes.

The FASST® two-step manufacturing process has resulted in modules with conversion efficiencies as high as 12.3%, with average efficiencies exceeding 11.7%. Furthermore, HelioVolt has developed a specific technological roadmap to achieve efficiencies of 16% by 2014. HelioVolt maintains that its FASST® automated and fully integrated manufacturing process can synthesize CIGS in only five minutes versus lead times as high as 15 minutes in other available processes. HelioVolt expects FASST® reaction time to decrease further as it continues to optimize the technology.

In August 2012, Austin Energy and HelioVolt announced a collaboration on the first commercial installation of locally manufactured solar modules in Austin, Texas, on the roof of the non-profit Yellow Bike Project—a volunteer-based advocacy group for bicycling. The project is the first by Austin Energy to pilot and research leasing rooftop space at non-profit and commercial locations and is a step forward in the development of a clean energy industry in Austin, with the first solar modules installed in the city produced by a local solar manufacturing company.

In September 2011, HelioVolt and Korea's energy, chemicals, and telecommunications company, SK Group, announced that the companies reached an agreement to collaborate on technology development and global manufacturing expansion. The SK Group invested $50 million to expand HelioVolt's manufacturing operations and began collaborating to develop HelioVolt's global capabilities, including the development of a manufacturing plant in Korea.

HelioVolt holds 11 patents, nine patent applications, and five patent applications in progress with over 100 international extensions. The company's Austin-Texas-based 125,000 sq. ft. research and manufacturing center is a LEED-certified facility. As a private company, HelioVolt's sales figures are not publicly available.

Pythagoras Solar

Closely held Pythagoras Solar has developed a method for the replacement of traditional windows in order to help fast-track net zero energy deployment with more attractive economics and aesthetics than current options are thought to provide. The company's solar windows leverage its patented technology in order to combine energy efficiency and PV power generation in a manner that optimizes daylighting systems.

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Pythagoras' solar window—the "optimized daylighting" photovoltaic glass unit (PVGU)—employs optical technology, high-efficiency crystalline silicon, and advanced materials to provide what Pythagoras' maintains is the highest transparency and highest density PV power generation in a standard double-pane window form factor, called an insulated glass unit. This technology, which leverages the modularity and ease of installation of the insulated glass unit, is designed to meet advanced building codes and standards and can be employed for a variety of uses. Additionally, it is eligible for incentives due to its energy and environmental benefits.

The company's initial products have been designed for curtain wall and skylight applications and can be modified for varying elevations, locations, and climates. The energy savings as well as energy generation afforded by the PVGU permits the product to pay for itself in less than five years. Pythagoras is now shipping on commercial installations and beginning to deliver on a full pipeline of projects across the U.S.

Pythagoras has delivered to market the first fully integrated PVGU to target the $1 billion BIPV glass market—a market the company expects to have a 20% CAGR—driven largely by government subsidies focused on energy security and climate change.

The company's business model is based on a partnering strategy in order to achieve more rapid market penetration and growth. Similar to standard insulated glass units, the PVGU is supplied to markets through glazing companies, making the integration process seamless as it fits into existing building design and construction practices. This business model has garnered the attention of global glass manufacturers in the U.S., France, Germany, and Japan that are seeking to embed the PVGU technology into their windows and bring to market a "Powered by Pythagoras" product. As well, key partnerships with Arkema SA (AKE-EPA), China Sunergy Co. Ltd. (CSUN-NASDAQ), Flextronics International Ltd. (FLEX-NASDAQ), and others enable Pythagoras to provide capital efficiency, reliability, and quality vis-à-vis common manufacturing techniques and standard materials as well as scale to accommodate global demand. The company has operations in the U.S., Israel, and China. As a private company, Pythagoras' sales figures are not publicly available.

Smart Grid Technologies

Market Snapshot

The smart grid combines traditional power hardware with new ways to produce and manage electricity.

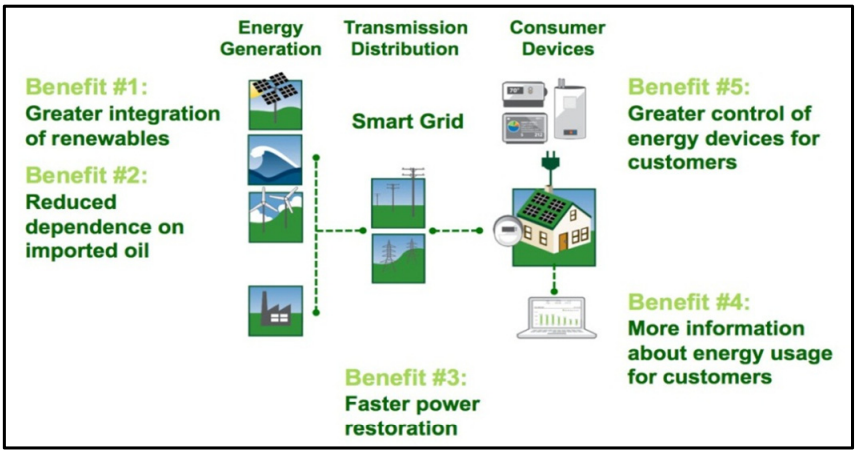
Over time, the architecture supporting today's power grid has aged and become obsolete, though power consumption is ever increasing. Simultaneously, environmental concerns surrounding the use of fossil fuels have led to increased demand for renewable energy sources, such as wind and solar power, which have highly variable production levels. Taking into account the increasing diversity and variability of power generation, the current grid is not adequate to support modern energy challenges. The American Society of Civil Engineers (ASCE) estimates that service interruptions in the grid—if left in its current state—could cost the U.S. $71 billion by 2020 (Source: *Forbes*, July 8, 2012).

By 2017, the market for smart grid-related products and services could top $26 billion.

To address these challenges, the industry is focused on creating a next-generation power grid called the "smart grid." The smart grid combines traditional power hardware with new ways to produce and manage electricity, such as smart meters, which record each consumer's electricity usage and communicate this information to the power company. These features help utilities and grid operators enhance grid performance and integrate renewable energy assets into existing infrastructure, while improving customer service and support (as overviewed in Figure 27). A number of segments exist within the smart grid market, including smart meters, grid networking, distribution automation, demand response, and security, among others.

Figure 27

A SELECTION OF KEY BENEFITS MADE POSSIBLE WITH SMART GRIDS



Source: the Maui Smart Grid Project.

Outlook

- Rising costs of electricity generation and government incentives for green energy are supporting growth of the U.S. smart grid market, which is forecast to expand at double-digit rates to reach roughly $26.7 billion by 2017 (Source: Lucintel's *Growth Opportunities in US Smart Grid Market 2012-2017*, June 2012).
- With an expanding demand for renewable energies, integration of these resources into the smart grid is likely to contribute to market growth in upcoming years.
- Industry leaders in the global smart utility network are collaborating to create global smart grid standards that ensure connectivity and interoperability of devices as well as facilitate widespread adoption of smart meter technology.

- Utility companies, government organizations, and nonprofit entities are seeking means to provide consumers real-time access to their electricity consumption information and potentially motivate consumers to take action to reduce energy use.

- As the smart grid market builds momentum, specialty companies have considerable growth potential, which may include as IPOs, acquisition targets, or strategic partners.

Key Developments During 2012

- Industry leaders in the global smart utility network united to establish the Wi-SUN (Wireless Smart Utility Network) Alliance in April 2012 with the objective of promoting increased smart grid technology interoperability and encouraging innovation by creating common standards for the global smart grid build-out.

- As part of the American Reinvestment and Recovery Act, the DOE continued its Smart Grid Investment Grant (SGIG) program, which allocates $3.4 billion in federal funds to smart grid technologies and is matched by industry funding for a total public-private investment worth over $8 billion. As of March 2012, two-thirds of the $3.4 billion had been invested across 99 projects.

- In September 2012, the Blackstone Group LP (BX-NYSE) entered into an agreement to acquire home energy management and security company Vivint Inc. for over $2 billion.

- In August 2012, Melrose PLC, a British buyout firm focused on engineering companies, completed the acquisition of German meter manufacturer Elster Group SE (ELS-NYSE) for $2.3 billion.

- In June 2012, Swiss grid company ABB Ltd. completed the $35 million acquisition of wireless mesh networking company Tropos Networks Inc. ABB has allocated up to $18 billion for acquisitions over the next five years.

- In March 2012, SCIEnergy Inc., a smart grid company, acquired Transcend Equity, an energy services financing model company, for an undisclosed amount.

- In March 2012, smart grid networking startup and IPO candidate Silver Spring Networks, Inc. (profiled on page 55) raised $30 million from Hitachi, Ltd. (HIT-NYSE).

- In February 2012, Itron, Inc. completed the acquisition of smart grid cellular networking company SmartSynch for $100 million.

- In January 2012, Siemens (profiled on page 23) entered into an agreement to acquire networking equipment manufacturer RuggedCom Inc. in a Board-supported takeover bid valued at roughly C$382 million.

- In December 2011, Siemens Energy acquired smart meter software company eMeter Corp. in a transaction valued at between $180 million to $240 million.

- The DOE continued implementing its Better Buildings Initiative program, which aims to make commercial and industrial buildings 20% more energy efficient by 2020 through private sector investments. The program, backed by tax credits and other incentives, initially announced $4 billion in financial commitments.

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Energy software company Opower was named the 2012 Global Cleantech 100 Company of the Year for North America, as awarded by the Cleantech Group, a global research and advisory firm for energy and environmental innovation.

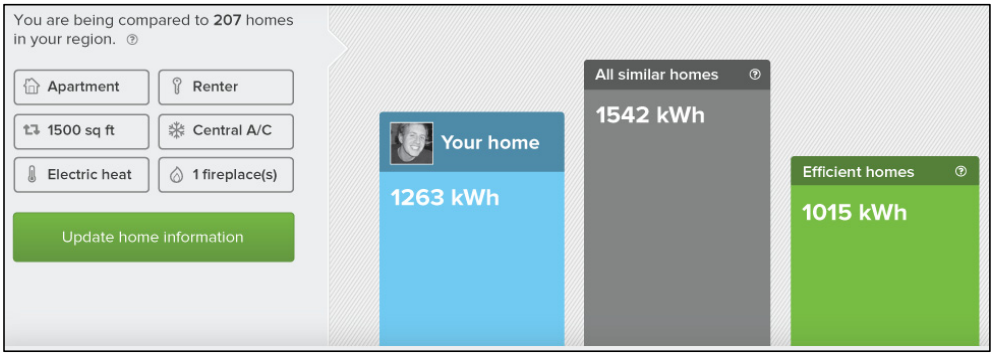
Opower is a closely held energy information software company that has been named the 2012 Global Cleantech 100 Company of the Year. The company's software uses behavioral science and patent-pending analytics to drive energy efficiency gains on a large scale while providing targeted energy data and recommendations to utilities' customers. Opower's core business is its customer-engagement tools, such as home energy reports, online energy management tools, and energy alerts. As of January 2012, the company had calculated and delivered 25 million Home Energy Reports and expected to double this to 50 million in 2012.

The company's customer-facing energy engagement platform—MyEnergyReport—helps utility customers take steps to control their energy usage and be more energy efficient. The web portal contains personalized, actionable data for pinpointing the sources of high energy usage, bill analyzers, a dynamic rate engine, and online energy audits, among other features. In October 2012, Opower's customer engagement program was launched to 50,000 Pepco Holdings, Inc. customers under the EmPower Maryland Initiative. As well, Opower partnered with EnergyAustralia (formerly TRUenergy) to employ MyEnergyReport at an additional 1.6 million homes in Australia. In the UK, Opower and First Utility launched a similar program called "my:energy" to roughly 100,000 First Utility customers in the UK.

Opower's social energy application, developed jointly with Facebook and the Natural Resources Defense Council (NRDC), capitalizes on social networking to raise consumer awareness about energy consumption, as illustrated in Figure 28.

Figure 28

OPOWER'S SOCIAL ENERGY APP: HOME COMPARISON TOOL



Source: Opower, Inc.

Opower has also partnered with Honeywell (profiled on page 20) to develop smart thermostats. As of May 2012, roughly 1,000 homes were testing Honeywell's Wi-Fi smart thermostats and cloud platform running Opower's customer management and data analysis software (Source: Greentech Media, Inc.'s May 16, 2012, press release).

Altogether, Opower's information-based approach has shown to consistently result in an average energy savings of 1.5% to 3.5% (Source: Opower). As of October 2012, Opower reported that it had saved residential energy customers 1.5 terawatt hours (TWh) of energy nationwide—the equivalent of removing a city the size of New Orleans off the grid for one year—resulting in over $168 million in savings on energy bills across 15 million homes.

Opower's backers include Accel Partners, Founder Collective, Kleiner Perkins Caufield & Byers, MHS Capital, New Cycle Capital, New Enterprise Associates, and entrepreneurs, Ali and Hadi Partovi. As of October 2012, the company had over 75 utility partners and 200 employees. Opower had revenues in fiscal 2011 of $11.4 million (Source: *Forbes*).

Silver Spring Networks, Inc.

Silver Spring Networks is a closely held, global smart grid solutions company that provides wireless components and other networking equipment and services for smart power grids. The company's "Smart Energy Platform" is composed of hardware, software, and services to connect every device on the power grid. This platform is designed to improve energy efficiency, give customers more control over their utilities, deliver low-cost, reliable services, and allow utilities to deploy advanced applications, such as smart metering, as well as to reduce carbon emissions. Silver Spring's Smart Energy Platform is an open, **IP version 6 (IPv6)**-based utility networking infrastructure. As of October 2012, Silver Spring's platform has connected more than 13 million homes and businesses worldwide.

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Silver Spring's software includes a customer interface, called the CustomerIQ™ web portal, for viewing consumption and pricing and managing energy efficiency programs. Additional components of the Smart Energy Platform entail Gridscape, an advanced network management suite, and the UtilityIQ application suite, which enables advanced meter management, outage detection, demand response, energy efficiency, and electric vehicle management. Silver Spring also offers SilverLink™ cloud services, which provide insights that help utilities improve operational efficiency and increase smart grid performance without requiring new software. In September 2012, Silver Spring launched Direct-to-Grid™, a load control solution allowing utilities to monitor and manage energy-intensive assets while offering fast demand response resources to reduce peak load and maintain grid reliability.

Silver Spring's Smart Energy Platform is deployed at over 13 million locations.

The company is focused on increasing and enhancing available offerings for its Smart Energy Platform. In early 2012, Silver Spring released the fourth generation of its networking technology, Gen4, which delivers faster performance as well as more transport flexibility and options for utilities. In September 2012, Silver Spring launched its UtilityIQ® Voltage Optimizer, a turnkey solution developed in partnership with Dominion Voltage Inc. Also in September 2012, the company introduced a "Speed-to-Value" program that enables utilities to quickly scope, deploy, test, and measure specific solutions to extract more return on investment (ROI) from smart grid investments.

The company capitalizes on strategic technology partnerships—for which it has more than 60—to broaden its product offerings for utility customers.

As of October 2012, the company had more than 60 technology partners globally, which allows it to offer utility customers more choices. Silver Spring has a strategic alliance with Hitachi to develop improved solutions for the smart grid, having worked together on the Japan-U.S. collaborative smart grid demonstration project in Maui since early 2011. In early 2012, Silver Spring expanded its partnership with Commonwealth Edison (ComEd), a unit of Exelon Corp., and finalized agreements to deploy a Smart Energy Platform networking nearly four million homes and businesses under Illinois' Energy Infrastructure Modernization Act (EIMA). Silver Spring has also been selected to serve smart grid networks in Florida and the Carolinas as part of Progress Energy's Next Generation Demand Response (NGDR) projects, which are partially funded by DOE grid modernization grants.

The company has received various awards and recognition, including Crossfire Media and TMC's 2011 Product of the Year Award, the TechAmerica Foundation's 2012 American Technology Award, and the McCulloch-Pitts award from the SunSpec Alliance. Bloomberg New Energy Finance also named Silver Spring a 2012 New Energy Pioneer.

Silver Spring is headquartered in California with offices in Australia and Brazil, and has roughly 570 employees worldwide. Silver Spring filed a registration for an IPO in July 2011, which has not yet occurred. To this effect, the company's most recently amended Form S-1 registration statement was filed with the SEC on September 14, 2012. Silver Spring reported 2011 revenue of $237 million.

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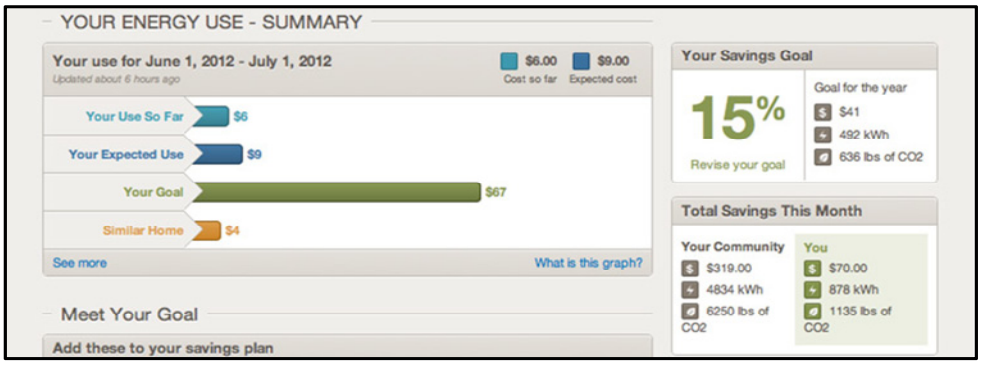
Tendril is a closely held smart grid company helping energy providers balance demand, mitigate peaks in real time, and minimize operational costs. With Tendril's smart grid platform, utilities can deploy advanced programs and customers can manage their own energy use and costs. In 2012, the company focused on expanding its services to new households and was benefitted by record summer heat, rising electricity bills, and the risk of brownouts. Over a five-month period, Tendril added more than 3.5 million households onto its software platform.

The company's cloud-based platform, Tendril Connect™, serves as an open, secure, scalable network to link energy providers with customers. Tendril Connect™ includes utility applications for demand response, load control, electric vehicles, and distributed generation. It also offers an interface for the customer's home area network (as shown in Figure 29), which allows consumers to track energy costs and consumption by appliances, electronics, and household devices, including the Tendril Insight in-home display, Tendril Set Point smart thermostat, Tendril Translate gateway, and Tendril smart outlet plugs.

Figure 29

TENDRIL CUSTOMER INTERFACE



Source: Tendril Networks Inc.

As of August 2012, Tendril Connect™ was processing nearly five terabytes of data each month, including real-time meter, pricing, billing, demographic, building science, weather, and behavioral data (Source: Tendril's August 8, 2012, press release). A range of companies, including Elster Group, Itron, Inc., Landis + Gyr AG, Sensus, Silver Spring Networks (profiled on page 55), and Trilliant Holdings, Inc., have built upon Tendril Connect™ for energy services. In early 2012, Tendril partnered with the BMW Group Technology Office USA to build a demonstration smart energy home powered by Tendril Connect™ to prepare for the roll-out and integration of BMW's ActiveE electric vehicle.

In February 2012, Tendril acquired California-based Recurve, Inc. to incorporate Recurve's residential energy auditing software and analytics into Tendril Connect™, which the company believes could accelerate adoption of its cloud platform by expanding support for a growing number of third-party developers. The acquisition included intellectual property and served as a foundation for establishing Tendril's West Coast operations.

In May 2012, Tendril raised $25 million to support further development of its home energy report software (Source: Greentech Media's May 7, 2012, press release). Tendril is backed by VantagePoint Capital Partners, Siemens Venture Capital GmbH, Good Energies, RRE Ventures LLC, and GE. The company employs roughly 115 individuals across headquarters in Colorado and regional offices in San Francisco, Boston, and Melbourne (Australia). As a private company, Tendril's sales figures are not publicly available.

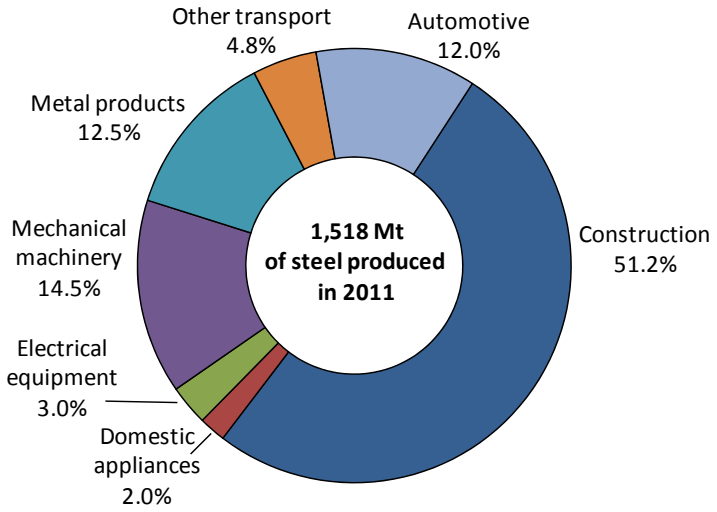
Steel

Market Snapshot

Steel, one of the world's most common materials, is relied upon for housing, transport, energy production, tools, healthcare, and food and water supply. In fact, practically everything society uses is either made of steel or manufactured by equipment that is made of steel. In the construction industry, steel—as a strong, versatile material—possesses a broad range of applications, including facilitating renewable energies, resource- and energy-efficient buildings, low-carbon transport, infrastructure for fuel efficiency and clean energy vehicles, and recycling facilities. Figure 30 summarizes major uses of steel, noting that construction is responsible for the majority of steel consumption.

With global costs of corrosion exceeding $2.2 trillion each year according to the World Corrosion Organization, stronger steel products that are less susceptible to corrosion, wear, and other forms of stress are needed.

Figure 30
STEEL USE BY SECTOR, 2011



Source: Sustainable Steel, At the Core of a Green Economy, The World Steel Association.

Despite its many advantages, steel is subject to fatigue and corrosion. Fatigue can lead to the structural failure of steel due to cyclic (repetitive) loading, such as on bridges or towers, even when the steel is subjected to forces below its yield point. To protect against fatigue, the industry has traditionally attempted to reduce the allowable stress, shorten service life, or stipulate more aggressive inspection schedules, among other initiatives.

Steel corrosion can cause structural weakness and is a major problem facing transportation infrastructure. More than 11% of highway bridges in the U.S. are classified as "structurally deficient" by the U.S. Federal Highway Administration (FHWA) (Source: Transportation for America's *The Fix We're In For: The State of Our Bridges*, 2011). Corrosion damage to bridges and highways requires government to spend billions of dollars annually to maintain infrastructure.

Nanostructured Steel

Nanotechnology has an important role in the production of high-performance steel. Improved corrosion and mechanical properties—in particular, an improved hardness-toughness relationship—may be achievable by controlling the morphology and chemical composition of steel at the micro- and nanometer scales (Source: Recent Patents on Engineering's "On the Use of Nanotechnology to Manage Steel Corrosion," 2010).

Nanosteel production seeks to differentiate the mechanisms governing strength from those governing toughness, optimizing both to overcome the existing inverse relationship found in conventional materials. Reducing steel's microstructure particle size improves homogeneity and reduces defects, resulting in improved wear resistance and fracture toughness. As an alternative to changing the nanostructure and chemical composition of steel, a thin coating of nanocomposite materials could also be applied to the steel as a technique for improving corrosion resistance.

Outlook

- The World Steel Association forecasts growth of global steel consumption in 2012 of 2.1%, a decrease from its previous estimate of 3.6%.

Nanosteel materials and steel with enhanced nanocoatings can be made stronger than conventional or high-strength steel, while maintaining toughness, ductility, and corrosion resistance.

- Technological advancements and new product development at competitive prices are expected to be key factors for future market expansion (Source: Lucintel's *Global Iron and Steel Industry 2012-2017: Trend, Profit and Forecast Analysis*, November 2012). As well, market growth will likely be tied to the recovery of the global economy. As such, growth projections are varied and cautious. Ernst & Young has forecast steel production expansion at a CAGR of 2.6% by 2015, while others have estimated annual revenue growth of 5.1% by 2017.

- Demand for steel is likely to vary by region and country, with stronger economic growth in China, India, Brazil, Russia, and South Korea contributing to greater steel use in these markets (Source: Ernst & Young's *Global Steel—2011 Trends, 2012 Outlook*).

Key Developments During 2012

- Over the past several years, the market for steel products contracted due to the U.S. financial crisis, Europe's debt crisis, and slowdowns in construction and large-scale infrastructure projects. However, in a possible sign of recovery, U.S. steel production was estimated at 68.1 million tonnes in the first nine months of 2012, an increase of 5.3% and 11.9% over 2011 and 2010, respectively (Source: World Steel Association).

- In 2012, the U.S. replaced Japan as the second largest steel producer, behind top producer China (Source: Zacks Equity Research's *Steel Industry Stock Outlook - Nov. 2012*, November 15, 2012).

- In September 2012, both U.S. housing starts and building permits were at their highest levels in four years, which could indicate expansion of steel markets as residential construction picks back up (Source: Zacks Equity Research, November 15, 2012). As well, while many major steel companies idled or shutdown some capacity during 2012, rebuilding activities following Super Storm Sandy may benefit the sector.

- Nisshin Steel Co. Ltd and Nippon Metal Industry Co. Ltd merged into a new entity, Nisshin Steel Holdings Co. Ltd (5413-JP).

- In mid-March 2012, nanotechnology materials science company MesoCoat Inc. (a subsidiary of Abakan Inc.** [ABKI-OTC], profiled on page 59) completed the cladding of the inside diameter of steel pipe with corrosion and wear-resistant alloys. This represented a major milestone in the move toward commercialization of a high-speed, large-area metallurgical cladding technology called CermaClad™, which Abakan believes could improve the performance and environmental impact of steel.

** See disclosures on page 77.

*Abakan Inc. (ABKI-OTC)***

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Abakan is an acquisition company that invests in and provides managerial and intellectual support to innovative companies, with a particular focus on corporations that have developed transformational surface modification solutions and technologies. The company targets the metal protection and material life extension market—which improve metal's resistance to corrosion and wear—by investing in early stage, next-generation companies.

Abakan has significant ownership interests in two late-stage surface technology companies: MesoCoat, Inc. and Powdermet, Inc. Through these subsidiaries, Abakan recently commenced sales of a line of nanostructured metallic powders known as PComP™, which have been shown to prevent corrosion and wear up to five times longer than available conventional coatings. In addition, the company is poised to commercialize a new technology to produce clad metal, called CermaClad™, which entails a faster and more efficient process for cladding steel as well as uses new materials designed to better protect steel infrastructure in corrosive or extreme environments.

The company is currently focused on moving into large-scale commercial production, with efforts directed at securing customer agreements and increasing production capacity. Abakan believes that the value proposition likely to drive adoption of CermaClad™ centers on being able to offer manufacturers a more compelling cost-benefit trade-off than presently exists. Abakan's technologies have shown to be 15 to 100 times faster to apply than current metal-protection techniques and offer six times greater corrosion resistance in nano-enhanced products, which are safer and more ecofriendly than alternative hard chrome coatings.

Qualification of Abakan's products is driven by agreements with Latin American oil/gas company Petroleo Brasileiro S.A. (PBR-NYSE) as well as a global heavy equipment manufacturer, and dozens of strategic collaborations, including with the Northern Alberta Institute of Technology (NAIT), which is facilitating Abakan's recent entry into Canada's lucrative oil sands market.

In 2011, the company's majority-owned subsidiary, MesoCoat, ranked #50 on *Forbes'* list of "America's 100 Most Promising Companies"—making it the highest-ranked materials and only nanocomposite company. MesoCoat has received honors and development funding from NASA; U.S. Departments of Defense, Energy, and Transportation; Fortune 100 sponsors; and other entities.

Abakan has been built largely on non-dilutive financing from grants, joint development agreements (JDAs), and similar sources. The company aims to raise $6 million in the near term followed by another $20 million equity financing in a year, which could be leveraged by debt financing for global expansion. Including subsidiaries and consultants, the company employs approximately 61 individuals. Based on the operations of its subsidiaries, Abakan reported revenue of over $2.9 million for the year ended May 31, 2012.

*** See disclosures on page 77.*

AMETEK, Inc. (AME-NYSE)

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Founded in 1930, AMETEK has evolved from a provider of heavy machinery to a manufacturer of analytical instruments, precision components, and specialty materials with operations in North America, Europe, Asia, and South America. The company comprises two major groups—the Electronic Instruments Group (EIG) and the Electromechanical Group (EMG)—which together, along with their respective divisions, hold a portfolio of over 100 brands, including analytical instruments; monitoring, testing, and calibration devices; and electrical motors, pumps, and interconnects.

EIG builds monitoring, testing, calibration, and display devices for the process, aerospace, industrial, power, and medical markets. EMG produces engineered electromechanical connectors for hermetic (moisture-proof) applications, specialty metals for niche markets and brushless air-moving motors, blowers, and heat exchangers. End markets include aerospace, defense, mass transit, medical, office products, and other industrial markets.

EIG's focus is on the process industries: oil, gas, and petrochemical refining, power generation, specialty gas production, water and waste treatment, natural gas distribution, and semiconductor manufacturing. AMETEK's analytical instruments are also used for precision measurement in a number of other applications, such as radiation detection for the U.S. Department of Homeland Security, materials analysis, nanotechnology research, and other test and measurement applications.

AMETEK has approximately 13,300 employees working at more than 100 manufacturing facilities and more than 100 sales and service centers in the U.S. and worldwide. In June 2012, AMETEK awarded $25,000 to the University of Tennessee's Material Science and Engineering Department to establish a fellowship and support nanotechnology research at the university. The company reported revenues of $3 billion in 2011.

Dynamic Materials Corporation (BOOM-NASDAQ)

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Founded in 1965, Dynamic Materials operates three business segments: (1) Explosive Metalworking, which uses proprietary explosive processes to fuse different metals and alloys; (2) Oilfield Products, which manufactures and markets specialized explosive components and systems used to perforate oil and gas wells; and (3) AMK Welding, which utilizes various technologies to weld components for use in power-generation turbines as well as commercial and military jet engines.

As an industrial manufacturer, the company is focused on niche markets related to building equipment and materials that support infrastructure in the process and energy industries. Explosion-weld cladding uses an explosive charge to bond together plates of different metals. Clad metal plates are used in the construction of heavy, corrosion-resistant pressure vessels and heat exchangers for oil and gas, alternative energy, chemical and petrochemical, hydrometallurgy, aluminum production, shipbuilding, power generation, industrial refrigeration, and similar industries.

Through its Oilfield Products segment, which it also refers to as DYNAenergetics, Dynamic Materials provides a range of products for the global oil and gas industries. DYNAenergetics designs and manufactures custom-ordered perforating products for third-party customers according to their designs and specifications. The products are sold to large, mid-sized, and small oilfield service companies in the U.S., Europe, Canada, Africa, the Middle East, and Asia, including direct sales to end users.

The company offers specialized welding services through its AMK Welding division. Its lead customers include a power turbine manufacturer and commercial and military aircraft engine manufacturers. Welding services are provided on a project-by-project basis according to specifications set forth in customers' purchase orders. Welding processes utilized by AMK Welding include electron beam and gas tungsten arc welding technologies. AMK Welding is located in South Windsor, Connecticut.

The company has headquarters in Boulder, Colorado, and employs approximately 450 individuals. Revenues in 2011 were $209 million.

PPG Industries Inc. (PPG-NYSE)

Founded in 1883 as the Pittsburgh Plate Glass Company, the company changed its name in December 1968 to PPG Industries Inc. and, in January 2008, acquired the SigmaKalon Group of companies from Bain Capital, enhancing its paint and specialty coatings business.

PPG Industries

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PPG is a global supplier of protective and decorative coatings—specifically paints, coatings, optical products, specialty materials, chemicals, glass, and fiberglass—and is operating in six business segments: Performance Coatings, Industrial Coatings, Architectural Coatings-EMEA (Europe, Middle East, and Africa), Optical and Specialty Materials, Commodity Chemicals, and Glass. The Performance Coatings, Industrial Coatings, and Architectural Coatings-EMEA segments supply protective and decorative finishes for customers in a range of end use markets—industrial equipment, appliances, and packaging; factory-finished aluminum extrusions and steel and aluminum coils; marine and aircraft equipment; automotive original equipment; and other industrial and consumer products. The Optical and Specialty Materials segment consists of the optical products and silicas businesses. As well, the company is a producer and supplier of basic chemicals. The Glass business segment consists of the flat glass and fiberglass businesses. PPG is also the world's third-largest producer of chlorine and caustic soda (used in a wide variety of industrial applications), vinyl chloride (for use in polyvinyl chloride resins), and chlorinated solvents.

The company's products include well-known lines such as the PPG Pittsburgh Paints and Olympic Paints brands in North America, and the Sigma Coatings, Seigneurie, Dekoral, Primalex, Univer, Johnstone's, and Master's Mark paint brands in other regions. Coatings by PPG protect airplanes, golf balls, circuit boards, packaging, appliances, flooring, automobiles, bridges, and buildings. PPG's chemicals help to purify water, and its optical and specialty materials go into high-performance lenses as well as applications ranging from electronic passports to green car tires. As well, many windows in houses and office towers, and windshields in aircraft, use PPG glass.

With headquarters in Pittsburgh, Pennsylvania, PPG operates in more than 60 countries around the world and employs roughly 38,000 individuals. Sales in 2011 were $14.9 billion.

Water Treatment

Market Snapshot

Nanotechnologies are being deployed by power and desalination plant operators that seek to upgrade traditional water systems to improve efficiencies and lower costs.

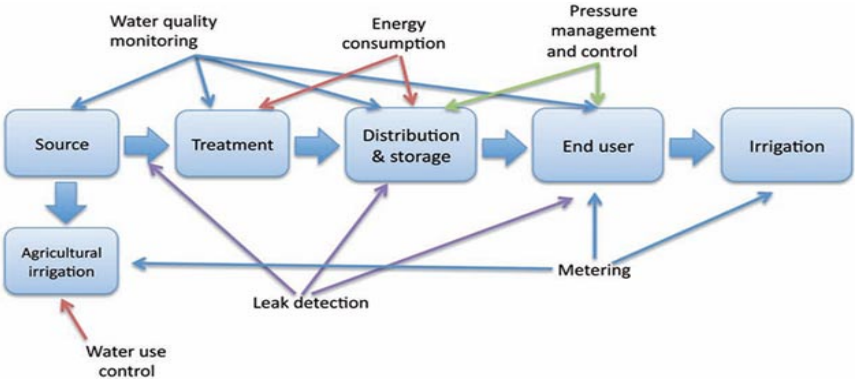
The water infrastructure in the U.S. is aging. Weakening water pipes, many of which were installed shortly after World War II, have yet to receive necessary maintenance or upgrades. A recent analysis by the American Society of Civil Engineers gave U.S. drinking water infrastructure a grade of "D-," and estimated that existing pipes lose up to billions of gallons of water daily (Source: http://www.infrastructurereportcard.org).

With these challenges paralleling the state of the U.S. power grid, companies are looking to harness the solutions being deployed in the smart electricity grid (e.g., smart meters) in today's water systems as well. Utilities can use smart water meters to measure how much water is getting to endpoints, to help enforce compliance with conservation rules, and to identify faulty pressure valves or leaky sprinklers, among other purposes.

Costs to repair existing U.S. water infrastructure are estimated at $365 billion. In contrast, deployment of a smart water grid may cost roughly $19 billion and could result in up to $102 billion in savings (Source: the Water Innovations Foundation's *Water Information Technology ROI Summary*, November 3, 2011). With improved monitoring, testing, and reporting systems, further benefits may include fewer waterborne illnesses and fewer chemicals used for water treatment.

Figure 31

HOW A SMART GRID CAN BENEFIT WATER MANAGEMENT



Source: Sensus Energy.

Water Treatment and Nanotechnology

While water is abundant on Earth, only roughly 2.5% is fresh water (Source: the U.S. Geological Survey). Water treatment markets have grown considerably in recent years due to increasing demand for potable water caused by a growing global population, greater agricultural and industrial efforts, and changing environmental regulations worldwide.

Various methods have been created to purify and treat water. Recently, nanomaterials have been employed to purify water of toxic metals, dangerous organic molecules, and salt. For example, researchers at MIT are exploring new materials to improve the efficiency of condensers, which are used in power and desalination plants (Source: MIT's *A better way to shed water*, October 21, 2012). Several companies are also employing nanomaterials to create improved distillation systems (e.g., membrane-based separation technologies) that can represent more effective, efficient, durable, and affordable approaches to remove pollutants than conventional methods.

Outlook

- The global market for water treatment equipment and supplies, including membrane-based separation technologies, is forecast to surpass $48 billion by 2018 (Source: Global Industry Analysts, Inc., November 2012).
- The global market for nanotechnology-based water treatment products is forecast to expand to $2.2 billion by 2015 (Source: BCC Research, September 13, 2012).
- In developed countries, water system investments are likely to support continued modernization of existing infrastructure while developing countries are expected to allocate funds toward installing new infrastructure to meet growing demand.
- M&A activity is expected to continue in the water industry as companies seek to increase market power or diversify holdings.

Key Developments During 2012

- In recent years, M&A activity has increased within the water industry, from roughly 40 transactions totaling $900 million in 2010 to 55 agreements valued at $12.7 billion in 2011 (Source: *Forbes' "*Water Acquisitions Rise: Will Venture Capital Follow?," February 18, 2012).
- APTwater, Inc., which commercializes technology to destroy water contaminants, and Rochem Group S.A., which deploys patented membrane modules, merged in November 2012.
- MLE Equipment Inc., Filter Innovations Inc., and Pacwill Environmental Ltd. merged to create newterra ltd., which was formed to provide turnkey treatment and remediation systems to industry and municipalities.
- Ecolab Inc. (ECL-NYSE) entered into an agreement to purchase chemical maker Champion Technologies Inc. in a $2.2 billion transaction.
- In September 2012, Pentair Ltd (PNR-NYSE) merged with Tyco International Ltd.'s (TYC-NYSE) flow control business in a transaction valued at $4.9 billion.
- In November 2012, Siemens announced plans to divest its Water Technology business unit, which offers solutions for municipal and industrial water purification and wastewater treatment primarily in North America. The company opted for the sale of the business as it entails a chemical expertise that does not align with Siemens' core industrial portfolio and electrical engineering competencies.
- In October 2012, Pennsylvania Governor Tom Corbett announced plans to invest $79 million in various non-point source, drinking water, and wastewater projects through the Pennsylvania Infrastructure Investment Authority (PENNVEST).
- In July 2012, Russia's state-owned enterprise OAO Rusnano entered into a partnership with clean technology investor, I2BF Global Ventures, to create a fund for investing in global business ventures with nanotech applications that benefit Russia's agriculture and water industries. The target size of the fund is $150 million.

Calgon Carbon Corporation (CCC-NYSE)

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Calgon Carbon specializes in activated carbon and other water and air treatment systems. The company offers a range of products, services, and equipment for the purification, separation, and concentration of liquids, gases, and other media. Uses of Calgon Carbon's technologies include purifying air, drinking water, food, and pharmaceuticals, as well as separating gas and removing mercury emissions from coal-fired power plants.

Calgon Carbon is believed to be one of the world's largest manufacturers of activated carbon, with a presence across North America, Europe, and Asia. Used in drinking water, wastewater, odor control, and pollution abatement systems, activated carbon removes organic compounds from liquids and gases in a process known as "adsorption." The company produces activated carbons in granular, powdered, or pellet form, as well as offers reactivation and field support services. Activated carbon and reactivation services accounted for roughly $486 million (or approximately 90%) of Calgon Carbon's revenues in 2011 (Source: Calgon Carbon's Investor Presentation, November 5, 2012).

The company offers a portfolio of standardized, pre-engineered systems that can be delivered and installed at treatment sites. It designs systems that utilize a combination of its enabling technologies—carbon adsorption, UV light, ballast water treatment, and advanced ion exchange separation (ISEP®)—in order to provide solutions to customers' air and water purification problems. In addition, Calgon Carbon's targeted consumer business mainly supplies activated carbon cloth for use in industrial and medical applications.

In mid-2012, Calgon Carbon entered into a 10-year contract with the city of Scottsdale, Arizona, to provide reactivation services for the city's activated carbon water treatments. Scottsdale uses reactivated granular activated carbon (GAC) in order to purify its drinking water, and Calgon Carbon is responsible for reactivating approximately six million pounds of GAC for the city annually.

Calgon Carbon also provides reactivation services for Phoenix, Arizona (for which the company received a long-term, 10-year contract earlier in 2012), and is constructing a reactivation facility in Gila Bend, Arizona, in order to better meet the needs of the expanding Arizona market. Anticipated annual capacity for the new facility is 25 million pounds of reactivated carbon, with a target completion date of construction in 2013.

Calgon Carbon offers an integrated pollutant control technology called DeSOx/DeNOx—the process for removing sulfur oxide (SOx), nitrogen oxide (NOx), and mercury from various gases—as part of its services. To do so, the company capitalizes on the adsorption and catalytic functionality of an activated carbon. The DeSOx/DeNOx process can also recover SOx as sulfuric acid.

In September 2012, Calgon Carbon's wholly owned subsidiary—Calgon Carbon Japan—was awarded a contract to supply roughly 5.3 million pounds of activated carbon to BlueScope Steel in Australia for removal of SOx and NOx from exhaust gases at one of its steel manufacturing facilities.

Headquartered in Pittsburgh, Pennsylvania, the company had 1,145 employees as of December 31, 2011. Calgon Carbon reported net sales for the 2011 fiscal year of nearly $541.5 million.

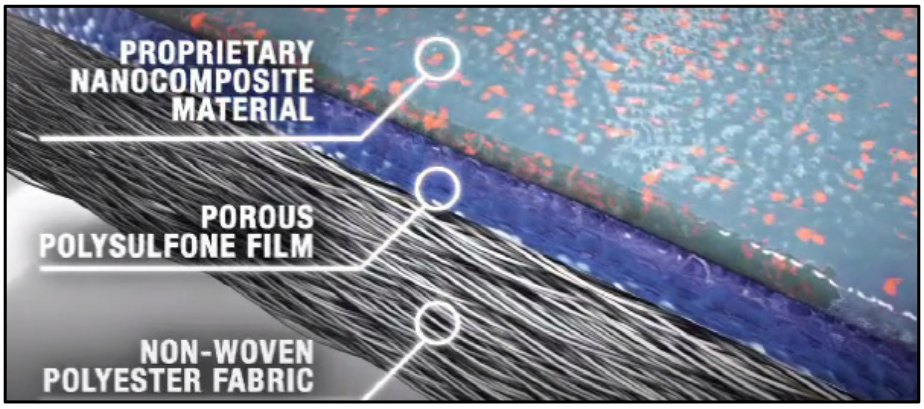
NanoH$_2$O, Inc.

NanoH$_2$O specializes in developing, manufacturing, and marketing reverse osmosis membranes that make the process of removing salt from seawater (desalination) more cost efficient. Reverse osmosis membranes can be used as filters in water treatment to help separate dissolved solids, salts, and minerals from water. To date, the company has over 50 installations of its reverse osmosis membranes in 33 countries across six continents.

The company's technology employs both novel nanostructured materials and proven polymers. NanoH$_2$O leverages nanotechnology to change the structure of the thin film of a reverse osmosis membrane, thus altering its permeability and salt rejection capabilities. During the synthesis process of a traditional polymer film, the company adds benign nanomaterials to produce a novel thin-film nanocomposite (TFN) membrane technology for reverse osmosis. Figure 32 illustrates the various layers composing NanoH$_2$O's patented TFN membrane. NanoH$_2$O's membrane can yield higher productivity, better water quality, and reduced energy consumption versus traditional membranes—potentially improving the economics of a desalination plant. Moreover, it can purify water from a range of sources.

Figure 32

QUANTUM FLUX MEMBRANE TECHNOLOGY



Source: NanoH$_2$O, Inc.

The company has branded its TFN membrane as *Quantum*Flux. *Quantum*Flux has been shown to improve permeability 50% to 100% versus the installed base of reverse osmosis membranes. NanoH$_2$O states that *Quantum*Flux delivers the highest flux and highest salt rejection of any salt water reverse osmosis membrane on the market (Source: NanoH$_2$O's November 5, 2012, press release). In April 2012, the company released additions to its *Quantum*Flux line—the Qfx SW 400 R and Qfx SW 400 SR—which achieve 99.85% stabilized salt rejection. *Quantum*Flux membranes are **Standard 61** certified by NSF International for producing drinking water.

NanoH$_2$O is one of the most highly funded water technology companies in the industry—having received $75 million in total equity funding and $100 million in total debt and equity funding. In April 2012, the company completed a $40 million equity financing led by BASF Venture Capital GmbH, Total Energy Ventures International, and Keytone Ventures—each of which had representatives join NanoH$_2$O's Board of Directors. The round also included NanoH$_2$O's existing investors, such as Khosla Ventures, Oak Investment Partners, CalPERS Clean Energy & Technology Fund (represented by Capital Dynamics), and PCG Clean Energy & Technology Fund. The company also secured $20.5 million in credit from Comerica Bank, Lighthouse Capital Partners, and the Export-Import Bank of the United States.

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As one of the most highly funded water technology companies, NanoH$_2$O has received a reported $100 million in debt and equity funding.

For the past four years, the company has been named to the Global Cleantech 100 and the Artemis Top 50 Water Tech Listing™.

NanoH$_2$O has received a number of awards for its innovations. The company has been named to the 2012 Global Cleantech 100 as well as to the 2012 Artemis Top 50 Water Tech Listing, which promotes solutions to address global water challenges. NanoH$_2$O has been included on both of these lists for four consecutive years. The company was also the 2011 Aquatech Innovation Award Winner in the Water Supply category.

NanoH$_2$O has headquarters in El Segundo, California. As a privately held company, sales figures are not publicly available.

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Omni Water Solutions develops systems for water treatment and reuse. These technologies have various applications, including oil and gas operations, where water can be treated and re-used instead of lost to disposal. The company focuses on creating highly automated systems that are easy to maintain and that require minimal training for operation. The company's automation technology—called OctoZone™—allows its systems to sense and respond to continually changing contaminant conditions in the field. The technology can be used to treat a broad range of contaminated, high-volume water sources.

Using this technology, Omni Water Solutions offers mobile platforms that can treat water to the level required by the user despite variations in contaminant levels (e.g., heavy metals, organic compounds, and dissolved solids) while minimizing energy and maintenance costs. The company's mobile HIPPO™ platform (as shown in Figure 33) is designed to treat and reuse water in hydro-fracturing operations. Hydro-fracturing is a water-intensive, well-completion method that can require several million gallons of fresh water for each well. Without treatment, the water that returns to the surface may contain chemicals, chlorides, and other pollutants and is typically re-injected in "disposal wells," a costly process that is used to permanently remove the water from the fresh water evaporation cycle. After processing with the HIPPO™ platform, which can treat up to 175 gallons per minute and up to 5,000 barrels per day, the water can be reused in subsequent wells.

Figure 33
OMNI WATER SOLUTIONS' HIPPO™ PLATFORM: A MOBILE WATER PURIFICATION SYSTEM

Source: Omni Water Solutions, Inc.

Omni Water Solutions' SIPS™ platform is designed for drinking water, such as during a natural disaster when local infrastructure cannot meet demand or in areas that lack proper sanitation. Omni's SIPS mobile recycling unit removes a number of contaminates, such as dissolved or suspended solids, magnesium, calcium, iron, barium, strontium, boron, sulfates, and bacteria. SIPS can be deployed quickly—taking only an estimated two hours to set up—and can treat roughly 175 gallons per minute. As well, SIPS offers the lowest energy and maintenance costs of the company's platforms. As of September 2012, Omni Water Solutions reported that it was in the final stages of manufacturing its first full-scale mobile water treatment unit, for which delivery was expected in early 2013 (Source: Austin Technology Incubator, September 19, 2012).

Omni Water Solutions' mobile water treatment systems enable oil and gas companies to purify up to 5,000 barrels of water a day, which can then be reused instead of permanently removed from the water cycle.

In April 2012, Omni Water Solutions became a portfolio company of the Austin Technology Incubator (ATI), a nonprofit unit of the IC2 Institute of the University of Texas at Austin. The entities have worked together for funding, market research, and relationship building with key professionals driving energy finance, regulation, and best practices. The company previously raised $7.9 million in February 2012 in a Series A financing led by Austin Ventures to support its plans to build and deploy HIPPO™ treatment units for oil and gas operations, and in mid-2012 received a key permit to perform mobile water treatment services for oil and gas companies using hydro-fracturing techniques in the Eagle Ford Shale area of Texas.

Omni Water Solutions was founded in 2010 and is based in Austin, Texas. In 2012, the company moved into its first manufacturing facility in Austin. As a private company, Omni Water Solutions' revenues are not publicly available.

Pall Corporation (PLL-NYSE)

Pall specializes in filtration, separation, and purification solutions. The company seeks to achieve internal sustainability goals and helps to identify solutions that allow customers to purify and conserve water, use less energy, employ alternative energy solutions, and reduce emissions and waste.

Pall Corporation

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Pall's water treatment products are used for a range of desalination, municipal, industrial, groundwater, and surface water applications. The company's Pall Aria™ technology serves as the foundation of its water treatment portfolio. Pall Aria™ employs membrane filtration—a process whereby a membrane filters bacteria, viruses, turbidity, and suspended matter from water—to cost-effectively produce water that often exceeds stringent water purity specifications, according to the company. Membrane-based systems offer enhanced performance and operational efficiencies versus coagulation and flocculation and sand filtration, while requiring 50% to 70% less space.

Pall Aria™ water treatment systems are mobile (as illustrated in Figure 34 [page 68]) and can be rapidly deployed when placed inside trailers or other containers for delivery to remote mines, oil or gas operations, and other industrial or municipal sites. In mine wastewater processing, Pall Aria™ systems can be used before conventional water treatment methods, such as reverse osmosis systems, due to its ability to handle significant variations in water quality and flow rate.

Figure 34

PALL ARIA™ MOBILE WATER TREATMENT SYSTEM

Source: Pall Corporation.

In August 2012, the U.S. Navy contracted with Pall for the development of a desalination system that allows ships to generate up to 400 gallons of fresh water per day.

In January 2012, the company was selected to supply a Pall Aria™ AP-Series packaged membrane system for Qatar Petroleum's (QP) 250-acre Ras Laffan Emergency and Safety College, which serves emergency responders throughout the Middle East and North Africa. Pall also offers systems for desalination, including Integrated Membrane System (IMS) freshwater generators. In August 2012, the U.S. Navy's Office of Naval Research (ONR) contracted Pall to develop a desalination system that allows a ship to generate large volumes of fresh water (400 gallons/day) in various environments, including open sea, coastal areas, rivers, and harbors, while meeting the Navy's low chemical use requirements. High concentrations of suspended solids and biological and organic contaminants make coastal water particularly challenging to treat. The project is designed to minimize energy use and maintenance while offering improved reliability versus currently available systems.

Additionally, BAE Systems plc (BA-LON) selected Pall to supply its IMS freshwater generators for the UK Royal Navy's Type 45 Destroyer after trials demonstrated Pall's ability to transform highly contaminated coastal waters into drinkable water. The IMS incorporates hollow fiber microfiltration and reverse osmosis to remove suspended solids (e.g., bacteria and viruses), dissolved components (e.g., salts), and other contaminants from seawater. It is both fully automatic and cleanable, reducing maintenance and ownership costs versus conventional water treatment systems.

Pall has presented its water treatment technologies at various conferences, including the 2012 International Water Conference, VGB's 2012 "Chemistry in Power Plants," Water in Mining 2012, MiningWorld Russia, and SEMICON West 2012. Pall as well participates in the Carbon Disclosure Project (CDP), a global initiative to inventory greenhouse gas emissions, and has been included in the Cleantech Index since 2006, among other indexes. The company was named to *Newsweek's* Green Rankings® in 2012, ranking 108th in *Newsweek's* U.S. 500 list and sixth in the industrial goods sector.

Pall is an S&P 500 company with headquarters in Port Washington, New York. As of July 31, 2012, the company employed 10,800 individuals and reported net sales of nearly $2.7 billion for its 2012 fiscal year (ended July 31).

Windows

Market Snapshot

Continued adoption of high-tech windows in the public sector could create the volume needed to drive costs down and spur an increase in use by the commercial sector beyond 2016.

Windows are an integral part of the built environment as they insulate, ventilate, and add to the overall appearance of a structure. Due to advancements in window technologies, such as intelligent glass, high-performance glazings, **low-emissivity (low-e)** coatings, and transparent solar cells, windows can now offer even greater insulation than the walls in which they are built. Some next-generation windows on the market today have been shown to reduce buildings' lighting, heating, and cooling costs while also integrating unique features designed to add to a building's aesthetics and increase occupant comfort, such as reduced glare, tint-changing glass that responds to outside sunlight conditions, and windows designed to maximize daylighting (natural sunlight) and clear views.

Figure 35 depicts Minnesota-based SAGE Electrochromics, Inc.'s SageGlass® at the Siemens Wind Turbine Facility in Hutchinson, Kansas. The windows provide heat and glare control and are integrated into the building's automation system. As sunlight or temperature increases, sensors electronically tint the glass to control how much light and heat enter the building, thereby reducing HVAC costs and eliminating the need for blinds or other window coverings.

Figure 35

SIEMENS WIND TURBINE FACILITY

Source: SAGE Electrochromics, Inc.

Inefficient conventional single-pane or dual-pane windows are a major contributor to wasted energy in buildings. Windows account for 12% of energy consumed by buildings in the U.S. (Source: DOE, October 2012), and heat loss through windows alone can comprise up to 25% of homeowners' heating bills (Source: Colorado's Governor's Energy Office [GEO]). Consequently, next-generation window technologies are topping the lists of energy-efficient products used by remodelers (Source: National Association of Home Builders).

Outlook

- The smart window industry will likely continue to gain traction driven by improved performance and demand for more energy-efficient products.
- The advanced glazings systems market—which includes insulated glass units, passive and active dynamic glazing, and windows that integrate PV and OLED lighting—currently generates $550 million in annual revenues, and is projected to double by 2015 (Source: NanoMarkets' *Advanced Glazing Systems Markets-2012*, October 2012).

- New certification and standards programs for building materials, including windows, are being adopted, such as the 2014 Energy Star criteria and the U.S. Environmental Protection Agency's (EPA) *Most Efficient Program* for window technology, which recognizes the most efficient products among those that qualify for the Energy Star certification.

- Continued adoption of high-tech windows in the public sector could create the volume needed to drive costs down and spur an increase in use by the commercial sector beyond 2016, which will in turn likely help suppliers scale solutions for residential use.

Key Developments During 2012

- The EPA announced that its *Most Efficient Program* for window technology certification program is scheduled to launch in January 2013.

- The DOE continued its *High Performance Windows Volume Purchase Program*, an initiative designed to expand the market for high-efficiency windows by making them more affordable.

- Researchers at the University of California, Los Angeles (UCLA) designed a visibly transparent polymer solar cell, overcoming major obstacles of previous efforts, such as limited transparency and device efficiency. The new solar cell could support the development of windows that generate electricity while offering clear views. Composed of plastic-like materials, UCLA's PSCs are lightweight, flexible, 70% transparent, and employ infrared light (versus visible light) to generate energy.

- In March 2012, the National Glass Association's *Window & Door* magazine released its ranking of the "Top 100 Manufacturers of 2012," based solely on annual sales (noting that the list only includes window and door manufacturers with operations in North America). The list can be viewed at www.windowanddoor.com/top-100-manufacturers-2012-sales-category. Sales categories ranged from $15 million to over $1 billion.

- In May 2012, France's Saint-Gobain acquired SAGE Electrochromics (http://sageglass.com), a maker of energy-saving electrochromic products (electronically tintable glass or "smart windows") for windows, skylights, and curtain walls.

- Canadian investment group, Onex Corp., acquired a majority stake in North American low-e window and door manufacturer JELD-WEN, Inc. valued at $870 million.

*Hüper Optik USA***

Hüper Optik USA is the U.S.-based producer and distributor of nano-ceramic window films. The parent Hüper Optik entity was established in 1997, and worked to commercialize nano-ceramic solar-control films for automotive, architectural, and marine markets.

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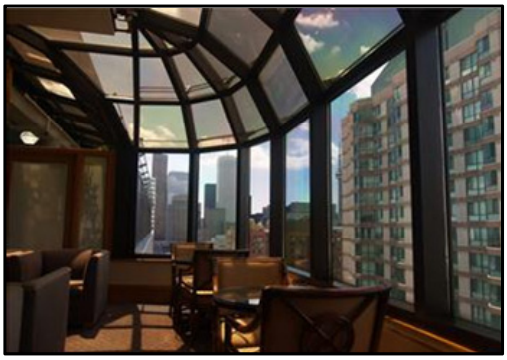
The company's nano-ceramic window films are optical coatings equivalent to 0.000000001 meters, which are deposited through reactive plasma processes. They contain electrically conductive oxynitride (a ceramic material), which enables the film to reject heat as well as improves durability. Hüper Optik deposits multiple films together to form a high-performance heat and glare barrier that the company states is 100% dye-free and 100% metal-free. The company estimates that its films' visible light transmission (VLT) ranges from 5% (reduced glare, increased privacy) to 70% (allows more sunlight to pass through for a more natural look). Clear glass with no window film has an approximate VLT of 89% (Source: Johnson Window Films, Inc.). Hüper Optik's VLT ranges are stated to meet most vehicle and building regulatory requirements, and come equipped with a scratch-resistant hardcoat.

The Hüper Optik network encompasses over 1,500 points of sale in more than 20 countries. Figure 36 illustrates the application of Hüper Optik's technology in the U.S. commercial buildings market.

Figure 36
HÜPER OPTIK: NANO-CERAMIC WINDOW FILMS (U.S. COMMERCIAL INSTALLATION)



Source: Hüper Optik USA.

With more than 2.5 million square feet of glass coated with Hüper Optik's nanoceramic films in just the North and South American markets alone, the company believes that it has enabled a CO_2 emission reduction of 100 million metric tons, derived from advocacy, education, a dedicated use of recycled and renewable resources, recycling within all internal and business processes, and careful selection of sustainable vendors and partners.

Additional window film technologies offered by Hüper Optik include the "Select Series," engineered with precious metals to offer a higher VLT; the "Exterior Series" with a weatherable coating, hardcoat, and anti-scratch coating for institutional installations; the "Fusion Series," which entails a dual reflective technology with low interior reflection and neutral tones (e.g., no bluish coloring); and the "Security Series," designed as an acrylic pressure-sensitive adhesive with a heavier weight to hold film together upon impact.

Hüper Optik® International Pte Ltd. has main offices in Singapore, Shanghai (China), and Munich (Germany) with additional operations and affiliates worldwide. As a private company, Hüper Optik's sales figures are not publicly available.

*** See disclosures on page 77.*

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View (formerly Soladigm, Inc.) is poised to ramp up high-volume manufacturing of its proprietary Dynamic Glass technology. Over the past five years, the company has developed a smart window designed to improve energy efficiency and offer unobstructed views by reducing glare (eliminating the need for shades, blinds, or other window treatments). View has produced its Dynamic Glass technology on a pilot scale, and recently constructed a full-scale 300,000 ft^2, $130 million manufacturing plant in Olive Branch, Mississippi.

In November 2012, Soladigm changed its name to View, concurrently with announcing that its commercial-scale Dynamic Glass was ready for global sales. The name change was intended to more clearly represent View's strategic vision as it markets its products: "a clear, uninterrupted view is the catalyst for a fundamental change in how people design and interact with buildings" (Source: View's November 12, 2012, press release).

Based on View's studies in commercial buildings, Dynamic Glass elicits a 20% annual reduction in energy use for lighting and HVAC, and is associated with a 25% reduction in HVAC peak load (maximum electrical power demand).

View's Dynamic Glass is based on electrochromic technology, which enables the window glass to continually adjust to external conditions, changing from a clear color to a dark tint on demand. To produce its electrochromic windows, View uses a thin-film deposition process to create two, transparent conductive oxide films between the two panes of glass in a double-paned window. When a low voltage is applied to the window, ions collide with the electrochromic material causing it to darken and either absorb or reflect light. When the voltage is reversed, the ions are driven away from the electrochromic material and back to their storage layer, causing the electrochromic layer to become clear again. During the course of one day, an electrochromic window's VLT can vary from approximately 60% to 4% to accommodate outside temperature and glare, as shown in Figure 37 (Source: Brandon Tinianov, technology and strategy consultant to View, August 2012).

Figure 37
DYNAMIC WINDOW WITH 4% VLT

Source: Brandon Tinianov <http://blog.abm.com/2012/08/dynamic-glass-emerges-as-a-new-design-option>, August 2012.

In late 2012, the company installed its Dynamic Glass in the lobby and lounge of the hotel W San Francisco. The glass was expected to enhance the W's signature contemporary style since it obviates the need for obstructive window treatments, which would diminish the hotel's panoramic view. The company reported that Dynamic Glass was easily retrofitted into the existing framing at the W. View holds patents for Dynamic Glass and has licensed technology from the Lawrence Berkeley National Laboratory for help in overcoming known shortcomings of common electrochromic materials. In mid-2012, the company raised $55 million in an equity financing co-led by NanoDimension Management Ltd and Reinet Investments S.C.A. To date, equity funding in View is roughly $125 million. As a private company, View's sales figures are not publicly available.

Glossary

3D Printing—The making of parts and products using a computer-driven, additive process, one layer at a time. 3D printing builds plastic and metal parts directly from CAD drawings that have been cross sectioned into thousands of layers. It provides a faster and less costly alternative to machining (cutting, turning, grinding, and drilling solid materials).

Admixtures—Ingredients added to a batch (typically as a minor ingredient) immediately before or during mixing. "Admixture" can also refer to a compound containing an admixture.

Amorphous—Without a clearly defined shape or form.

Anhydrides—The compound obtained by removing water from a particular acid.

Autoclave Aerated Concrete (AAC)—A masonry building material made of Portland cement, sand, water, and potentially other agents in an autoclaving process (heating under pressure), where the setting results in the production of air pockets in the material, making it less dense and better insulating.

Built Environment—It encompasses all buildings, spaces, and products that are created, or modified, by people. It includes homes, schools, workplaces, parks/recreation areas, greenways, business areas, and transportation systems. It extends overhead in the form of electric transmission lines, underground in the form of waste disposal sites and subway trains, and across the country in the form of highways. It includes land-use planning and policies that impact communities in urban, rural, and suburban areas.

Cradle to Cradle®—Certification from McDonough Braungart Design Chemistry that measures products' manufacturing characteristics and ecological impact.

Cryogenics—The branch of physics that deals with very low temperatures.

Electrochromic—Pertaining to a substance that changes color when placed in an electric field.

Energy Star®—A voluntary U.S. government program establishing a standard set of guidelines for labeling the energy efficiency of various products.

Epoxy—A thermosetting resin used chiefly in strong adhesives and coatings and laminates. Alternatively, an adhesive, plastic, paint, or other material made from a class of synthetic thermosetting polymers containing epoxide groups.

Float Glass—Glass made by allowing it to solidify on molten metal. It produces a high-optical-quality glass with parallel surfaces without polishing and grinding.

Fracking—The procedure of creating fractures in rocks and rock formations by injecting fluid into cracks to force them further open. The larger fissures allow more oil and gas to flow out of the formation and into the wellbore, where it can be extracted.

Gallium Nitride (GaN)—A hard, mechanically stable semiconductor material with high heat capacity and thermal conductivity.

Green Building—Also known as sustainable or high-performance building, green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's lifecycle—from siting to design, construction, operation, maintenance, renovation, and deconstruction. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy, water, and other resources; protecting the health of a building's occupants; and reducing waste, pollution, and environmental degradation.

Insulated Glass Units—Thermal glass. Usually two pieces of glass separated by a spacer and sealed as a unit to trap air in between the two pieces of glass for insulation purposes. Additional forms of insulation can be used as well.

IP Version 6 (IPv6)—The next-generation Internet Protocol (IP) standard. IPv6 increases the number of available Internet IP addresses (combating problems that are arising as more and more computers seek to connect to the Internet), as well as improves quality of service and data security. While IPv4, which has been used since the 1970s, supports approximately four billion separate IP addresses, IPv6 is estimated to allow for over 340 trillion addresses.

Leadership in Energy and Environmental Design (LEED)—A third-party certification program and a nationally accepted benchmark for the design, construction, and operation of high-performance green buildings developed by the U.S. Green Building Council in 2000. LEED is a point-based system where building projects earn LEED points for satisfying specific green building criteria. The five categories include Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (IEQ), and Innovation in Design (ID).

LEED Gold—On a 100-point scale, a LEED Gold Certified project would achieve 60 to 79 points. Platinum is over 80 points. Below the Gold tier, Silver-certified projects earn 50 to 59 points.

Low-Emissivity (Low-E)—A quality of a surface that radiates, or emits, low levels of radiant thermal (heat) energy.

Nanomaterials—Any material that has an average particle size of between 1 and 100 nanometers.

Nanoparticle—A nanoscale particle. One nanometer would span three to five atoms if they were lined up in a row. In contrast, the diameter of a human hair is approximately five orders of magnitude larger than a nanoscale particle.

Nanoscale—Of a size measurable in nanometers or microns.

Nitrous Oxide—Commonly known as laughing gas, it is a colorless gas with a sweetish odor, which produces exhilaration or anesthesia when inhaled. It is used in surgery and dentistry for its anesthetic and analgesic effect, as an oxidizer in rocketry, and in motor racing to increase the power output of engines.

Organic Light-Emitting Diode (OLED)—A self-luminous diode (it glows when an electrical field is applied to the electrodes) that does not require backlighting or diffusers.

Pavers—A brick, tile, stone, or block used for paving.

Photovoltaics—The branch of technology concerned with the production of electric current at the junction of two substances.

Plasticizer—A substance (typically a solvent) added to a synthetic resin to produce or promote plasticity and flexibility and to reduce brittleness.

Portland Cement—(often referred to as Ordinary Portland Cement [OPC]) A type of cement widely used around the world because it is a basic ingredient of concrete, mortar, stucco, and most non-specialty grout. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate (which controls the set time), and up to 5% minor constituents as allowed by various standards.

Post-industrial Recycled Content—Manufacturing waste material (not waste generated by consumers) that has been diverted from landfills to be integrated into new products.

Power Grid—(in the U.S.) The U.S. power grid consists of three loosely connected parts, referred to as interconnections: eastern, western, and Texas. Within each, high-voltage power lines transmit electricity from generating sources, such as coal or hydroelectric plants, to local utilities that distribute power to homes and businesses.

Quantum Mechanics—The branch of mechanics that deals with the mathematical description of the motion and interaction of subatomic particles.

Selective Laser Sintering—An additive manufacturing technique that uses a high-powered laser to fuse small particles of plastic, metal, ceramic, or glass powders into a mass that has a desired 3D shape.

Silicon Carbide (SiC)—A hard refractory crystalline compound of silicon and carbon that can be used as a semiconductor.

Standard 61—The NSF/ANSI standard that establishes minimum health effects requirements for materials, components, products, or systems that contact drinking water, drinking water treatment chemicals, or both.

Start-Stop Vehicles—These gas-powered vehicles use a system where the engine is automatically cut off when the vehicle is idling.

Thin Films—Denoting a miniature circuit or device consisting of a thin layer of metal or semiconductor on a ceramic or glass substrate.

Volatile Organic Compound (VOC)—Any organic compound that evaporates readily to the atmosphere. VOCs contribute significantly to photochemical smog production and certain health problems.

Wafers—A very thin slice of a semiconductor crystal used as the substrate for solid-state circuitry.

Company Index

** *See disclosures on page 77.*

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Investing in Nanotechnology-driven Businesses

Nanotechnology has the potential to greatly improve the quality of life and provide tremendous benefits to society by transforming the fundamental knowledge of material sciences. Such development offers opportunities to implement the new technologies into new applications, generating benefits in areas such as medicine, infrastructure, manufacturing processes, water purification, and energy, among others. However, nanotechnology remains a relatively new science and is thus subject to many of the risks associated with emerging technologies, including potential social, ethical, safety, and feasibility concerns.

Thus, when considering an investment into nanotechnology-based businesses, products, and technologies, it is important to consider issues inherent to the development of early stage sciences as well as to independently evaluate the developer's likelihood of commercial success and the dynamics and prospects of the industry as a whole.

Nanotech startups rely on the science for their business model as do multinational companies that are involved in or have invested in the development of nanotechnology as part of their operations. Since many aspects of nanotechnology are new, the economic risks of any investment are less well-known than in more established industries, with many of these risks being similar to those associated with startups from other industries. Yet unlike most established technologies, many nanotechnologies could be embedded into products in ways not visible to consumers. Furthermore, as with any new science, the frequent replacement of new technologies with even newer forms makes this a highly competitive and fast-paced field, making the longevity of certain technologies and business applications unpredictable.

As with many advanced, next-generation innovations, there is the potential for abuse or misuse of new technologies as well as potential health and environmental effects not yet known. The misuse of nanotechnology can come in many forms, including the creation of new weapons systems; privacy concerns as nanosensors and materials become more advanced; or waste and run-off generated by products or during manufacturing processes. Effects of nanoparticle waste penetrating animal and plant cells are not yet fully known, although in 2005, a North Atlantic Treaty Organization (NATO) Parliamentary Assembly (The Security Implications of Nanotechnology) found that as long as nanoparticles are embedded in common materials, they are unlikely to pose any particular environmental threat.

In terms of safety, there is little available information on the effects of nanomaterials on human health, although the small size of nanomaterials indicates that they are more readily taken up by the human body. Lung damage is the chief human toxicity concern surrounding nanotechnology, with studies showing that most nanoparticles migrate to the lungs. However, research is still exploring how nanoparticles behave inside the body. The large number of variables influencing toxicity makes it difficult to generalize health risks associated with exposure to nanomaterials—each nanomaterial must be assessed individually.

Government Regulation

Significant debate exists as to the ability of government regulation to prevent future social and environmental concerns. It has been argued that the development of comprehensive nanotechnology regulation could be vital to ensure that the potential risks associated with its research and commercial application do not overshadow the benefits. Currently, neither engineered nanoparticles nor the products and materials that contain them are subject to any special regulation regarding production, handling, or labeling. However, regulatory bodies, such as the U.S. Environmental Protection Agency (EPA), the U.S. Food and Drug Administration (FDA), and the Health and Consumer Protection Directorate of the European Commission are becoming more involved in the safety of nanotechnology. In the future, government regulation may have the ability to alter the landscape in which today's nano-based businesses operate.

NANOTECHNOLOGY AND THE BUILT ENVIRONMENT: INVESTING IN GREEN INFRASTRUCTURE

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Crystal Research Associates is led by veteran Wall Street sell-side analyst Jeffrey Kraws, who is well known by the international financial media for his years of work on Wall Street and for providing consistent award-winning analyses and developing long-term relationships on both the buy-side and sell-side. He has been consistently ranked on Wall Street among the Top Ten Analysts for pharmaceutical stock performance in the world for almost two decades as well as ranked as the Number One Stock Picker in the world for pharmaceuticals by Starmine and for estimates from Zacks. Additionally, Mr. Kraws has been 5-Star Ranked for top biotechnology stock performance by Starmine.

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