Crystal Research Associates, LLC
800 Third Avenue, 6th Floor
New York, NY 10022
(212) 851-6681
www.crystalra.com

November 17, 2011

Commissioned by

Livingston Securities LLC
825 3rd Avenue, 2nd Floor
New York, NY 10022
(212) 520-8481
www.livingstonsecurities.com

NANOTECHNOLOGY AND THE BUILT ENVIRONMENT: THE TRANSITION TO GREEN INFRASTRUCTURE

INNOVATIVE COMPANIES IN THE NANOTECHNOLOGY ARENA MAY BE THE KEY FOR NEW GROWTH AND VALUE IN ESTABLISHED BUILDING SECTORS, AS INVESTMENT IN NANOSCIENCE IS LEADING TO MORE ECOFRIENDLY, ENERGY-EFFICIENT, HIGHER-QUALITY INFRASTRUCTURE.

"From the 1930s to the 1960s, the U.S. built the greatest infrastructure the world had ever seen, and it played a critical role in our rise as a superpower. That whole build-out is reaching the end of its lifecycle and groaning under loads it was never supposed to handle. Design flaws, not enough money, normal corrosion, and decades of deferred maintenance have conspired to break America's infrastructure down."

— The History Channel's documentary,
"The Crumbling of America"
June 22, 2009

****

A new built environment is seeking to deliver solutions to America's impending infrastructure breakdown. Specifically, nanomaterials (in both new construction and retrofit projects) are being used to fix outdated and inefficient infrastructure. As nanotechnology brings new ways to customize and improve building materials, it is likely that "intelligent" products will be the future for the built environment. Much like the great innovators of our time (e.g., Microsoft, Apple, Google, Facebook, and the like), companies involved in successfully bringing new products to market will reap the benefits. For the purpose of this report, Figure 1 (page 2) depicts key areas within the built environment being addressed through nanosciences.

Figure 1
AREAS OF THE BUILT ENVIRONMENT BENEFITING FROM NANOTECHNOLOGY-DRIVEN PRODUCT DEVELOPMENT (Applicable to Both New Construction and Retrofit Projects)

Sources: Shutterstock Images LLC and Crystal Research Associates, LLC.

Table of Contents

The Changing Face of Technology in the Built Environment

Worldwide population growth, continued geopolitical conflict in oil-producing regions, volatile energy prices, and heightened concerns of climate change are fueling demands for energy efficiency—specifically for products that can cut energy consumption and costs, reduce dependence on oil, and reduce emissions of carbon dioxide (CO_2) and other harmful greenhouse gases. In the U.S., commercial and residential buildings account for nearly 40% of energy used, with an estimated 52% of CO_2 emissions tied specifically to the built environment (Sources: *Inc.* magazine, May 2011 and Serious Energy, Inc.). Thus, "greening up" the U.S.'s buildings, roads, and other infrastructure represents a big challenge and, concurrently, a big opportunity going forward.

An estimated 52% of CO_2 emissions are tied to the built environment.

In parallel with a global movement toward more energy-efficient, sustainable products, much of the infrastructure in the U.S. is reaching the end of its lifecycle, necessitating either repair or new, improved construction. These needs for both greening up U.S. infrastructure as well as for retrofitting the existing built environment are being achieved through nanotechnology, which is shaping up to become a driving force for innovation and sustainability in the 21st century and beyond. Nanotechnology enables new approaches to solving many of today's social, economic, environmental, and infrastructure concerns, and in doing so, is changing the landscape of virtually every aspect of the built environment. The potential benefits of energy-saving, ecofriendly materials are considerable.

Many sectors within the built environment are considered to be slow-growth industries, such as markets for bricks or windows. However, the companies that manage to out-innovate the competition and introduce the revolutionary new product (e.g., a green brick that costs less and does not harm the environment but rather offsets normal CO_2 pollution), may quickly become more valuable than its peers—thereby providing a new growth opportunity in a mature industry. Fueled by an array of such startups and new technologies, the global market for **green building**† materials to date has become a $156 billion industry per year (Source: *Inc.* magazine, May 2011).

WHAT IS NANOTECHNOLOGY?

Nanotechnology is becoming a driving force for innovation and sustainability in the 21st century and beyond.

In the early 1980s, IBM Corp. (IBM-NYSE) developed the electron microscope and, for the first time, there was an ability to view atoms—to physically see matter at the atomic level. Microscopes and other manipulation tools—which allowed individuals to see and manipulate atoms, move them around, build with them, and change the atomic structure of materials—created unprecedented abilities for scientists and engineers. Today, similar extraordinary advances are taking place in the field of nanoscience, where researchers are now able to individually manipulate pieces of material even smaller than atoms, yielding the ability to study the world at an ever smaller and smaller scale.

The word "nanotechnology" involves the creation or presence of a spatial dimension that is smaller than one hundred nanometers. A single nanometer is one millionth of a millimeter. In comparison, the diameter of a human hair is roughly 50,000 nanometers. Particle size is important because at the nanometer scale a material's intrinsic properties can be affected. At less than 100 nanometers in size, physics begins to give way to **quantum mechanics** so that the properties of matter can change substantially.

Manipulating matter at the sub-100-nanometer scale unleashes new properties that engineers can capitalize on in order to build better products. *That is nanotechnology.* It is not only about making things smaller (and smaller and smaller); it is about leveraging the properties that exist at the **nanoscale** for next-generation innovations.

†**BOLD** WORDS ARE REFERENCED IN THE GLOSSARY ON PAGES 66-69.

At the nanoscale, properties—such as surface area to volume ratios, **tensile strength**, and **heat dissipation** ratios—change dramatically. For instance, nanostructured opaque substances can become transparent (copper); inert materials can attain catalytic properties (platinum); stable materials can turn combustible (aluminum); and insulators can become conductors (silicon). Materials with engineered nanostructures often exhibit unique properties versus the "traditional" materials made from the same chemical constituents.

Between 1997 and 2005, government investments in nanotechnology increased from $432 million to over $4 billion, with even greater investment coming from industry (Source: *Scientific American*, July 2006). In 2009, the worldwide market for nanotechnology was valued at over $11 billion, forecast to exceed $26 billion by 2015 (Source: BCC Research's *Nanotechnology: A Realistic Market Assessment*, 2010).

Nanotechnology's Application in Construction

When nanomaterial is engineered into end-user products, these products can benefit from enhanced uniformity, durability, strength, bonding, adhesion, and longevity. Thus, as a broad, highly diverse field of technology, nanosciences have set the stage for a host of innovations across many industries, including automotives, electronics, pharmaceuticals, and construction, among others. For the purpose of this report, the focus is on construction.

Figure 2
NANO CONSTRUCTION

Italy's Jubilee Church
Nano Photocatalytic Concrete

Japan
Photocatalytic Pavers

Source: Concrete Décor®.

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—strengthening steel and concrete, keeping dirt from sticking to glass windows, creating **electrochromic** (tint-changing) windows that adjust to outside temperature and light in order to promote energy efficiency, killing bacteria on walls/surfaces, making materials inherently fire-resistant, improving the efficiency of solar panels, boosting lighting efficiencies, and allowing bridges and buildings to "feel" the cracks, corrosion, and stress that could eventually cause structural failures, in addition to many other innovative products.

Figure 2 exemplifies how nanotechnology can be used to improve construction. The Jubilee Church in Rome, Italy, was built using concrete that incorporated a nano **photocatalytic** additive, anticipated to keep the bright white building clean for 1,000 years. Likewise, the **pavers** in the Japanese sidewalk in Figure 2 are designed to reduce the effect of air pollution. *Concrete Decor*® magazine reports that a study of nano photocatalytic paving found that this technology has the potential to decompose 15% of the **nitrous oxide** released by cars. The use of such pavers could be more effective at maintaining air quality than planting trees on the side of the roadway.

****

The following pages overview the state of infrastructure in the U.S. today, highlighting the weaknesses and concerns being addressed through new nanotechnology-driven building products. As well, this report examines a future for U.S. infrastructure, specifically as it relates to the widespread "green building" movement (both new construction and retrofit projects) characterized by the use of energy-efficient, recyclable, and sustainable building materials—initiatives greatly enabled through advancements in nanoscience.

The State of U.S. Infrastructure

A massive and widespread infrastructure upgrade is needed across the U.S.

The majority of buildings, bridges, and roads in use today across the U.S. were constructed using technologies that existed when they were built 50 to 70 or more years ago. As energy awareness was not as much of a concern then as it is now, this older infrastructure is frequently inefficient and constrained by high operating and maintenance costs. Moreover, much of today's infrastructure was initially constructed with the intent of only lasting approximately 50 to 70 years, putting it at the end of its lifecycle. Thus, roads, bridges, buildings, the **power grid**, and so forth, are now literally crumbling and falling apart from age, deterioration, corrosion, and stress. It is believed that many U.S. cities, including sites in and around New York City, may already be structurally unsound. By 2050, the U.S. population is expected to reach 420 million, 50% more than in 2000. Much of this growth is likely to occur in metropolitan areas, where the infrastructure is in a dilapidated state.

Performing the necessary fixes on these and other problems threatening critical U.S. infrastructure could cost upward of $1.6 trillion (more than half of the annual federal budget), according to estimates from the American Society of Civil Engineers. This does not include costs for new capacity to serve the growing population. The U.S.'s waning infrastructure is described in brief below, followed by an explanation on page 7 of the estimated costs to maintain and repair the aging built environment.

More than 25% of America's nearly 600,000 bridges need significant repairs or are burdened with more traffic than they were designed to carry.

- ***Bridges.*** According to the U.S. Department of Transportation, more than one in four of the U.S.'s nearly 600,000 bridges need significant repairs or are burdened with more traffic than they were designed to carry. As well, of the more than 150,000 bridges in need of repair or replacement, more than half are considered to be functionally obsolete—meaning they do not pass current standards for weight limits, height clearance, or other federal requirements.

- ***Roads.*** Furthermore, over 30% of the highways and roads in the U.S. are in very poor shape—a significant factor in a third of the more than 43,000 traffic fatalities each year, according to the Federal Highway Administration.

- ***Dams.*** Since 1999, the number of dams that could fail has increased by 134% to 3,346. More than 1,300 of these are "high-hazard," where their collapse would threaten lives, according to the Association of State Dam Safety Officials (ASDSO). More than a third of dam failures or near failures since 1874 have happened in the past decade alone.

- ***Sewers.*** Aging sewer systems are leaking raw sewage. Sewers spill an estimated 1.26 trillion gallons of untreated sewage every year, resulting in over $50 billion in cleanup costs, according to the U.S. Environmental Protection Agency (EPA).

- ***Water.*** The EPA further estimates that the nation is falling short on water infrastructure by $22 billion annually. The federal Clean Water State Revolving Fund, which makes low-interest loans to clean up or protect water supplies, has shrunk from more than $3 billion in 1990 to roughly $1 billion in 2007. At the same time, the U.S.'s drinking water infrastructure, encompassing collection, holding, treatment, and distribution systems, has been in place for most of the 20th century and is becoming subject to frequent failures.

- ***Power Grids.*** Power grids are straining to keep up with the ever-increasing demand for electricity. Rolling and regional blackouts, such as has occurred in Texas, California, and the northeastern U.S., will likely continue (many times during peak usage) and may worsen until the power structure is more capable of efficiently supporting demand. The U.S.'s fuel and power generation and delivery systems were built primarily between the 1920s and the 1970s. Today, they cannot fully provide for the increasing energy demand of the country's consumers and businesses. Adding to the challenge of appropriately addressing energy infrastructure goals are the difficulties stemming from climate change.

In 2009, the Empire State Building began a "green renovation" with a $20 million investment to reduce the building's energy usage by up to 38%, resulting in $4.4 million in energy savings annually.

Pages 11-12 profile the retrofit, which uses products from Johnson Controls, Inc. (page 16) and Serious Energy, Inc. (pages 30-31).

COSTS TO MAINTAIN AND IMPROVE INFRASTRUCTURE

The below estimates from the U.S. Chamber of Commerce are representative but not exclusive of the amount and value of development that is needed to bring U.S. infrastructure up to date.

- A decaying transportation system costs the U.S. more than $78 billion per year due to lost time and fuel.
- The U.S. must invest $225 billion per year over the next 50 years to maintain and adequately enhance the surface transportation systems. Right now, less than 40% of this amount is being spent.
- U.S. transit systems earned a D+ rating from the American Society of Civil Engineers. Transit funding is decreasing while transit use is increasing faster than any other mode of transportation.
- Airline delay costs—due in large part to congestion from an antiquated air traffic control system—could triple to $30 billion from 2000 to 2015.
- By 2020, every major U.S. container port could be handling twice as much or more in volume than was originally intended.
- U.S. railroads are projected to require nearly $200 billion in investment over the next 20 years to accommodate more freight.

RECENT INFRASTRUCTURE FAILURES

The threat of catastrophic infrastructure failures is not merely theoretical. In the past several years, there have been a number of costly as well as deadly accidents caused by deteriorated construction.

Among the most notable recent infrastructure failures occurred in August 2007, when the Interstate 35 bridge in downtown Minneapolis, Minnesota, collapsed into the Mississippi River, killing 13 people and injuring nearly 150. According to the National Transportation Safety Board (NTSB), this collapse was due to undersized metal **gusset plates**, an increased concrete surfacing load, and construction supplies/equipment that weighed too much for the bridge to support. This particular bridge was designed in the 1960s and, while it could support its weight at that time, by 2007 the bridge had gained weight, both from added traffic and new concrete structures to separate the eastbound and westbound lanes. Over time, strain on the weak gusset plates led to the collapse (Source: *New York Times*, January 15, 2008). Figure 3 shows this bridge following its collapse.

Figure 3
MINNEAPOLIS BRIDGE COLLAPSE

Source: AP.

Other infrastructure failures include the May 2002 collapse of the Interstate 40 bridge near Webbers Falls, Oklahoma, into the Arkansas River, which killed 14 people. Subsequently, in March 2006, the 116-year-old Kaloko Reservoir Dam in Hawaii collapsed after heavy rains, killing seven people and causing nearly $15 million in damage. Similarly, in August 2005, after Hurricane Katrina, levees holding back Lake Pontchartrain gave way, flooding major parts of New Orleans and leading to more than 1,000 deaths and over $100 billion in damage. In 2009, steam pipe explosions in Midtown Manhattan killed one person, injured dozens, and disrupted multiple businesses.

A massive power failure occurred in the afternoon of August 14, 2003, throughout parts of the Northeastern and Midwestern U.S. and Ontario, Canada, affecting an estimated 10 million people in Ontario and 45 million people in eight U.S. states. It was caused by a power line failure in Ohio followed by an overtaxed power grid that could not handle the extra burden. Termed the "Northeast Blackout of 2003," this was the second largest outage in history, second to the 1999 Southern Brazil blackout. Leaving millions without power for days, it resulted in 11 deaths and a cost of $6 billion (Source: *Scientific American*, August 13, 2008). Moreover, current statistics indicate that a 2003-level blackout could occur every 25 years or more if improvements to the U.S.'s power structure are not implemented.

Researchers from Carnegie Mellon have found that the frequency of blackouts affecting more than 50,000 people has been about 12 each year from 1984 to 2006.

In some cases, scheduled inspections have been able to identify weaknesses in time to prevent a loss to human life, although the costs to remove and/or repair the weaknesses can still be sizeable. For instance, in 2009, the governor of New York State declared an emergency for areas in and around Essex County affected by the closure of the Champlain Bridge, which links New York and Vermont, following analysis that the bridge's **pilings** had deteriorated to a perilous state. The Champlain Bridge (also known as the Crown Point Bridge) was a 2,184-foot long vehicular bridge first opened to traffic in 1929. On December 28, 2009, the bridge was taken down by explosive demolition at a cost of roughly $4 million (Source: *Vermont Business Magazine*, December 28, 2009).

Today, "smart grid" technologies capable of monitoring and self-repair are being introduced across U.S. power systems.

NEW AND REVISED BUILDING CODES

In the aftermath of many of the aforementioned failures, consumers and regulatory agencies alike have called for greater oversight of the built environment, particularly in terms of implementing and enforcing mandatory controls. Following the Northeast Blackout of 2003, the U.S.–Canada Power System Outage Task Force recommended making the North American Electricity Reliability Council's (NERC) voluntary standards mandatory and legally enforceable. Congress subsequently passed the Energy Policy Act of 2005, expanding the role of the Federal Energy Regulatory Commission (FERC) to approve new reliability standards and impose fines of up to $1 million a day for infractions, depending on risk (Source: *Scientific American*, August 13, 2008).

In general, building codes are transitioning from a prescriptive approach—requiring specific manufacturing techniques and materials—to a performance-based system that allows builders to use a product or technology as long as it performs in accordance with building code requirements. This strategy not only encourages product innovation but also places the focus on efficient results rather than the types of products employed.

Building codes in the U.S. are being revised to promote energy efficiency and sustainability, with an emphasis on heating, cooling, insulation, and lighting. The trend toward energy efficiency began in 1978, when California adopted Title 24, a collection of energy-saving requirements for various building elements. These standards, combined with the adoption of energy-efficient appliances, have resulted in over $56 billion in electrical and natural gas savings since 1978 and could save an additional $23 billion by 2013 (Source: the California Energy Commission). In 2010, California became the first state to adopt a statewide green building code, called "**CALGreen**."

To increase safety and longevity, new building codes are more stringent and often require greater protection against seismic activity, mold, fungus, rot, termite infestation, and fire as well as energy efficiency.

While the federal government holds the enormous responsibility of keeping the U.S. functioning, state and local governments are also accountable for supplying more than half of the funding and all of the manpower to build and maintain the U.S.'s massive transportation network, among other types of infrastructure. In the U.S., each state develops and enforces its own building codes. Many states incorporate elements from **model energy codes** developed by leading building code organizations—such as the International Code Council (ICC) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). Model energy codes are typically updated every three years. In 2010, the ICC and ASHRAE released new standards—called the International Energy Conservation Code 2012 and the ASHRAE 2010 Standard 90.1, respectively—which are believed to be 30% more efficient than prior versions. They include novel elements such as automatic lighting in commercial buildings, minimum energy performance standards for heating systems in computer rooms, and more efficient water-cooled air conditioners. In 2010, ASHRAE, the ICC, and several other organizations also released a draft of the first International Green Construction Code.

As model energy codes increase efficiency standards, many jurisdictions have adopted stricter requirements for energy conservation in parallel. A number of locales have implemented the **Leadership in Energy and Environmental Design (LEED)** green building standard (mainly for public buildings). LEED is an internationally recognized green building certification system developed by the U.S. Green Building Council.

While many states use model energy codes as a guide, they are not required to do so. States may opt out due to the associated costs of compliance. To promote the adoption of more efficient building practices and to reduce financial burdens, the U.S. government has issued a number of incentives, including local and federal tax credits and rebates. For example, in order to qualify for funding through the 2009 American Recovery and Reinvestment Act's (ARRA) State Energy Program, the government requires states to meet current model code standards. The ARRA has also encouraged energy efficiency and sustainability through a 30% federal tax credit for energy-producing **photovoltaic** systems. Building-integrated solar technologies are described on pages 38-40.

Overall, building codes in the U.S. and globally are increasingly emphasizing sustainability, energy efficiency, and compliance, particularly as technologies that enable these goals become more widespread and affordable. Think tanks in energy efficiency are further encouraging building codes that regulate and measure the amount of energy a building consumes over time to determine if buildings are truly performing efficiently once erected (although debate over how to measure the performance of buildings has prevented this from being fully established to date).

Green Building

Rising oil prices in conjunction with environmental movements of the 1960s and 1970s led to initial experiments with contemporary green building.

Employing local and renewable materials or passive solar design has been long used—the **Anasazi** (an Indian civilization in the Southwestern U.S. from about 1200 B.C. to A.D. 1300) built entire villages where every home received solar heat in the winter—although green building has not been widely commercialized in today's culture until relatively recently. Modern green building efforts are emerging out of the need and desire for more energy-efficient and ecofriendly building practices—with buildings responsible for an estimated 40% of all U.S. greenhouse gas emissions (Source: *Governing* magazine's "Reconstructing Building Codes for Greater Energy Efficiency," May 2011).

Today, the EPA defines green building (also known as *sustainable* or *high-performance building*) as 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. As well, there are a range of additional environmental, economic, and social benefits related to green building.

GOVERNMENT POLICY TOWARD GREEN BUILDING UPGRADES

Government policies toward the green building upgrade cycle include Renewable Portfolio Standards (RPS) that are being passed at the state level, which call for more energy to come from renewable sources. An RPS regulation requires increased production of energy from renewable sources, such as wind, solar, biomass, and geothermal energy. It often places an obligation on electricity supply companies to produce a specific fraction of their electricity from renewable energy sources. Certificates are earned by qualified renewable energy generators for each unit of electricity produced and in turn can be sold along with their electricity to supply companies, who then pass the certificates to some form of regulatory body—thereby demonstrating compliance with their regulatory responsibilities.

The U.S. green building industry is valued at over $38 billion, with demand forecast to expand 13% annually through 2015.

Better Buildings Initiative to Make U.S. Businesses More Energy Efficient

In 2009, President Obama laid out a vision in the State of the Union Address for investing in innovative clean energy technologies and doubling the share of electricity from clean energy sources by 2035. As well, he proposed efforts to improve the energy efficiency of commercial buildings across the country. In addition to the investments of the Recovery Act, the President's Better Buildings Initiative, announced in February 2011, is expected to make commercial buildings 20% more energy efficient over the next decade and accelerate private sector investment in energy efficiency by offering a series of incentives to upgrade offices, schools, stores, municipal buildings, universities, hospitals, and other commercial installations.

Supporting Retrofit Projects in the Built Environment

Federal policies, such as the Better Buildings Initiative, drive investment in new energy-efficient projects as well as retrofits for existing buildings.

The Better Buildings Initiative is intended to reduce energy bills by approximately $40 billion per year by creating more energy-efficient buildings which, according to the White House, would increase the money available for hiring workers, inventing new products, and generating shareholder value. President Obama is seeking an aggressive reform of existing tax and other incentives for commercial building retrofits and has recommended a new competitive grant program.

Thus, commercial buildings across the U.S. have begun undergoing retrofits in order to become more energy efficient and to comply with new building codes and government policies (such as those described on pages 8-9). However, while new construction is presently being outfitted with the latest in energy efficiency, it requires significant added investment to retrofit older cities, such as tenements in Queens and Brooklyn, New York, with today's greener products.

Using nanoscience to engineer products with smaller form factors can help alleviate the costs of upgrading existing buildings to meet new building codes. For instance, aerogel insulations have been developed that are considerably thinner and perform better than traditional wall insulation materials; thus, it is less likely that aerogel insulation will require the builder to tear down walls in order to increase a building's insulation. Such new nanotechnology-enabled building materials are likely to be well suited to many of these ongoing retrofits in addition to new construction projects.

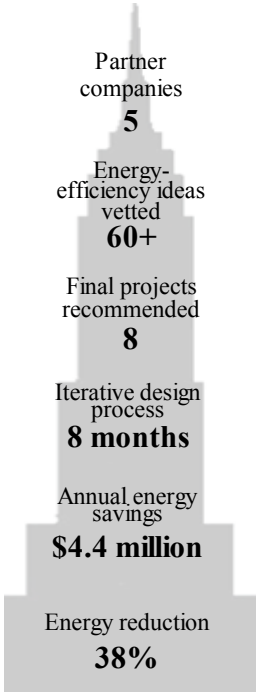
The Empire State Building's Green Renovation

One of the most high-profile retrofits is occurring at New York City's Empire State Building. The objective of this project is to reduce emissions and energy costs. Within New York City, 78% of the city's greenhouse gas emissions are derived from its buildings, largely due to the use of electricity and natural gas (Source: *New York Times*, April 6, 2009).

The economic and environmental revitalization underway at the Empire State Building is budgeted to be a $550 million renovation of the building. This retrofit (summarized in Figure 4), which is backed by companies including Johnson Controls, Inc. (JCI-NYSE) (see page 16 for corporate profile), the Clinton Climate Initiative, and the Rocky Mountain Institute, includes $20 million to transform the building into a more energy-efficient and ecofriendly structure. In September 2011, it was announced that the Empire State Building was awarded LEED Gold certification, making it one of the most well-known buildings in the U.S. to receive a green building certification from the U.S. Green Building Council.

Constructed during the Great Depression and designed to be the world's tallest building at the time, the Empire State Building is becoming one of the most energy-efficient commercial buildings in the U.S. Renovations to the building have included refurbishing over 6,500 windows while reusing 96% of the existing window glass; insulating radiators with heat-reflective shields; implementing energy-efficient lighting, including sunlight; upgrading air conditioning units; using demand control ventilation 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. The project is scheduled for completion by December 2013, with an ensuing annual energy reduction of approximately 38%, which could prevent the release of 105,000 metric tons of CO_2 over the next 15 years (equivalent to the annual emissions of 20,000 cars).

Figure 4
EMPIRE STATE BUILDING RETROFIT



Source: the National Institute of Building Sciences.

The Empire State Building renovation is key to the future of the built environment, as it is demonstrating solutions to several concerns that have previously limited investment in energy-efficient upgrades, including those described below.

(1) While upfront costs are often a deterrent to retrofitting a building, the Empire State Building retrofit is expected to not only pay back all costs of the project in roughly three years but it is also forecast to lead to an annual energy savings of $4.4 million (Source: *New York Times*, April 6, 2009).

(2) The renovations exemplify how older buildings, regardless of how large they are, can be retrofit to the highest energy standards and effectively cut down greenhouse gas emissions by reducing energy consumption.

(3) The project is helping to validate the capabilities of new, nanotechnology-based "green" companies, such as Serious Energy, Inc. (profiled on pages 30-31), which completed the renovations of all 6,500 windows in the Empire State Building onsite using its energy- and cost-efficient SeriousGlass™ technology.

Energy Star Rating Expected Upon Renovation Completion

When it is complete, the Empire State Building is expected to achieve an **Energy Star** rating for its energy efficiency. The EPA's research shows that buildings carrying the Energy Star label consume about 40% less energy than typical buildings. Moreover, the building will likely be ranked in the top 10% of Energy Star office buildings. Energy Star (www.energystar.gov) is a joint certification program from the EPA and U.S. Department of Energy (DOE) that recognizes products, builders, manufacturers, and buildings for above-average energy efficiencies. Under the Energy Star program, more than 6,200 commercial and institutional buildings have earned the certification by achieving at least 30% greater efficiency than comparable buildings.

****

This report overviews the state of the U.S. built environment and the green building efforts underway. Several key multinational corporations are making investments into nanotechnology and its application within the built environment, as profiled on pages 14-17. The efforts of these companies further validate the potential value in this space. As well, specific emphasis is given to the growth prospects stemming from innovative tech startups that have demonstrated an ability to capitalize on advancements in nanotechnology in order to create the next generation of building materials. Profiles for a selection of these entities are provided on pages 19-65.

Sectors and Companies to Watch

Capitalizing on advancements in nanotechnology for the built environment has the potential to greatly reduce the lifetime energy footprint of a building as well as to enable the development of higher-quality, more innovative building materials. **Nanoparticle** research has led to the introduction of building materials with quality and environmental improvements. Thus, as construction projects today are increasingly required to meet stringent building codes and regulations, the industry is transitioning to the use of next-generation nanomaterials that offer enhanced performance. Further, consumers and governments alike are demanding more energy-efficient and ecofriendly infrastructure, which is driving adoption of sustainable building materials.

The new generation of building materials includes hundreds of innovations, many of which fall into the categories outlined in Table 1.

Table 1
A SELECTION OF NEXT-GENERATION, NANOTECHNOLOGY-BASED INNOVATIONS

▪ Stronger, lighter nano-steels	▪ Insulating nano-glass
▪ Translucent nano-concrete	▪ Waterproof nano-drywall
▪ Ultra-low-energy nano-lighting	▪ Durable nano-coatings and paints
▪ Flexible nano-solar panels	▪ Dirt-proof nano-enhanced fabrics/furnishings

Sources: Livingston Securities LLC and Crystal Research Associates, LLC.

As demand for green building materials expands over the coming years, one of the most valuable sectors is expected to be concrete products that feature recycled content (e.g., **fly ash**, **blast furnace slag**), such as those from novel clean energy companies, Calera Corp. and CalStar Products, Inc. (profiled on pages 20-23) (Source: the Freedonia Group, Inc.'s *Green Building Materials to 2015* [April 2011]).

Being able to innovate is critical to future success—businesses that do not keep up with technology risk losing market share to competitors that have learned how to supply an enhanced, more efficient, and greener product created at the nanoparticle level.

Because nanotechnology has become an integral technology across so many fields—from semiconductors, solar cells, energy storage and transmission, drug delivery, diagnostics, building materials, and electronics—it is likely that those capitalizing on advancements in nanotechnology in order to remain competitive will prove to be among the most successful. Thus, the company that manages to introduce a revolutionary new material may quickly become more valuable than its peers, thus creating new growth opportunities in a mature industry.

However, not every business possesses the expertise and capabilities to innovate; thus, many firms may seek to acquire and/or enter into joint ventures with companies that have already demonstrated technological competencies. In today's environment, technology changes rapidly, consistently becoming more advanced. Companies that cannot out-innovate the 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 on top of these advancements. Should these companies fail to do so, they risk losing market share to competitors that have learned how to supply an enhanced, more efficient, and greener product.

LARGE-CAPS IN THE BUILT ENVIRONMENT

Leading multinational corporations are making investments into nanotechnology and its application within the built environment—moves that are viewed as further validating the potential value in this space.

The need to stay current on nanotechnology developments is particularly evident for the global, large-cap companies with operations targeting the built environment. To this effect, leading multinationals are investing in energy platforms and specific software, as well as entering into acquisitions and strategic partnerships.

In July 2011, diversified technology company Johnson Controls, Inc. (profiled on page 16) completed the acquisition of EnergyConnect Group, Inc., a provider of smart grid demand response services and technologies, for $32.3 million. Prior to that, in May 2010, Honeywell International Inc. (also profiled on page 16) acquired its own smart grid arm, San Rafael, California-based Akuacom, a provider of automated demand response technology and services for the smart grid. Similarly, global chemicals company DuPont (DD-NYSE) completed the acquisition of California-based solar startup Innovalight, Inc. (www.innovalight.com) in July 2011 (as further described on page 38).

Siemens AG (profiled on page 17) is also invested in smart energy technologies. In December 2010, its Building Technologies Division acquired Texas-based Site Controls, LLC, a supplier of enterprise-wide energy management solutions for multi-site commercial businesses. Siemens is further partnered with smart grid company Tendril Networks Inc. (profiled on page 53). Since 2000, Siemens' venture capital arm has invested more than €30 million in smart grid technologies, systematically building a portfolio of companies that provide technologies and solutions for grid management, energy efficiency, demand response, and electric vehicle infrastructure (Source: Tendril's June 13, 2011, Press Release).

Described below and on pages 15-17 is a selection of some of the leading corporations involved in nanoscience and the built environment.

BASF SE

Germany-based BASF (BASFY-OTC) is among the world's leading chemical companies, employing around 110,000 individuals and reporting sales in 2010 of approximately €63.9 billion ($86.4 billion). The company's portfolio ranges from oil and gas to chemicals, plastics, performance products, agricultural products, and fine chemicals. BASF operates under sustainable development principles and has made nanotechnology a key to its future business practices.

BASF SE
Carl Bosch Strasse 38
Ludwigshafen,
Germany 67056
Phone: +49 (0)621 60-0
Fax: +49 (0)621 60-42525
www.basf.com

BASF is currently formulating nanoparticles and developing nanostructured surfaces and materials. The company participates in the field of chemical nanotechnology, already applying its knowledge in established areas. For example, in cosmetics, the company supplies ultraviolet (UV) absorbers based on nanoparticulate **zinc oxide** and titanium dioxide (TiO_2). Integrated into suntan lotions, the small particles are effective at filtering the high-energy radiation from sunlight. For textiles, products treated with Mincor® keep water drops and dirt at bay. These coatings are used to manufacture awnings, parasols, and tents. In the construction industry, PCI Nanosilent® is an isolation mortar creating an improved tile-**substrate** interface. PCI Nanosilent® is also beneficial in leveling substrate irregularities, isolating the floor covering from the substrate and reducing footfall sound. BASF is partnered with Aspen Aerogels, Inc. (profiled on pages 26-27) to improve thermal performance in new and retrofit building wall systems. Other industries where BASF capitalizes on nanotechnology include electronics and automotives via its Ultradur® High Speed engineering plastic. Including this nanoparticulate additive improves plastic's **flowability** while preserving its mechanical properties.

BASF has also developed structures with nanosized pores organized in the form of cubes. These structures consist of a three-dimensional metal-organic framework and have demonstrated the ability to store hydrogen and other high-energy gases. The enlarged specific surface area and high porosity of these "nanocubes" likely make them appropriate as a storage medium for comparatively large amounts of 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. As well, BASF is developing nanoporous foams, which have demonstrated improved insulating properties versus established insulating fabrics. These materials could improve energy efficiency and sustainability.

Through BASF Future Business GmbH, BASF is jointly developing materials for next-generation illuminants with strategic partners. The company's "Opal 2008" project is devoted to researching and developing **organic light-emitting diodes (OLEDs)** as light sources. These lights do not grow hot when emitting light, indicating that less energy is lost through radiant heat than with conventional light sources. OLEDs use only half as much electricity and could save consumers about two-thirds of their lighting costs. Moreover, BASF's organic photovoltaics could enable solar cells in which the current solar cells' silicon is replaced by organic semiconducting materials, creating more cost-efficient production processes as well as new applications.

General Electric Company

imagination at work

General Electric Co.
3135 Easton Turnpike
Fairfield, CT 06828-0001
Phone: (203) 373-2211
Fax: (203) 373-3131
www.ge.com

General Electric (GE-NYSE) is a diversified infrastructure, finance, and media company. From aircraft engines and power generation to financial services, medical imaging, and television programming, the company operates in 160 countries and had roughly 287,000 employees globally as of December 2010.

GE Global Research is the hub of technology development for all of the company's businesses, with 10 global laboratories organized by scientific disciplines—all focused on leveraging technology breakthroughs. Specifically, scientists at the company are working to discover material properties at the nanoscale to achieve new performance levels for GE's products. The key challenge to making products better is grounded in creating ways to make enhanced materials. The team of GE Global Research consists of more than 70 scientists who work out of the company's nano lab in Niskayuna, New York, and represents virtually every scientific discipline.

For example, GE's nanocoatings are being developed to control moisture on electricity-generating turbine blades, making them more efficient. "Icephobic" nanocoatings, which create anti-icing surfaces on wind turbines and jet engines, may be able to eliminate the need for costly, energy-intensive systems for de-icing airplanes. In medical research, magnetic nanoparticles may one day be used to develop new contrast imaging agents, with the goal of taking breakthroughs from the chemistry labs and employing them to increase imaging resolution for physicians. In materials, GE is making more efficient blades in giant gas-powered turbines to generate electricity. Moreover, a project is underway with the U.S. Army's Tank Automotive Research, Development, and Engineering Center (TARDEC) to explore nanostructured techniques for improving the strength of transparent armor, such as a windshield. GE's nanoengineered transparent ceramic is believed to be three times stronger than similar materials used today.

Honeywell International Inc.

Honeywell International (HON-NYSE) invents and manufactures technologies for safety, security, and energy. The company employs approximately 122,000 individuals globally, including more than 19,000 engineers and scientists. Its aerospace products and services are in use worldwide on commercial and business aircraft as well as for applications in defense and space.

Honeywell's environmental controls, life safety, security, sensing, scanning, and mobility products, as well as its building and process solutions are at work in 120 million homes, 10 million buildings, 5,000 industrial facilities, and hundreds of public and private utilities worldwide. Its transportation systems provide technologies and solutions to automakers, their suppliers, and consumers. The company develops high-purity, high-quality performance chemicals and materials, which can reduce emissions, stop bullets, enable the production of green diesel and green gasoline, increase oil refinery capacity, speed drug discovery, and protect medicines.

Additionally, Honeywell Aerospace is working to create functional surfaces for a variety of aerospace applications. Similarly to how the company leveraged Akuacom's smart grid competencies, it has as well partnered with closely held company Nano Terra, Inc. to capitalize on Nano Terra's surface engineering expertise. The two companies are developing a fabrication of **thin films** for certain military and commercial aerospace applications designed specifically to enhance performance.

Honeywell International Inc.
101 Columbia Road
P.O. Box 4000
Morristown, NJ 07962
Phone: (973) 455-2000
Fax: (973) 455-4807
www.honeywell.com

Johnson Controls, Inc.

Johnson Controls (JCI-NYSE) is a global diversified technology and industrial company with customers in more than 150 countries. The company's 162,000 employees are focused on optimizing buildings' energy and operational efficiencies, as well as pioneering automotive and energy technologies. Johnson Controls' automotive experience has provided new interior products and technologies specifically for smaller and more energy-efficient vehicles. The company's power solutions extend its market leadership in advanced battery technology for vehicles, as Johnson Controls believes that it is among the first and one of the only companies in the world mass producing **lithium-ion** batteries for hybrids. The company has been committed to sustainability since 1885, when it invented the first electric room thermostat.

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. To date, the company has stated that it has saved its private and public sector customers more than $19 billion in energy and operating costs and that its projects have cut greenhouse gas emissions by 16 million metric tons (equal to that of 1.3 million homes in one year). Johnson Controls is one of the primary partners responsible for the ongoing retrofit of the Empire State Building (described on pages 11-12).

Johnson Controls, Inc.
5757 North Green Bay Ave.
Milwaukee, WI 53209
Phone: (414) 524-1200
Fax: (414) 524-2070
www.johnsoncontrols.com

The Sherwin-Williams Company

Sherwin-Williams Co.
101 West Prospect Avenue
Cleveland, OH 44115-1075
Phone: (216) 566-2000
Fax: (216) 566-2947
www.sherwin.com

Sherwin-Williams (SHW-NYSE) is a global leader in the manufacture and sale of coatings and related products. The company produces products under well-known brands such as Sherwin-Williams®, Dutch Boy®, Krylon®, Minwax®, and Thompson's® WaterSeal®. 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.

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 selection of products that meet new **volatile organic compound (VOC)** guidelines for industrial and architectural applications and offering products qualified for LEED projects. Sherwin-Williams' GreenSure symbol helps 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. As well, the company has pioneered the use of renewable or sustainable raw materials in some formulations and uses blown-in-line colorant bottles that have less resin, save freight costs, and reduce hazardous waste. Part of Sherwin-Williams' development efforts are directed toward embedding solar cells into paint, whether by developing these capabilities internally or acquiring the required technologies.

Siemens AG

SIEMENS

Siemens AG
Wittelsbacherplatz 2
Munich, Germany 80333
Phone: +49 89 636-00
Fax: +49 89 636-34242
www.siemens.com

Siemens (SI-NYSE) is a global electronics and electrical engineering company operating in the industry, energy, and healthcare sectors. 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 IT systems for clinical and administrative purposes. The company also provides technical maintenance, professional, consulting, and financing services. Siemens was founded in 1847 and is headquartered in Munich, Germany. In fiscal 2011 (ended September 30, 2011), the company had roughly 360,000 employees worldwide in continuing operations, with activities in more than 130 countries.

Siemens offers a variety of technologies—from building automation, fire protection, and security to lighting and low-voltage power distribution—to meet high standards of efficiency, security, reliability, comfort, and flexibility. Its total building solutions entail certified packages of products and systems that fulfill all the requirements of advanced building technology. Siemens' researchers have further developed a non-stick coating based on chemical nanotechnology that improves the production process for printed circuit boards. The coating is already used in manufacturing processes for various electronic devices.

GROWTH OPPORTUNITIES IN THE BUILT ENVIRONMENT

In the coming years, transformation within the built environment will come not only as a result of technologies developed and marketed by large-cap entities but also from mid-caps, such as Cabot Corp. (CBT-NYSE) and Titanium Metals Corp. (TIE-NYSE), and small-cap or privately held organizations. As well, IPO candidates in this market include Aspen Aerogels, Inc., Serious Energy, Inc., Bridgelux, Inc., and Silver Spring Networks, Inc., among a host of other startups. To this extent, Table 2 notes several cleantech firms, including Aspen Aerogels (profiled on pages 26-27) and Silver Spring Networks (pages 51-52), that have recently filed for an IPO.

Intelligent products will likely be the future for building. Much like the great innovators of our time (e.g., Microsoft, Apple, Google, Facebook), companies involved in successfully bringing new products to market will reap the benefits.

Table 2
CLEANTECH FIRMS THAT FILED AN S-1 FROM APRIL 2011 THROUGH SEPTEMBER 2011

Filing Date	Company	Sector	Amount	Investors
9/16	Mascoma Corp.	Biofuel	$100 M	SunOpta, Khosla, Flagship, General Catalyst, KPCB, Blackrock, VPCP
8/24	Genomatica, Inc.	Green Chem	$100 M	TPG, MDV, Vantage Point, Alloy, DFJ, Batios Holdings, WMOG
7/29	Intermolecular, Inc.	PV, LED, Semi	$200 M	ATMI, CMEA, Redpoint, Symyx, USVP
7/18	Renewable Energy Grp.	Biodiesel	$100 M	Viant, Natural Gas Partners
7/7	Silver Spring Networks	Smart Grid	$150 M	Foundation, KPCB, Google Ventures, WR Holdings, NCD Investors, Contra Costa Capital, JVB Properties
6/29	Luca Technologies Inc.	Biofuels	$125 M	KPCB, One Equity, BASF, Oxford Biosci.
6/24	Aspen Aerogels, Inc.	EE	$115 M	BASF
6/15	Enphase Energy, Inc.	Solar	$100 M	Rockport, KPCB, Applied Ventures, Madrone, Bay Partners, Third Point
5/27	Myriant Corp.	Green Chem	$125 M	PTT Chemical, Plainfield Direct
5/23	Ceres, Inc.	Biofuel Feedstock	$100 M	Artal, Warburg Pin., Ambergate Trust, Oxford Biosci., Gimv, Oppenheimer Growth, QIP, SFM, Monsanto
4/22	BrightSource Energy	Solar	$250 M	VPVP, DFJ, Morgan Stanley, Alstom

Sources: Greentech Media, Inc.'s "Cleantech IPOs On Deck..." (September 20, 2011) and Google Finance.

The accompanying pages describe key industries within the building arena (as listed below) where market dynamics are changing as a result of nanotechnology. Included within each industry's overview are profiles of companies that may stand to benefit from the new built environment.

Concrete/Cement/Brick

Concrete, a $200 billion industry in the U.S., is responsible for high carbon emissions and a good portion of municipal waste.

Worldwide, concrete is one of the most extensively used materials for building. Its use is estimated to be second only to water. In the U.S. alone, concrete represents a $200 billion industry. Although critical to the built environment, concrete is responsible for between 5% and 10% of global greenhouse gas emissions due to its maintenance and production, specifically the carbon footprint of ingredients in its composition (Source: *R&D Magazine*, August 30, 2011).

Concrete, a mixture of sand, water, rocks, and cement, should be simple to breakdown and recycle. However, concrete is inherently porous, allowing water and salts to seep in over time. Water penetration causes cracks in the concrete and corrosion of the steel components, such as rebar, often used for reinforcement. Essentially, concrete exposed to the environment (rain, ground water, freezing temperatures) over time will likely show structural damage, corrosion, and leaking (as shown in Figure 5).

Figure 5

CONCRETE SUPPORTS CORRODED DOWN TO THE STEEL REINFORCEMENTS

Source: http://theeconomiccollapseblog.com.

To prevent these effects, builders waterproof concrete. Traditionally, waterproofing is performed by applying a coating or membrane made of rubber, plastic, or asphalt (Source: *Concrete Contractor*, January 12, 2011). Such coatings are difficult to remove after the concrete's useful life and are not recyclable. Thus, roughly 25% of municipal waste comes from construction and demolition debris, nearly half of which is concrete (Source: *Inc.* magazine, November 1, 2007). As well, coatings and membranes can be difficult to apply and repair, are time consuming, and can be costly over time.

Next-generation concrete products are forecast to become the largest green building material segment by 2015.

Nanotechnology has enabled the development of next-generation solutions to keep concrete "green" and recyclable while reducing its carbon footprint. Importantly, such technological advancements not only offer greater environmental benefits, but are also often able to provide improved performance and cost benefits for builders. For example, closely held nanotech firm Hycrete, Inc. (profiled on page 23) has developed a green waterproofing molecule that can be integrated directly into concrete mixtures at the plant (versus being externally applied at the jobsite). The chemical bonds that this molecule creates make concrete hydrophobic, so the concrete itself actively repels water, thereby increasing its durability without affecting builders' material costs or time. Hycrete's **Cradle to Cradle®** environmentally certified system waterproofs the entire volume of concrete rather than just the surface layer, and reformulates concrete in a way that allows recycling in the future.

Cementitious (Cement-like) Materials and Brick

The most active component of concrete is cement, which in itself entails a very energy-intensive manufacturing process. Making concrete sustainable also requires using cleaner cement. Currently, the most popular cement used by concrete producers is **Portland cement**, which is manufactured by heating pulverized limestone and clay to harden under water (Source: the U.S. Federal Highway Administration, April 7, 2011). Producing one metric ton of cement releases approximately 650 kg to 920 kg of CO_2. Cement production accounted for roughly 5% of all CO_2 emissions worldwide in 2009 (Source: *Time*, December 6, 2010).

Next-generation bricks may be able to save roughly 1 lb. of CO_2 per brick.

In an effort to increase the sustainability of cement, several companies have devised nanoscience techniques to make both cement and its production process cleaner. Furthermore, some early stage projects even absorb CO_2 from the air as the cement hardens, potentially making it a carbon-negative material.

Additionally, it is estimated that seven billion bricks are used in the U.S. each year, with the manufacture of each kiln-fired clay brick emitting roughly a pound of CO_2 (Source: CalStar Products, Inc. [profiled on pages 22-23]). As a result, some architects have begun opting for wood and other non-brick materials, as they are concerned that brick is not a green option for sustainable infrastructure. Solutions from companies like CalStar, which manufactures a new type of brick without kiln firing or using Portland cement, may hold the potential to modernize the brick industry.

Figure 6
FLY ASH

Source: National Precast Concrete Association.

Other approaches seek to turn existing, problematic waste materials, such as fly ash (illustrated in Figure 6) produced as a byproduct from combustion at coal plants, into recycled building products. Over 136 million tons of fly ash and other coal waste are produced each year in the U.S., creating one of the world's most difficult waste management issues as disposal of these substances in landfills is hazardous for groundwater and nearby communities (Source: *National Geographic*, August 15, 2011). However, fly ash's chemical properties make it a nearly perfect substitute for Portland cement and as a replacement for clay in bricks—creating an opportunity to recycle this waste into a useful product.

Calera Corp.

Calera is a closely held clean energy company based outside of San Francisco, California. The company is working to commercialize technologies for reducing CO_2 emissions. Calera's proprietary approach, named Mineralization via Aqueous Precipitation (MAP), converts CO_2 emissions into a **calcium carbonate** material with cement-like characteristics.

CALERA

Calera Corp.
14600 Winchester Blvd.
Los Gatos, CA 95032
Phone: (408) 340-4600
Fax: (408) 340-4650
http://calera.com

Calera is developing Supplementary Cementitious Materials (SCMs), which are inorganic materials, such as fly ash (a byproduct of coal-fired furnaces at power-generation facilities), that either react with Portland cement to form a cementitious compound or that can be used to enhance the properties of concrete. With MAP, Calera captures CO_2 from flue gas and converts the gas to stable solid minerals. These minerals enable the production of highly reactive cement without **calcining** the carbonate, as is presently performed in cement manufacture.

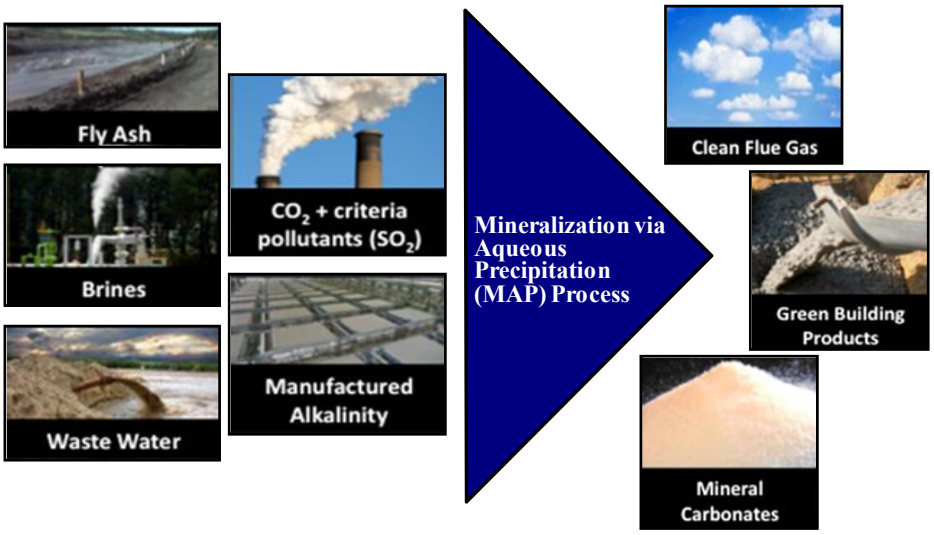
The company believes that its SCM can be used to replace the cement currently used in concrete mixtures, thereby avoiding the CO_2 emissions that are associated with the production of traditional Portland cement. Calera estimates that every ton of SCM it produces as a cement replacement could avoid the release of approximately one ton of CO_2 that would otherwise be emitted through cement manufacture.

In addition to reducing the environmental impacts of cement production, Calera's technology reduces CO_2 emissions at the emitter (e.g., power plant) by transforming waste materials into mineral carbonates, clean gases, and green building products, as illustrated in Figure 7. In comparison to other CO_2 capture technologies, Calera believes that its approach is innovative in that the company seeks to generate revenues from the sequestration of CO_2, mercury, and other heavy metals.

Figure 7

Calera Corp.

CONVERTING CARBON DIOXIDE EMISSIONS INTO BUILDING PRODUCTS



Source: Calera Corp.

To date, Calera has not fully commercialized its technology; however, the company has demonstrated the process and constructed a one-ton-per-day pilot scale system at its California facility. The company initially intends to introduce SCM into applications for pavers, non-structural block, miscellaneous precast products, sidewalks, and other building and construction applications.

Calera's initial carbonate product, a partial cement substitute (PCS), was derived from the gas emitted from a northern California power plant coupled with naturally occurring, water-based calcium or magnesium sources. The company demonstrated the function of its PCS in a curb and gutter mix in Santa Cruz, California, in the summer of 2011, through which Calera sought to replace 30% of the Portland cement in a 400-foot span of concrete to reduce the concrete's CO_2 factor.

Calera was founded in 2007 and, as of early 2010, was estimated to have 130 employees (Source: *Santa Cruz Sentinel*, July 23, 2010). Management is experienced in new technology execution, global project management, geochemistry, combustion technologies, air pollution control, waste treatment, and advanced power systems. The company is led by professional engineers and geochemists, inventors, MBAs, and a former member of several U.S. National Academy of Science panels and the EPA's Science Advisory Board. Calera's chief financial officer, Mr. Robert D. Kelly, has raised $48 billion in capital markets through acquisitions, IPOs, spin-offs, divestitures, and contract structuring and monetization. Calera is backed by Khosla Ventures and U.S. government funding. In July 2010, the company was awarded $19.9 million in federal stimulus funds in recognition of turning a harmful exhaust into a useful industrial product (Source: *Santa Cruz Sentinel*, July 23, 2010). However, as a private company, Calera's sales figures were not publicly available.

CalStar Products, Inc.

Headquartered in California's Silicon Valley technology hub, closely held CalStar creates sustainable building products designed to reduce the energy and carbon dioxide footprint of the built environment. The company uses an innovative manufacturing process to produce bricks and pavers (brick for exterior walkways) that have 40% post-industrial recycled content. In addition to the use of recycled materials, manufacturing CalStar's bricks requires up to 85% less energy and emits 85% less CO_2 than conventional masonry production, which entails firing clay brick and pavers.

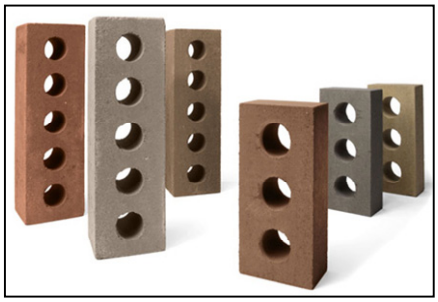
CalStar Products, Inc.
6851 Mowry Avenue,
Newark, CA 94560
Phone: (510) 793-9500
Sales: (877) 700-9501
Fax: (510) 793-9501
www.calstarproducts.com

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.

To create its novel brick products, CalStar uses recycled fly ash. Illustrated in Figure 8, fly ash 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's building products are available in multiple colors and modular and utility sizes.

CalStar is helping to turn a waste material into a functional green building product.

Figure 8
CalStar Products, Inc.
GREEN BUILDING PRODUCTS

CalStar's Bricks	CalStar's Pavers
	

Source: CalStar Products, Inc.

CalStar operates a manufacturing plant in Racine, Wisconsin, with annual capacity of 40 million brick equivalents. The company's products became commercially available during 2010. Since then, CalStar's products have received numerous recognitions for their value as innovative, green building products, including being selected as *Architectural Record's* Editor's Pick for new building product in the Concrete, Masonry, and Exterior Improvements category. Additional awards have included ranking among 2011's "most valuable products" in *Building Products* magazine and *Professional Builder*, receiving awards for cleantech and sustainability from the *San Francisco Business Times* and through AlwaysOn's GoingGreen 100, and being recognized for innovation from *Builder News* and *Fast Company*, among other venues.

CalStar's masonry products are available across North America through independent distributors, and it has shipped several million bricks made of 40% fly ash (Source: *National Geographic*, August 15, 2011). The company was founded in 2006 and, as of June 2011, employed 40 individuals (Source: *San Francisco Business Times*, June 2011). Company leadership includes construction industry veterans as well as individuals with high-tech and green-tech startup experience. As a private company, CalStar's sales figures were not publicly available.

Hycrete, Inc.

Hycrete
Delivering Concrete Solutions

Hycrete, Inc.
462 Barell Avenue
Carlstadt, NJ 07072
Phone: (866) 492-7383
or (201) 386-8110
Fax: (201) 386-8155
www.hycrete.com

Founded in 2002, closely held Hycrete is focused on sustainable construction practices that offer cost benefits, simplify and speed assembly, and enable more durable structures. The company's core initiative has been to develop a water-repellant molecule for intelligent moisture and corrosion control. With this formulation, Hycrete markets products to waterproof concrete and other cementitious materials (e.g., mortar and stucco), and form a protective layer over the steel reinforcements often used in concrete, such as rebar. Hycrete's water-based concrete **admixture** transforms concrete into a waterproof building material. Sand, aggregate, cement, water, and a Hycrete admixture are combined to create a hydrophobic concrete. When the concrete hardens, the admixtures turn from a liquid to a solid, which is bonded to the concrete. Because it is batched at the plant, Hycrete reduces containers and materials on the jobsite.

Over time, environmental agents (e.g., snow, rain, groundwater) attack concrete. Water and chlorides accelerate corrosion and rebar may expand, cracking the concrete. The company's admixtures react with the metallic ions 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. The molecules in Hycrete's admixtures also bind to the surface of any steel reinforcement in the concrete to inhibit corrosion.

Integrated waterproofing, such as Hycrete's admixtures, help eliminate the need for external protection systems. Since they are integrated into the concrete mixture, the waterproofing is accomplished at the time of concrete placement, thereby shortening construction time and lowering project costs versus alternative membrane solutions while delivering high-performance waterproofing and corrosion protection. Hycrete reports that its waterproofing solutions are generally lower cost than alternative membrane solutions and offer enhanced durability for long-term waterproofing, so repair and maintenance costs due to moisture penetration are reduced and there is no need to reapply coatings. In addition, Hycrete's proprietary molecules are recyclable, environmentally friendly, and hold Cradle to Cradle® certification. Using this technology for waterproofing allows the concrete to be considered a sustainable building material, as it can be recycled and may contribute to LEED credits for construction waste management, recycled materials, being sourced locally within 500 miles, or having 2.5% of building materials Cradle to Cradle® certified.

First used in 2003, the Hycrete technology was employed in its 100th project in January 2011, treating more than five million square feet of concrete. Applications for concrete made with Hycrete admixtures include virtually anywhere concrete is found, including balconies, decks, roof slabs, pavers, water tanks and treatment facilities, cast in place/shotcrete walls (concrete applied by spraying), foundations and slabs on grade, elevator pits, underground vaults, pools, parking structures, fountains, green roofs, bridges, subway systems, airports, sea walls, and dams. As of March 2010, the company had approximately 40 employees (Source: *Forbes*, March 15, 2010). As a private company, Hycrete's sales figures were not publicly available.

Insulation and Energy Conservation

Proper insulation protects building interiors from external temperature variations, thereby reducing energy costs. Insulation systems in the built environment are commonly applied to walls, floors, ceilings, roofs, window and door frames, and in solar thermal panels and systems. The global annual market for insulation materials totaled over $31 billion, with demand for building insulation specifically expected to increase an average of 5% per year (Source: Freedonia Group's *World Insulation to 2014*, February 2011). In addition to use in the building and construction market, insulation is also largely employed for industrial applications to cover pipes, valves, and storage tanks, and for original equipment manufacturer (OEM) use in transportation, appliances, and apparel.

Demand for building insulation is expected to increase by an average of 5% per year.

In 2010, thermal insulation used in North American building and construction (both residential and commercial) was valued at $5.2 billion, a 30% decrease from 2006 due to the slowdown in construction during the economic recession. As a result of the slowdown, insulation is now purchased more often for repair and remodeling projects than for new construction (Source: Principia Partners' *Residential and Commercial Insulation 2010*).

Retrofitting existing buildings with newer, more advanced insulation materials 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 energy cost savings, advanced insulation technologies can offer environmental benefits.

Figure 9
FIBERGLASS BATTING

Source: Minnesota Roofing llc.

Traditional insulation materials are often not well suited to such retrofit projects, as increasingly stringent thermal standards have become more difficult to meet with conventional products. To increase the effectiveness of insulation, builders double the thickness of the insulating material (e.g., fiberglass batts, as depicted in Figure 9). However, increasing thickness may not be possible in renovation projects due to space constraints. Even in new construction, thick layers of insulation in walls, floors, and on the roof consumes valuable space, forcing aesthetic and functional compromises.

One solution is to capitalize on next-generation, nanotechnology-based aerogels (such as illustrated in Figure 10), which deliver enhanced thermal properties in a much thinner, often cost-efficient form factor. The nanoporous structure of today's aerogels, which range from only 2 mm to 10 mm in size from companies like Aspen Aerogels, Inc. (profiled on pages 26-27), minimizes energy transfer by reducing three mechanisms of heat transport: convection, conduction, and radiation. Nanotechnology-based insulation techniques may further enhance the feasibility, safety, and cost of renovating infrastructure by reducing the likelihood that walls will need to be torn down to accommodate added insulation thickness. To this extent, Cabot Corp.'s loose-fill aerogel particles (profiled on pages 27-28) may be particularly useful in confined spaces, as these particles can be poured like water and packed densely with no residual air gaps to maximize flexibility and efficiency.

Figure 10
AEROGEL INSULATION

Source: CNET.

Growth Drivers for New Insulation Technologies in the Building and Construction Sector

- Worldwide emphasis on energy conservation and efficiency
- New building codes with stricter insulation requirements, such as **IECC 2012**, which represents a 30% increase in energy savings versus the previous 2006 version
- Government incentives to fund energy-saving initiatives
- Increased awareness of technologies that improve the performance, efficiency, cost, and breadth of application of insulation materials

R-Value Comparison

In June 2011, advanced insulation company Aspen Aerogels®, filed for a $115 million IPO on the New York Stock Exchange.

Marketed insulation materials vary in cost, efficiency, ease of application, and R-value, among other criteria. R-value measures the ability to resist the transfer of energy, in essence, keeping the heat out and the cold in, or the cold out and the heat in. A larger R-value indicates more effective insulation. Recently, the two most commonly used insulation products have been foamed plastics (spray **polyurethane** foam) and fiberglass. These accounted for more than 90% of demand in 2009 (Source: *Durability + Design* [the journal of architectural coatings], February 15, 2011).

As scientists and engineers obtain a better understanding of how nanotechnology can be employed to improve insulation, more advanced materials, such as Aspen's Spaceloft® aerogel insulation for building and construction (described on page 26), are likely to garner increased market share. Table 3 summarizes estimated R-values per meter of thickness for a variety of common insulation materials, as presented in Aspen's recent Form S-1 filings with the SEC.

Table 3

APPROXIMATE R-VALUE OF AEROGELS AND TRADITIONAL INSULATION MATERIALS

		R-value per meter of thickness	
Material	**Form**	From	To
Aerogel	Blankets, Beads	66	100
Cellulose	Loose Fill	22	26
Expanded Clay	Loose Fill	4	4
Expanded Polystyrene (EPS)	Boardstock	26	31
Extruded Polystyrene (XPS)	Boardstock	35	40
Fiberglass	Blankets/Loose Fill/Pipe Covering	20	28
Foamed Glass	Boardstock	21	21
Mineral Wool	Blankets/Loose Fill/Pipe Covering	17	26
Perlite	Pipe Covering/Loose Fill/Board	17	21
Polyurethane	Spray On/Rigid Board	44	44
Polyisocyanurate	Rigid Board	45	50
Vermiculite	Loose Fill	17	26

Source: Aspen Aerogels, Inc.'s Amendment No. 2 to its Form S-1 (filed with the SEC on August 8, 2011).

Aspen Aerogels, Inc.

Headquartered approximately 25 miles outside of Boston, Massachusetts, Aspen Aerogels® uses a patented nanoscience to create advanced aerogel insulation. Aerogels are low-density solid materials produced when the liquid component is removed from a gel. In Aspen's aerogels, 97% of the volume is air trapped in nanopores between intertwined clusters of **amorphous** silica solids. Essentially, the company's technology converts standard aerogels into a flexible aerogel blanket reinforced with non-woven fiber batting (illustrated in Figure 11) that is believed to offer up to five times better performance than materials used for insulation today, including fiberglass, polyester microfiber, foam, and microporous silica. A 6-millimeter thick Aspen aerogel heated on one side by a 1,000°C flame torch measures only 100°C on the other side. This same insulation nanotechnology enables an Aspen aerogel blanket to rest on dry ice at -78.5°C but maintain room temperature of 22°C on the other side.

Aspen Aerogels, Inc.
30 Forbes Road, Bldg. B
Northborough, MA 01532
Phone: (508) 691-1111
Fax: (508) 691-1200
www.aerogel.com

Figure 11
Aspen Aerogels, Inc.
ADVANCED AEROGEL BLANKET INSULATION

Source: Aspen Aerogels, Inc.

Aerogel insulation is used to conserve energy, reduce CO_2 emissions, and protect workers and assets in a number of industries, including oil and gas, natural gas, industrial and refinery operations, defense and aerospace, appliances and apparel, and building and construction, among others. Aspen manufactures three ultra-thin aerogel insulation product lines—Cryogel®, Pyrogel®, and Spaceloft®—that are sold primarily through distributors, contractors, and OEMs.

Aspen Aerogels® reported net revenues in 2010 of over $43 million.

The Spaceloft® line, ranging from 5 mm to 10 mm in thickness, is targeted to residential and commercial building applications. It can be applied to interior and exterior walls, framing, floors, and roofs. The patented Spaceloft® nanotechnology has been shown to offer low thermal conductivity, improved flexibility, compression resistance, hydrophobicity, and ease of installation in an environmentally safe product. Spaceloft® repels water and can withstand a maximum heat temperature of 390°F. As well, it may simplify logistics due to the reduced volume and weight of material needing to be purchased, inventoried, transported, and installed in the field. As an indication of expanding global demand for next-generation insulation materials, Aspen commenced doubling its production capacity at its Rhode Island manufacturing facility in March 2011.

Aspen maintains technical and commercial relationships with oil and energy companies like Exxon Mobil Corporation (XOM-NYSE) and NextEra Energy, Inc. (NEE-NYSE) (among others), as well as a joint development agreement with BASF's Construction Chemicals division, part of global chemical company, BASF SE (profiled on pages 14-15). The partnership with BASF is directed specifically to the building and construction market and enables Aspen and BASF to develop products addressing increasingly stringent building standards that require improved thermal performance in retrofit and new-build wall systems, particularly in Europe. Aspen works with other insulation manufacturers as well to create new products and new product applications for the built environment. In 2010, Aspen was selected as one of 50 private companies creating new opportunities in green technology, as recognized in AlwaysOn's GoingGreen East Top 50.

Founded in 2001, Aspen employs approximately 160 individuals, and is led by skilled engineers and business professionals with expertise from Cabot Corp., Dow Chemical Co. (DOW-NYSE), Pittsburgh Corning Corp., and Brookhaven National Laboratory. Aspen's Board of Directors includes founder and CEO of Cabot Microelectronics Corp. (CCMP-NASDAQ), William P. Noglows, as well as David J. Prend, member of the National Advisory Council to the National Renewable Energy Laboratory. Aspen holds 37 issued and pending U.S. patents and 47 issued and pending foreign patents (some of which are co-owned).

On June 24, 2011, Aspen filed Form S-1 with the SEC for a $115 million IPO of its Common Stock. The company seeks to list its stock on the NYSE under the ticker "ASPN." For the year ended December 31, 2010, Aspen reported revenues of approximately $43.2 million.

Cabot Corp.

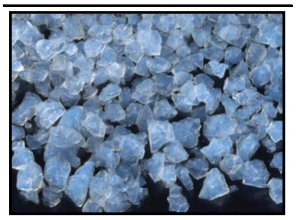
CABOT

Cabot Corp.
2 Seaport Lane, Ste. 1300
Boston, MA 02210
Phone: (617) 345-0100
Fax: (617) 342-6103
www.cabot-corp.com

Cabot (CBT-NYSE) is a performance materials company headquartered in Boston, Massachusetts, with global manufacturing facilities. It offers products for aerospace, defense, chemical processing, construction, electronics, energy, environmental protection, glasses, ceramics, life sciences, mineral processing, plastics, printing, textiles, and transportation, among many other sectors. To target the building insulation market specifically, Cabot capitalizes on aerogel technologies. The company maintains a cross license agreement with Aspen Aerogels (profiled above), under which both entities have granted each other certain intellectual property rights.

Cabot possesses technical skill in handling and manipulating very fine particles, including altering the function of these particles and designing them with specific properties. By capitalizing on its nanotechnology expertise to enhance building insulation, Cabot has developed aerogels that offer ultra-low thermal conductivity (R-value of 9.6 per inch); reduce outside noise; are water repellant and durable over time; and that resist settling. Uses of Cabot aerogel also include oil and gas pipelines, coatings formulations, industrial and cryogenic plants and vessels, outdoor gear, apparel, and personal care.

Figure 12
Cabot Corp.
AEROGEL PARTICLES



Source: Cabot Corp.

From a manufacturing plant in Frankfurt, Germany, Cabot produces aerogel particles (depicted in Figure 12) and a Thermal Wrap aerogel blanket (shown in Figure 13 [page 28]). 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**.

Cabot's aerogel particles are useful as loose-fill insulation in walls or other confined spaces, particularly in retrofit projects where installing other types of insulation may be complicated. In contrast to larger, bulky insulation, Cabot's particles can be poured like water and packed densely with no residual air gaps to maximize flexibility and efficiency. Aerogel particles can also be added to plasters and other coating systems to provide thermal insulation. Cabot's Thermal Wrap aerogel blanket, pictured in Figure 13, is used to insulate façades, roofs, and walls. The company states that the thermal properties of its Thermal Wrap do not degrade but rather improve as the wrap is compressed. 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 products hold Silver Cradle to Cradle® certification.

Figure 13

Cabot Corp.

A SELECTION OF CABOT'S AEROGEL SOLUTIONS

Thermal Wrap	Aerogel Insulation used in Architectural Daylighting	
	JF Ahern Building (WI)	Yale University Sculpture Building

Source: Cabot Corp.

In September 2010, Cabot and Rockwool International A/S (www.rockwool.com), a provider of stone wool products, jointly introduced a new insulation material, which entails aerogel within a rigid, mineral wool-based board. The companies collaborated for two years to create this product leveraging the novel thermal properties of granular aerogel in a new form. Primarily targeted to the built environment, this high-performance aerogel/mineral wool composite is beneficial to building applications where space is at a premium, as it provides equivalent performance to traditional materials at a reduced thickness (Source: Cabot's September 7, 2010, Press Release).

Cabot aerogel can also be employed in architectural daylighting, which allows architects to create unique glass and window designs while still meeting energy and building code requirements. Branded Lumira™, Cabot's translucent aerogel has been employed in daylighting systems across the U.S. and Europe, including on the glass-covered atriums and walkways at the JF Ahern Building in Fond du Lac, Wisconsin, and on the transparent walls of Yale University's Sculpture Building (both pictured in Figure 13). Lumira™ has a thermal efficiency (an R-value) of 8.0 per inch.

Founded in 1882, Cabot had approximately 3,900 employees as of September 2010. The company reported FY 2011 (ended September 30, 2011) net sales and other operating revenues of approximately $3.1 billion.

Windows

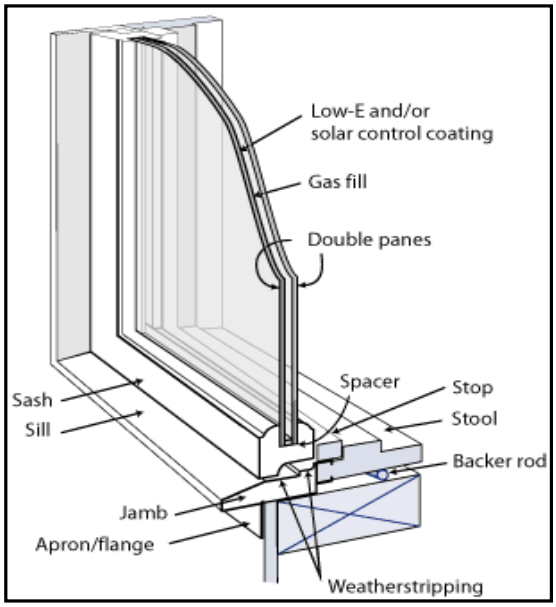
Windows are an integral part of the built environment, not only because they let in light but also because they insulate, ventilate, and add to the overall appearance of a structure. Accordingly, modern day windows have become high-tech building components that must fulfill multiple functions, including supporting energy efficiency.

Windows in the 21st century emphasize energy efficiency, lower costs, ease of installation, comfort, and aesthetics.

Inefficient single-pane or dual-pane windows are a significant contributor to wasted energy in buildings. Heat loss through windows alone can account for 10% to 25% of homeowners' heating bills (Source: Colorado's Governor's Energy Office [GEO]). However, with advancements in the types of materials used for window construction and new technologies enabling higher-performance glass, windows can now be more energy efficient and offer even greater insulation than the walls in which they are built (Source: *Qualified Remodeler*, July 2011). Figure 14 illustrates an energy-efficient window, which includes three key parts that help determine window quality: (1) the frame material; (2) glazing; and (3) the space (or "spacers") between the panes.

Figure 14

ENERGY-EFFICIENT WINDOW TECHNOLOGIES



Source: U.S. Department of Energy.

A number of companies and research institutions are ramping-up development of new, cleantech innovations to improve the energy efficiency of windows and glass while emphasizing cost competitiveness, ease of installation, comfort for building occupants, and aesthetics. Three such firms, which have received national recognitions for their next-generation innovations in glass technology, are profiled on the accompanying pages.

Serious Energy, Inc.

Serious Energy, formerly Serious Materials, markets a portfolio of energy-efficient products and services for the built environment. Serious Energy's offerings combine real-time, connected building analytics with material science innovations. The company provides a number of products for windows, which seek to improve energy performance and comfort, and reduce heating and cooling demands. In addition to its window enhancements, Serious Energy is a provider of reduced-material patented soundproofing drywall technologies (called "QuietRock") and a cloud-based enterprise software program (called "SeriousEnergy Manager" [detailed on page 54]) for monitoring, optimizing, and controlling building energy use. While not yet a public company, Serious Energy may become an IPO candidate during 2012. However, to date, it is a private company and sales figures are not readily available.

SERIOUS ENERGY

Serious Energy, Inc.
1250 Elko Drive
Sunnyvale, CA 94089
Phone: (408) 541-8000
or (800) 797-8159
www.seriousenergy.com

Serious Energy's suite of building products and energy software services—which have been used in over 70,000 projects worldwide—are designed to increase net operating income for building owners through increased energy efficiencies. The company also intends for its products to increase occupants' comfort, productivity, and health at a lower operating cost.

Serious Energy operates six manufacturing plants and maintains an advanced software development team. The company employs an estimated 135 individuals at its headquarters and 90,000 ft^2 manufacturing/R&D facility in Sunnyvale, California. This does not include personnel at additional locations in Newark (California), Boulder (Colorado), Vandergrift (Pennsylvania), Chicago (Illinois), and Bangalore (India). Products are distributed through a network of U.S. and Canadian distributors.

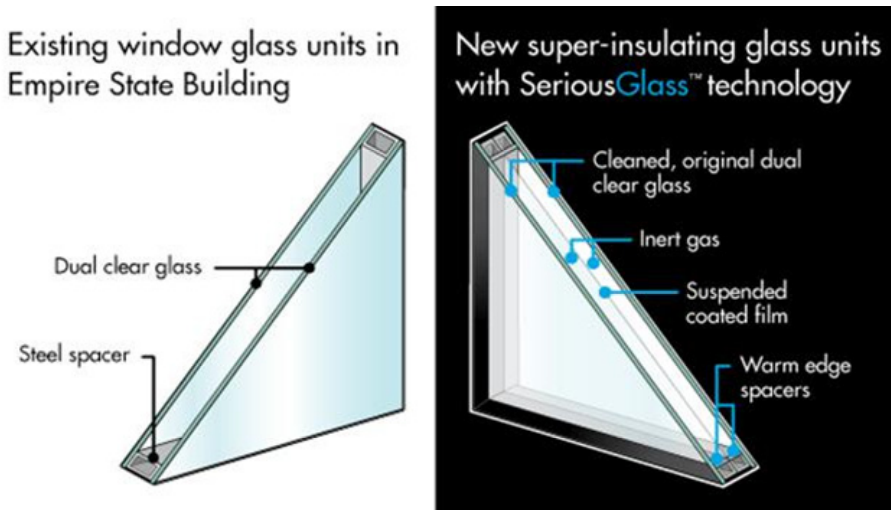
While not yet a public company, Serious Energy may become an IPO candidate during 2012.

The company's energy-efficient window and glass systems are powered by its SeriousGlass™ technology for commercial and residential installations and architectural glass. SeriousGlass™ reduces the energy lost through windows and improves both thermal comfort and efficiencies. Whereas conventional approaches to making windows more efficient entail adding a third pane of glass in the middle of a double-paned window (which adds to the weight of the glass and limits design possibilities), SeriousGlass™ comprises a combination of high-performance, **low-emissivity (Low-E)** coatings, suspended film technology, multiple chambers with air or gas fills, and a low conductivity spacer system. Since 1982, SeriousGlass™ units have been installed in over 10,000 residential and commercial projects.

For retrofit projects, the company offers an iWindow glazing system that allows builders to treat existing windows rather than replace them. A SeriousGlass™-designed iWindow panel can be installed on the inside of a window in as little as 20 minutes. This product does not alter the exterior appearance of a building, and is believed to be up to 75% less costly to install than typical aluminum replacement systems.

In 2010, SeriousGlass™ was employed as one part of the retrofit of New York City's Empire State Building (described on pages 11-12). Designed to produce a 38% reduction in annual energy consumption, this investment was expected to pay for itself within three years (Source: *Time*, May 1, 2011). Serious Energy upgraded over 6,500 dual-pane windows on the building by removing the existing glass from the window frames, separating the panes, and cleaning them in a dedicated processing space located onsite in the building. The company then created new super-insulating glass units using the old glass panes, new spacers, suspended coated film, and a special gas fill, as illustrated in Figure 15 (page 31). The new windows have increased the thermal performance by up to four times, from R-values of 2.0 up to an R-value range of 5.0 to 8.0. The new super-insulating glass also reduces solar heat gain by more than 50% versus the old windows.

Figure 15
Serious Energy, Inc.
SUPER-INSULATING TECHNOLOGY USED IN THE EMPIRE STATE BUILDING



Source: Serious Energy, Inc.

Hüper Optik USA

Hüper Optik USA
5821 West Sam Houston Parkway North, Ste. 400
Houston, Texas 77041
Phone: (832) 467-1170
Toll Free: (888) 296-FILM
Fax: (832) 467-1190
www.huperoptikusa.com

Closely held Hüper Optik USA is the U.S. arm of global company Hüper Optik® International Pte Ltd. Hüper Optik manufactures and distributes multilayered nanotechnology-based window films. At present, the Hüper Optik network encompasses 1,500 points of sale in more than 20 countries. The company has headquarters in Singapore, Shanghai, and Munich, and U.S. headquarters in Houston, Texas.

Since its inception in 1998, Hüper Optik has worked to market an energy-saving, green technology that protects against harmful UV rays. Today, the company's patented window films have been installed throughout the U.S., Canada, Mexico, and South America on over 2.5 million square feet of glass, representing a CO_2 emission reduction of 100 million metric tons. Hüper Optik's reduced carbon footprint comes through 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.

Hüper Optik believes that it is offering one of the world's first nanoceramic window films. Hüper Optik's products were developed as a result of more than six years of R&D in collaboration with major corporations and institutions, particularly Germany's Fraunhofer Institute, the U.S.'s Southwall Technologies Inc. (SWTX-NASDAQ), and Singapore's PSB Corporation and Novomatrix Pte Ltd. The initial batch of nanoceramic film was manufactured by Southwall in 1999. Subsequently, in 2001, U.S. patent number 6,188,512 ("Dual Titanium Nitride Layers for Solar Control") was granted.

Hüper Optik's German-engineered nanoceramic film does not incorporate dyes or metals but rather is embedded with titanium nitride beads that block UV and infrared light and heat while transmitting visible light. As well, by using multiple layers of ceramic, Hüper Optik's products are intended to outperform single-ply ceramics by increasing infrared heat rejection and durability while lowering visible light reflection.

Benefits of Hüper Optik's multilayered nanoceramic films include the following:

- Aesthetics, as Hüper Optik's ceramic films do not change the aesthetic of glass;
- Durability that is believed to be as much as 25 times greater than conventional film, with chemical stability in saltwater, coastal, and elevated environments (improving the potential for energy conservation on vacation properties); and
- Performance, as Hüper Optik's window film provides up to 98% infrared rejection and 99% UV rejection, increases the shatter resistance of glass, and has shown to be up to 13°C cooler than unprotected glass.

In addition to capitalizing on ceramics, the company offers several other nanotechnology window films targeted for different uses. Among these, its "Select Series" is engineered with precious metals and is thought to offer a high visible light transmission (VLT) coupled with energy-saving features. Hüper Optik's "Exterior Series" film technology incorporates a weatherable coating for institutional installations, an exterior hardcoat specially manufactured for weather exposure, and an anti-scratch coating. The "Fusion Series" entails a dual reflective technology with low interior reflection and neutral tones (e.g., no bluish coloring). A "Security Series" is designed as an acrylic pressure-sensitive adhesive with a heavier coat weight to hold film together upon impact. Additional options include Traditional, Automotive, and Clear Shield films.

Hüper Optik's products are used by residential and commercial customers in the architectural, automotive, marine, and security industries, and are sold through a strategic network of authorized dealers. Its technologies have been used by Google Inc. (GOOG-NASDAQ), 23 cruise ships from Royal Caribbean Cruise Lines (RCL-NYSE), and the U.S. Coast Guard, among others. As a private company, Hüper Optik's sales figures were not publicly available.

Soladigm, Inc.

Soladigm, Inc.
195 South Milpitas Blvd.
Milpitas, CA 95035
Phone: (408) 263-9200
http://soladigm.com

Closely held Soladigm, founded in 2007, has developed a "smart window" technology designed to both improve energy efficiency and offer unobstructed views by reducing glare (thus eliminating the need for shades, blinds, or other window treatments). The company's lead initiative is an electrochromic window technology called Dynamic Glass. Windows made with Dynamic Glass can change from a clear color to a dark tint on demand.

To produce electrochromic windows, Soladigm 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 (contained between the two oxide films within the window) collide with electrochromic material that is also contained between the conductive oxide films. This causes the electrochromic material 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. Soladigm has patented the use of different materials for creating its Dynamic Glass and licensed technology from the Lawrence Berkeley National Laboratory for help in overcoming known shortcomings of common electrochromic materials.

By allowing the consumer to control how much light and heat enters through glass, Dynamic Glass may enable cost, environmental, and quality of life benefits. In a study of commercial buildings in five cities, Soladigm's Dynamic Glass elicited a 25% reduction in energy use for heating, ventilation, and air conditioning (HVAC). The company further states that use of this glass is associated with a 30% reduction in peak load. Because they control glare, Dynamic Glass windows are not anticipated to need curtains or window coverings, thereby maximizing views for building occupants.

Soladigm believes that it is among the first to create an electrochromic window technology delivering performance, scalability, and durability at affordable price points that encourage adoption, though there are similar technologies in development elsewhere. Soladigm announced in July 2010 that it was building a 300,000 ft^2, $130 million manufacturing plant in Olive Branch, Mississippi. This factory was scheduled to begin shipping electrochromic windows in the first quarter 2012 (Source: *New York Times*, February 15, 2011). To date, Soladigm is only selling its Dynamic Glass on a pilot scale in North America while the company ramps up manufacturing (Source: *+Plastic Electronics*, August 25, 2011).

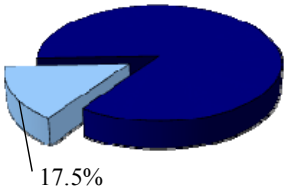
To fund product development and ramp-up, Soladigm received a $40 million loan and $4 million in other incentives from the state of Mississippi, was awarded nearly $4 million in federal and California research grants, and raised venture capital of $70 million from inception through February 2011. Investors in Soladigm include DBL Investors, NanoDimension Management Ltd, Navitas Capital, Khosla Ventures, Sigma Partners, the Westly Group, and GE Energy Financial Services. The investment by GE was part of GE's $200 million "ecomagination Challenge," which challenges entrepreneurs to share next-generation, energy-efficient, green-tech ideas. Through the challenge, Soladigm was selected as a business partner for investment and commercial partnerships.

Soladigm's California site includes R&D and a pilot plant. As of mid-2010, Soladigm planned to increase its R&D team and hire as many as 300 individuals over the next several years (up from a staff of roughly 50 in mid-2010) for its Mississippi manufacturing plant (Source: *Silicon Valley/San Jose Business Journal*, August 8, 2010). As a private company, Soladigm's sales figures were not publicly available.

Lighting/LEDs

As shown in Figure 16, lights are responsible for up to 17.5% of all global electricity consumption. Within that market, the U.S. accounts for 20% of worldwide electricity consumption for lighting. Commercial and public buildings represent the greatest share of U.S. lighting electricity, followed by residential, industrial, and outdoor/street lighting (Source: Pike Research's *Energy Efficient Lighting for Commercial Markets*, January 2011). Altogether, the global market for lighting products is estimated to range between $40 billion to $80 billion a year (Source: Bloomberg New Energy Finance).

Figure 16
GLOBAL ELECTRICITY CONSUMPTION



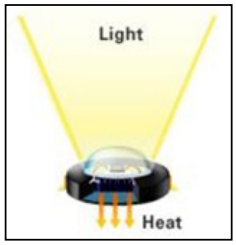
Source: Crystal Research Associates, LLC.

Traditionally, the most commonly used light is the 60-watt incandescent light bulb, which sells approximately 425 million bulbs each year (Source: the U.S. Department of Energy [DOE], August 4, 2011). However, up to 90% of the energy produced from an incandescent bulb is heat, not light, making these bulbs highly inefficient (Source: *Indianapolis Star*, September 10, 2011). As a result, in 2007, the U.S. signed into law provisions to begin phasing out the use of incandescent light bulbs. As of January 1, 2012, when the new law goes into effect, the 100-watt incandescent bulb will effectively transition out of use, followed by the 75-, 60-, and 40-watt bulbs, as the law would require most light bulbs to be 25% to 30% more efficient by 2014 and at least 60% more efficient by 2020. Globally, many other regions, including the European Union, have mandated a switch to more energy-efficient lighting as well.

Today, a variety of more energy-efficient options are available, including halogens (a type of incandescent bulb), compact fluorescent lamps (CFLs), and light-emitting diodes (LEDs), which are semiconductors that give off light (as illustrated in Figure 17). As well, global R&D efforts are continuously leading to the introduction of newer light sources that offer benefits beyond solely energy efficiency.

Both incandescent and fluorescent lights are forecast to be phased out in the coming years in favor of more energy-efficient options.

Figure 17
COMMON LIGHTING TECHNOLOGIES

Incandescent Bulbs	CFLs	LEDs
		
▪ Passes electricity through a metal filament ▪ Releases 90% of energy as heat	▪ An electric current is driven through a tube of gases ▪ Releases ~80% of energy as heat	▪ Moves electrons through a semiconductor on a tiny chip ▪ Small of amount of heat released backwards; cool to the touch

Source: the U.S. Environmental Protection Agency and U.S. Department of Energy's Energy Star website.

As a result of next-generation R&D, even the main alternative to incandescents at present—the CFL bulb—is likely to be phased out in the coming years, as new LED technologies increase advantages and decrease costs of using LEDs in new and retrofit building projects. Fluorescent lighting is already being referred to as a "doomed" technology that will likely be replaced by more efficient and environmentally friendly technologies (Source: *ConstructionWeekOnline*, September 14, 2011). New nanotechnology-based LED systems have been outfitted specifically to meet the needs of lamp and luminaire manufacturers, facilitating LED adoption in the marketplace.

Nanotechnology-based LEDs Gaining Ground

LEDs are forecast to achieve a 46% penetration of the U.S. lighting market by 2020.

In the past three years, LED products have progressed considerably in the quality of light emitted and the variety of luminaires and fittings available. LED technology can be up to 95% more efficient than incandescent bulbs and is also more efficient than CFLs, which give off a portion of their energy as heat rather than as light. Further, some 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).

Research and consulting firm for global clean technology markets, Pike Research, forecasts that LED lighting may become an increasingly important segment of the industry, achieving a 46% penetration of the $4.4 billion U.S. market for commercial, industrial, and outdoor stationary lighting by 2020 (Source: Pike Research's May 5, 2010, Press Release).

In August 2011, the DOE reported that if every 60-watt incandescent bulb in the U.S. was replaced with a 10-watt LED bulb, the nation could avoid 20 million metric tons of carbon output (Source: Bloomberg L.P., August 3, 2011). Moreover, the U.S.'s Energy Star website estimates that adopting LED lighting in the U.S. over the next 20 years can achieve the following:

- Save costs in the range of $265 billion;
- Avoid 40 new power plants; and
- Reduce lighting electricity demand 33% by 2027.

With revenue growth of roughly 792% from 2006 to 2010, solid-state lighting company Bridgelux, Inc. was ranked #135 on Deloitte's 2011 Technology Fast 500™ list of the fastest-growing North American companies.

See page 36 for profile.

The LED market is composed of well-known electronics companies, such as Royal Philips Electronics (PHG-NYSE) and General Electric, as well as companies focused primarily on LED light bulbs, such as Lighting Science Group (LSCG-OTC), LEDnovation, Inc., and Lemnis Lighting Inc. (profiled on page 37). The market further contains LED system and component manufacturers, such as Bridgelux, Inc. (profiled on page 36), Cree, Inc. (CREE-NASDAQ), and Osram GmbH, a division of Siemens AG.

Among today's privately held LED companies, *Fortune* listed Bridgelux as one of 13 companies with revenues under $200 million that have registered to go public or that industry experts expect to do so within the next 6 to 12 months (Source: *Fortune*, July 29, 2011). As well, another company profiled in this report, Lemnis Lighting entered into a license agreement with Royal Philips in November 2010 giving Lemnis access to Philips' LED systems and controls patent portfolio.

Bridgelux, Inc.

Founded in 2002, Bridgelux is a vertically integrated developer of **solid-state** light sources. The company works to provide high-power, cost-effective, energy-efficient solutions that expand the LED market by both driving down the cost of LED lighting systems and increasing efficacy, as measured in **lumens per watt**. From 2007 to 2010, Bridgelux reported revenue growth of approximately 417%, with 2010 revenues of nearly $32 million (Source: *Inc.* magazine, 2011). Additionally, more than 500 patent applications have been granted or filed worldwide for its technologies.

Bridgelux, Inc.
101 Portola Avenue
Livermore, CA 94551
Phone: (925) 583-8400
Fax: (925) 583-8401
www.bridgelux.com

The company targets the general lighting market (interior and exterior; consumer and commercial [lamp or luminaire manufacturers]) with LED products that it believes can replace traditional light sources, including incandescent, halogen, fluorescent, and high-intensity discharge lighting. By reducing energy consumption in lighting, Bridgelux's products support clean energy projects and are considered to be ecofriendly solutions.

Bridgelux offers LED arrays, LED chips, and the Helieon® Sustainable Light Module. In order to market these products as improvements over existing lighting technologies, Bridgelux has developed technological expertise (and consequently, intellectual property) in core materials technology (**epitaxy**) and advanced chip design, among other areas. Bridgelux believes that its emphasis on continuously investing in new epitaxial processes distinguish its LED arrays and chips from other products on the market, particularly in terms of performance and cost benefits. Bridgelux has stated that its investments in chip design R&D enable it to introduce new LED chips approximately every six months, with performance improvements in the range of 15% to 20% per introduction.

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

In May 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, Title 24, Part L, 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.

Fortune has listed Bridgelux as one of 13 startups with revenues under $200 million that have registered to go public or that could do so within the next 6 to 12 months.

Due to its rapid growth over the past several years, Bridgelux was ranked #135 on Deloitte's 2011 Technology Fast 500™ list of fastest-growing North American companies. As well, in September 2011, the company was selected as one of AlwaysOn's GoingGreen Global 200. Bridgelux received $60 million in financing led by Craton Equity Partners in August 2011 that is expected to fund further R&D, with a focus on **gallium nitride on silicon (GaN-on-Si)** and LED "chip-on-board" technology. The company subsequently raised an additional $15 million of financing earmarked to accelerate its GaN-on-Si development, which could be ready for commercialization in 2013. Including these financings, Bridgelux's total funds raised are estimated at nearly $200 million (Sources: Bloomberg L.P., August 3, 2011, and Crystal Research Associates). Bridgelux is believed to have considerable near-term IPO potential. It presently employs approximately 230 individuals.

Lemnis Lighting Inc.

Lemnis Lighting Inc.
555 De Haro St., Ste. 340
San Francisco, CA 94107
Phone: (415) 979-0280
Fax: (415) 992-5252
www.lemnislighting.com

Closely held Lemnis Lighting Inc. is the U.S. subsidiary of Dutch company, Lemnis Lighting B.V., which has additional subsidiaries in Hong Kong, Singapore, and South Africa. The Lemnis brand and group of companies is held by parent company, Tendris Holding (www.tendris.com), a cleantech incubator that invests in and develops technologies for sustainable products.

In addition to Lemnis, other companies and brands in the Tendris family include RePay, a carbon offset plan made available through global financial service providers; Innolumis, providing LED luminaries for the road system; Sparkxis, engaged in commercial production of customized organic coated titanium dioxide (TiO_2) nanoparticles that were inspired by the search for more energy-efficient LED lighting; Greenbookings, a way to travel the world carbon neutral; The New Motion, a sustainable mobility provider for electric transport; and Algae Food & Fuel, which designs, builds, sells, and installs systems for the industrial and agricultural production of algae.

As part of Tendris' global network of sustainability companies, Lemnis Lighting operates in the market for energy-efficient, reduced-carbon-footprint alternatives to current lighting solutions. The company designs LED products that are sold through dedicated business units for home, public, greenhouse, and solar lighting.

With low energy usage, the company's LED technology 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 achieves CO_2 reductions through both the energy-saving properties of LEDs as well as emphasizing efficient manufacturing.

In November 2010, Lemnis Lighting entered into a license agreement with Royal Philips Electronics giving Lemnis access to Philips' LED systems and controls patent portfolio.

Lemnis Lighting's chief product is the Pharox LED brand, which has sold more than three million bulbs since 2006. Lemnis believes that this bulb is among the best-selling household LED lights globally. In May 2011, the company announced a new addition to this line, the Pharox 400 (over 400 lumens in light output). 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.

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 Inc. 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. The company was founded in 2005 and had roughly 50 employees as of 2010 (Source: the *Guardian's* Cleantech 100 [2010]). As a private company, Lemnis Lighting's sales figures were not publicly available.

Photovoltaics

Photovoltaic (PV) devices generate electricity from sunlight via an electronic process that occurs naturally in certain types of material, 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 typically have lower efficiencies but are simpler and less costly to manufacture.

North America is expected to be one of the fastest growing solar markets, topping $14 billion by 2016.

Thin-film solar cells are flexible, high-efficiency modules manufactured by applying very thin layers of semiconductor material to inexpensive substrates, such as glass, plastic, or metal. Many PV manufacturers and researchers are largely focused upon **copper-indium-gallium-diselenide (CIGS)** thin-film technology (Source: Solar Energies Industry Association [SEIA]). CIGS developers have two primary goals: (1) increase solar panels' sunlight-to-electricity conversion efficiencies; and (2) devise cost-effective manufacturing processes that meet demand and maintain the higher energy conversion. CIGS companies are currently manufacturing panels in efficiencies around 10% to 12% versus 16% to 17% using silicon solar panels (Source: GigaOm's *How CIGS Solar Can Become Mainstream*, March 2011).

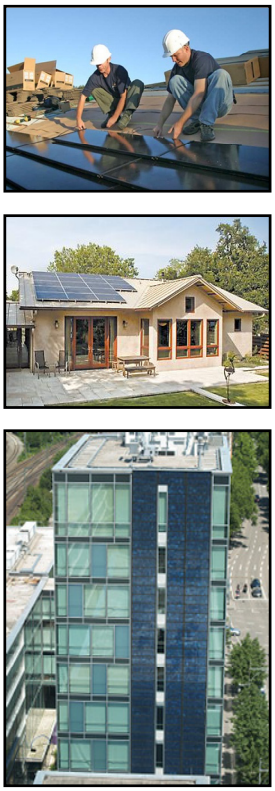
In 2011, the global solar energy market was estimated at $39.6 billion, expected to reach $75.2 billion in 2016. Led by U.S. investment in both PV and concentrated solar thermal technologies, North America is expected to be the fastest growing market, reaching $14.8 billion by 2016 (Source: MarketsandMarkets' *Solar Power Market by PV, CSP Technologies by Installations, Price, Cost, Trade Trends & Global Forecasts [2011 – 2016]*, 2011). The European Photovoltaic Industry Association predicts that the U.S. could overtake Germany as the world's top solar customer by 2014 (Source: *Money Morning's "*Solar Power Market Emerging as a Sleeper in 2011," 2011).

Within this market, applications for building-integrated photovoltaics (BIPV) are expanding as well. As illustrated in Figure 18, 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. As architects and building owners become more familiar with BIPV technologies and costs continue to decline, solar projects in the built environment are likely to continue to increase (Source: *Glass Magazine*, October 3, 2011).

The industry's growth has gained the attention of the investment community. Oil price fluctuations and world events, such as Japan's nuclear fallout after its devastating 2011 tsunami, have prompted greater long-term interest in clean technology ventures, including solar energy. The increase in both investments and M&A activity in the solar industry is likely to continue, behind the development of new cost-effective technology (Source: *USA Today's* "Big Companies Aggressively Jump into Clean Tech," 2011).

In July 2011, DuPont acquired solar startup Innovalight. Innovalight's nanotechnology-based silicon ink decreases electrical resistance and was designed to allow solar cell manufacturers to increase energy conversions and reduce manufacturing costs. Prior to this acquisition, DuPont had already exceeded $1 billion in revenue from PV sales in 2010. Through acquiring Innovalight, DuPont added customers that have licensed Innovalight's technology, including global solar-cell makers Yingli Green Energy Holding Co., Ltd. (YGE-NYSE), JA Solar Holding Co., Ltd. (JASO-NASDAQ), and Motech Industries, Inc. (6244-Taiwan) (Source: GigaOm's "DuPont Buys Solar Ink Maker Innovalight," 2011).

Figure 18
BIPV INSTALLATIONS



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

HelioVolt Corporation

HelioVolt Corp.
6301-8 East Stassney Lane
Austin, TX 78744
Phone: (512) 767-6000
www.heliovolt.com

HelioVolt manufactures thin-film solar CIGS PV modules. HelioVolt 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. HelioVolt is also developing BIPV offerings that place the flexible solar cells onto a plastic substrate or directly onto conventional construction materials that 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®). HelioVolt believes that the combination of its product architecture and production process allows it to generate materials that are more efficient, flexible, economical, and provide better long-term product reliability than competing processes. According to HelioVolt, 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.

Korea's SK Group recently committed to invest $50 million in expanding HelioVolt's global manufacturing.

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.

HelioVolt holds intellectual property of 11 patents, nine patent applications, and five patent applications in progress with over 100 international extensions. On September 19, 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 has begun collaborating to develop HelioVolt's global capabilities, including the development of a manufacturing plant in Korea. Although details are not finalized, the SK Group expects to also fund the factory, dependent on HelioVolt meeting specific milestones. As a private company, HelioVolt's sales figures were not publicly available.

MiaSolé

California-based MiaSolé is a high-volume manufacturer of CIGS thin-film PV solar panels. The company believes that its CIGS solar panels are among the lowest cost and highest efficiency thin-film solar panels available globally. MiaSolé's manufacturing process has shown to lower costs while providing predictable reliability (high uniformity). The resulting product is a solar module exceeding 120 W, which is sold to utilities and independent developers of solar power plants for industrial-scale deployments (large-scale rooftop and ground mount installations).

MiaSolé
2590 Walsh Ave.
Santa Clara, CA 95051
Phone: (408) 919-5700
Fax: (408) 919-5701
www.miasole.com

The company operates two manufacturing facilities in California for the production of two primary product lines: (1) the MS Series PV Module; and (2) the MR Series PV Module. The MS Series' key features are that it is a high-efficiency CIGS solar panel that comes in a convenient corner junction box designed to reduce wiring cost and installation time. As well, its tempered front and back glass is robust under high snow and wind load conditions, and it maintains a Class A fire rating. The MR Series has many of the same characteristics but is more ideally suited for large-scale, low-cost installations. Its durable glass/glass construction is designed to enable a long lifetime in harsh environments. Notably, in December 2010, MiaSolé reported that the National Renewable Energy Laboratory independently confirmed the 15.7% efficiency of its large-area production modules (1 m^2 in size)—ranking it among the highest efficiencies demonstrated for commercial-size thin-film modules.

In February 2011, MiaSolé raised most of a $125 million funding round, and could be preparing for an IPO.

In April 2011, MiaSolé entered into an agreement with Intel Corp.'s (INTC-NASDAQ) Technical Manufacturing Services practice. Under the agreement, Intel provides MiaSolé with customized manufacturing services and systems, strategic consulting, operational knowledge, and training as the company ramps up manufacturing in 2011 and 2012. MiaSolé aims to reach annual production of over 150 MW by the end of 2011. It is estimated that the company is currently producing approximately 15,000 modules per week (Source: Greentech Media, Inc., September 18, 2011). Furthermore, as the company continues working toward the expansion of its business, it has recently appointed new members of executive management who specifically bring expertise in marketing and business development. In March 2011, MiaSolé was ranked number four on the *Wall Street Journal's* list of the Top 10 Clean-Tech Companies.

The National Renewable Energy Laboratory has confirmed a 15.7% efficiency of MiaSolé's large-area solar modules—among the highest demonstrated for commercial-size thin-film modules.

To date, MiaSolé's technology has been shipped to more than 30 customers across the U.S., Germany, Spain, Italy, France, Portugal, India, and Saudi Arabia. MiaSolé's customers have included Chevron Corp. (CVX-NYSE), a partnership with SolarCity (www.solarcity.com) to install MiaSolé's modules at multiple Wal-Mart Stores, Inc. (WMT-NYSE) locations throughout the southwestern U.S., and other global entities with projects across the U.S. and Europe. In February 2011, MiaSolé raised most of a $125 million round F of funding, and could be preparing for an IPO (Source: VentureBeat's "MiaSolé Reportedly Raises $125M for Solar, IPO Question Hangs," February 18, 2011). In October 2011, MiaSolé was named to the Global Cleantech 100 list. As a private company, MiaSolé's sales figures were not publicly available.

Structural Steel

With annual direct costs of corrosion exceeding $276 billion, stronger steel products that are less susceptible to corrosion are needed.

Steel is a strong, highly versatile material with a broad range of applications in the construction industry. In 2010, world crude steel production was estimated at 1,414 million metric tons, a 15% increase over 2009, and a new record for global crude steel production. In the U.S., the steel industry ships approximately $70 billion of material every year, and creates more than one million direct and indirect jobs (Source: World Steel Association 2011).

However, 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 causes structural weaknesses and is one of the major problems 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, such as is shown in Figure 19, requires local, state, and federal authorities to spend billions of dollars annually simply to maintain infrastructure. In 2001, an FHWA-funded study determined that the annual direct cost of corrosion was approximately $276 billion, while estimated global costs exceed $1.8 trillion (Source: the World Corrosion Organization's *Global Needs for Knowledge Dissemination, Research, and Development in Materials Deterioration and Corrosion Control*, May 2009).

Figure 19

CORROSION DAMAGE IN BRIDGES

Source: Matco Services, Inc.

Companies like The NanoSteel Co., Abakan, Inc., and MMFX Technologies Corp. are investing in advanced nanosteel used to rebuild today's deteriorating steel infrastructure.

See pages 43-47 for corporate profiles.

The trade-off between strength (hardness) and **ductility** (toughness) is also a significant issue for steel. Modern construction requires high strength whereas safety (especially in seismic areas) requires high ductility. Hardness and toughness are considered inversely proportional. Increasing hardness to improve wear performance normally leads to lower toughness, while increasing toughness—thus increasing a material's ability to flex and return to its original form—can lead to decreased hardness. A material's properties, such as flexibility, wear, and impact resistance, are dependent on its hardness-toughness ratio (Source: *Dekker Encyclopedia of Nanoscience and Nanotechnology*, Volume 5).

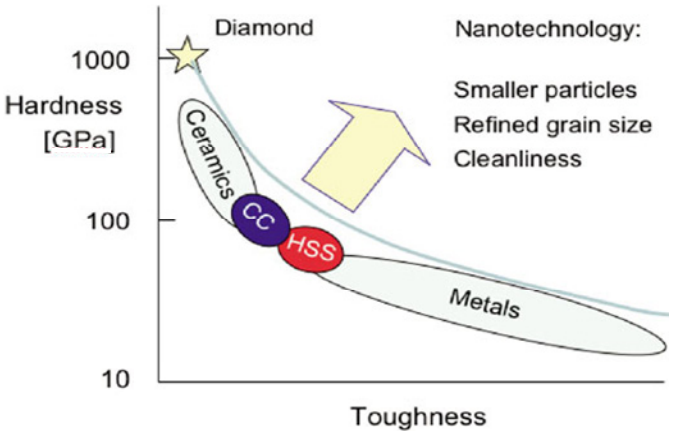
Nanostructured Steel

Nanotechnology has played a key role in the production of high-performance steel. Enhanced corrosion and mechanical properties, specifically 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* "On the Use of Nanotechnology to Manage Steel Corrosion," 2010).

The objective of nanosteel production is to differentiate the mechanisms governing strength from those governing toughness, optimizing both to overcome the existing inverse relationship found in conventional materials (Source: *Journal of Materials Engineering and Performance* "Enabling Factors Toward Production of Nanostructured Steel on an Industrial Scale," 2005). Reducing steel's microstructure particle size improves homogeneity and reduces defects, resulting in improved wear resistance and fracture toughness. As illustrated in Figure 20, nanosteel materials can be made stronger than conventional or high-strength steel (HSS), while maintaining toughness, ductility, and corrosion resistance—properties previously thought to be mutually exclusive.

Figure 20

HARDNESS-TOUGHNESS RELATIONSHIP



Source: Gear Solutions magazine's "Wear Mechanisms of HSS Cutting Tools," June 2008.

Enhancing steel's mechanical properties through the utilization of nanotechnology can be performed in two ways: (1) changing the actual microstructure and chemical compositions of steel; or (2) applying a thin coating of nanocomposite materials to the steel. Technology advancements have enabled manufacturers to refine steel's microstructure to the nanometer scale, thus improving corrosion resistance and other properties (Source: *Recent Patents on Engineering*, 2010). Incorporating nanosized particles into conventional polymer coatings through **cladding** (i.e., coating) processes can also increase steel's anti-corrosive and material performance.

The NanoSteel Company, Inc.

The NanoSteel Co., Inc.
272 West Exchange
Street, Ste. 300
Providence, RI 02903
Phone: (401) 270-3549
Fax: (401) 270-9306
www.nanosteelco.com

The NanoSteel Co. is a closely held business designing a patented portfolio of Super Hard Steel® (SHS) products, which entails a line of proprietary iron-based nanostructured steel **alloys** for industrial applications. The company is headquartered in Providence, Rhode Island, with R&D and engineering offices in Idaho.

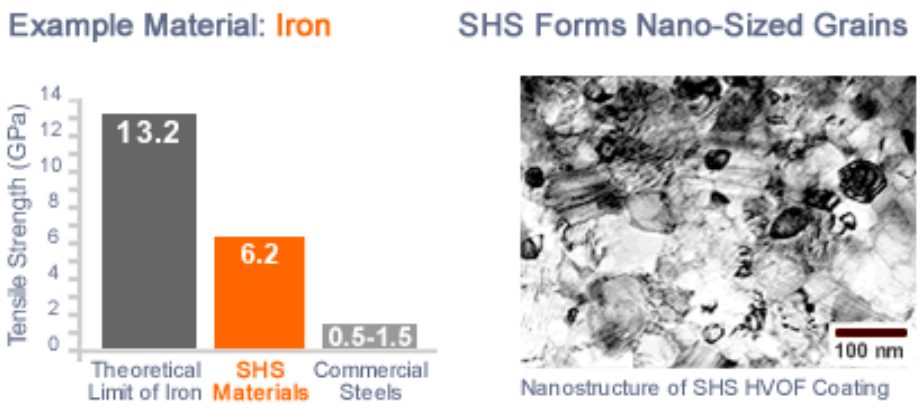
NanoSteel Co. was founded in 2002 as a spin-off from the Idaho National Laboratory. It holds more than 150 licenses, patents, and patent applications, including an exclusive worldwide license to nanostructured iron-based alloys developed by the DOE. The company's platform technology has received five R&D 100 Awards from *R&D Magazine*, and NanoSteel Co. has introduced more than 15 first-generation proprietary coating alloys that can be applied to steel substrate as thermal sprays and weld overlays. A weld overlay is essentially overlaying carbon or another alloy steel onto a pressure vessel to help protect it from corrosive elements.

Today, NanoSteel Co. produces metallic coatings for thermal spray and weld overlay applications as well as formed products incorporating these technologies for specific uses in environments that require high corrosion, wear, temperature, and impact resistance. Using its SHS steel alloys, NanoSteel Co. also develops sheet steel, steel plates, and structural steel members with applications in the construction industry. The company maintains that its products are stronger than current steels and feature attributes that improve resistance to wear and corrosion and offer a longer service life than conventional alloys.

Essentially, the company has developed materials that combine the toughness of steel with the hardness of carbides, allowing customers to select the appropriate material to perform in extreme service environments where severe wear and impact may pose costly problems. Moreover, due to dimensional microstructure defects in normal conditions, there is often a significant difference between the theoretical maximum strength of a material—based on the strength of its atomic bonds—and the actual strength exhibited in real life.

For example, based on metallic bonding properties, the theoretical tensile strength of iron (which is the base material of NanoSteel Co.'s SHS alloys) is calculated at 13.2 gigapascals (GPa). However, the actual tensile strength of commercial iron-based steel alloys is only 0.5 GPa to 1.5 GPa (Source: *Journal of Materials Engineering and Performance* 2005). In contrast, NanoSteel Co.'s next-generation SHS alloys are able to exhibit tensile strength levels of approximately 6.2 GPa, as shown in Figure 21.

Figure 21
THE NANOSTEEL COMPANY, INC.



Source: The NanoSteel Company, Inc.

NanoSteel Co. believes that the use of iron-based alloys provides a competitive advantage over other steel alloy options. While many new techniques have focused on the use of costly, rare, and exotic raw materials to create alloys, NanoSteel Co.'s approach is to further explore iron using new technologies because iron is an abundant and readily available raw material used in a wide variety of industrial applications with well-understood manufacturing methods. The company reports that this strategy creates a competitive advantage derived from lower raw material and manufacturing costs. In addition, NanoSteel Co.'s alloys are environmentally friendly and recyclable with minimal environmental impact.

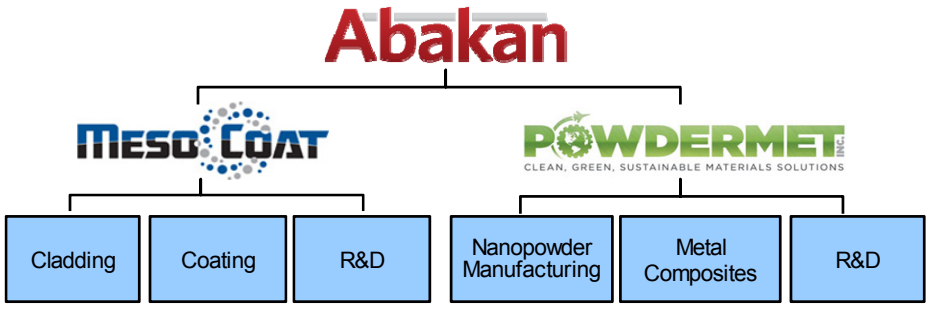
As a private company, NanoSteel Co.'s sales figures were not publicly available. Investors with a stake in NanoSteel Co. have included Chrysalix Energy Venture Capital, Cycad Group, LLC, EnerTech Capital, Fairhaven Capital Partners, MILCOM Technologies, Inc., and Octane Venture Partners.

Abakan, Inc.

Abakan (ABKI-OTC), formerly Waste to Energy Group, Inc., is an acquisition company that invests in and provides managerial and intellectual support to innovative companies, with a focus on corporations that have developed transformational surface modification solutions and technologies. Abakan targets the metal protection and material life extension market by investing in early stage, next-generation companies capitalizing on advanced materials technologies.

Abakan holds a 41% interest in Powdermet, Inc. (www.powdermetinc.com), a nanotechnology and advanced materials R&D organization based in Euclid, Ohio, as well as a controlling interest (71.1% of shares with a contractual right to increase its ownership to 75%) in MesoCoat Inc. (www.mesocoat.com). MesoCoat, a subsidiary of Powdermet, is a nanotechnology materials science company focused on metal protection and repair. Figure 22 depicts Abakan's holdings.

Figure 22
ABAKAN'S HOLDINGS



Source: Abakan, Inc.

Formed in 1996, Powdermet creates metallic and ceramic nanopowders for coating and cladding applications. The company has benefitted from over 80 government-sponsored grants. Currently, it is transitioning from a nanopowder R&D laboratory into a commercial business. Powdermet has developed multiple technology platforms to improve materials' properties, such as reducing weight, resource consumption, environmental footprint, and lifecycle costs, and improving manufacturing and energy efficiencies.

Abakan

Abakan, Inc.
2665 Bayshore Drive,
Ste. 450
Miami, FL 33133
Phone: (786) 206-5368
Fax: (786) 347-7706
www.abakaninc.com

These platforms include PComP™, a nanocomposite ceramic-metallic (**cermet**) powder designed to replace toxic chrome plating alternatives and provide improved wear and corrosion resistance. PComP™ is sold exclusively through MesoCoat. Powdermet's additional product lines include SComP™, a family of light-weight metal and ceramic composites with an ability to absorb energy; MComP™, metal micro-nanocomposites with high strength-to-weight ratios and toughness; and ENComP™, nanocomposites for energy applications. Many of Powdermet's products are sold to and rebranded by multinational companies.

Initially created to commercialize Powdermet's PComP™ suite of powders and technologies, MesoCoat is an Ohio-based coating and cladding company. Its CermaClad™ brand, a complete metal cladding solution, entails a process where a layer of corrosion-resistant alloy or composite material is atomically bonded into a continuous structure onto the substrate (normally carbon steel). The materials used in the CermaClad™ process include cermet and metallic nanopowders that combine costly alloys and inexpensive filler materials intended to deliver enhanced protection at a low cost. MesoCoat maintains that the structure and low ductility of CermaClad™ results in improved surface bonding and near 100% deposition of materials—versus 50% to 60% deposition efficiency of currently used cladding—which reduces waste and generates material savings of approximately 25%. CermaClad™ products in development today primarily use carbon and low alloy steel as the substrate.

MesoCoat believes that CermaClad™ is applicable to large metal structures, not only replacing existing cladding but expanding the technology to areas where it overcomes economic or logistic concerns. CermaClad™ is employed for aerospace and defense, oil and gas, infrastructure, and marine industries, and may be beneficial at replacing the **epoxy** paints and coatings normally used in bridges and other structural steels. MesoCoat has received three R&D 100 awards, the NorTech Innovation Award, and the Technology Innovation Program (TIP) Award through the U.S. National Institute of Standards and Technology. In addition to holding 14 patents and patent applications globally, MesoCoat owns exclusive rights to the engineered nanocomposite coating structures and high-energy density fusion cladding technology.

Going forward, Abakan intends to evaluate further acquisition opportunities. The company seeks to establish a portfolio of brands dedicated to solving critical industry problems, and believes that key acquisition targets will likely possess more than one market solution, established R&D programs, and possibly pilot-scale production. Concomitant with its investment, Abakan provides its technology-centric portfolio companies with its own corporate strategy, market development, licensing, and contracted support. Abakan is presently a development-stage company, and did not report any revenues for the fiscal years ended May 31, 2011 and 2010. Including subsidiaries and consultants, the company employs approximately 50 individuals.

MMFX Technologies Corporation

Founded in 1998, MMFX is a material science company formed to commercialize its proprietary micro and nanotechnologies that enable the manipulation of microstructures to improve mechanical properties. The current focus for MMFX is the application of its technology to uncoated steel, creating a nanostructured steel with increased strength and resistance to corrosion.

MMFX Technologies Corp.
2415 Campus Drive,
Ste. 100
Irvine, CA 92612
Phone: (949) 476-7600
or (866) 466-7878
Fax: (949) 474-1130
www.mmfx.com

The company has corporate headquarters in Irvine, California, as well as facilities in Florida and Oregon. MMFX operates through several wholly owned subsidiaries, including the following: (1) MMFX Steel Corp. of America, which commercializes concrete reinforcing steel products based on the company's proprietary technology; and (2) MMFX International Holdings, Inc. for global operations.

The company has developed "MMFX 2 steel," a low-carbon, chromium alloy uncoated steel that is produced using a controlled-rolling production process (i.e., rolling steel within a well-defined temperature range and cooling it at a specific rate). The nanostructure of MMFX 2 steel is designed to reduce or eliminate carbides, chemicals that are recognized as contributing to corrosion in steel. In addition, MMFX 2 steel forms a surface-layer chromium oxide barrier—the same mechanism that protects stainless steel—resulting in a resistance to corrosion similar to stainless steel but believed to be lower cost.

MMFX's materials have been tested by the U.S. Federal Highway Administration, U.S. Department of Transportation, and various other agencies and universities. Such tests have validated the improved corrosion performance of MMFX 2 steel. Corrosion test results indicate that MMFX 2 rebar has five times the resistance to corrosion of common rebar steel specifications and performed 1.75 times better than stainless steel, also outperforming epoxy-coated steel reinforcements.

The primary application of MMFX 2 steel is uncoated, corrosion-resistant, high-strength concrete reinforcing steel rebar. MMFX 2 reinforcing steel rebars hold an American Society for Testing and Materials (ASTM) specification of 100 ksi and 120 ksi, indicating that they have greater strength than historically required for conventional steel, which customarily dictates 60 ksi. In many applications, the added strength of MMFX 2 steel results in a significant decrease in the amount of steel required, substantially reducing project costs from material and labor.

MMFX 2 rebar has five times greater resistance to corrosion than common rebar steel.

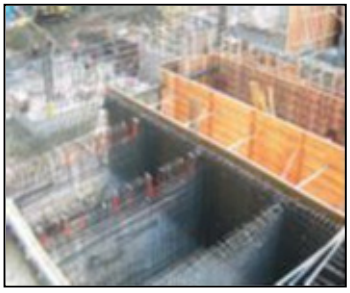
MMFX 2 rebar has been used in public infrastructure and public and private development projects across the U.S., Puerto Rico, Abu Dhabi (United Arab Emirates), Bahamas, and Canada for bridges, highways, marine facilities, parking structures, high-rise structures, and residential and commercial real estate projects. Figure 23 (page 47) illustrates several of MMFX's construction projects using its advanced steel products as well as highlights the strength of the company's engineered rebar versus traditional rebar. As shown on the right side of Figure 23, both constructions—conventional steel and MMFX steel—have equivalent strength although MMFX steel requires less material.

In August 2011, MMFX emerged from Chapter 11 bankruptcy reorganization. The company's ownership now includes PP Equity Holdings, LLC, White Strategic Master Fund, LP, and Investment Funding, Inc. The company holds seven U.S. patents and approximately 350 patent applications worldwide. As a private company, MMFX's sales figures were not publicly available.

Figure 23

A SELECTION OF CONSTRUCTION PROJECTS THAT HAVE USED MMFX 2 STEEL

California Academy of Science, San Francisco, CA



Strength Comparison

Conventional Steel MMFX Steel

Escala Condominiums, Seattle, WA

Gulf State Park Fishing Pier, Gulf Shores, AL

Causeway Bridge, Jensen Beach, FL

Source: MMFX Technologies Corporation.

Smart Grid Technologies

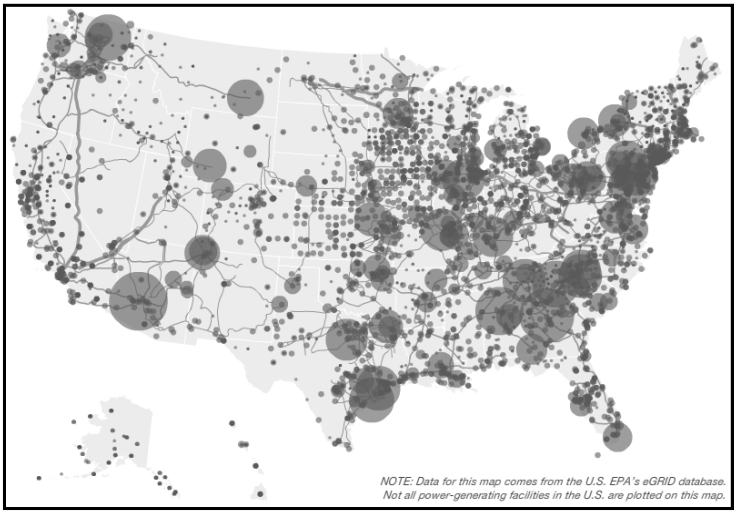
A "smart grid" delivers power to consumers using intelligent equipment and digital technologies. It is often capable of advanced monitoring and self-repair.

The U.S. power grid encompasses a network of independently owned power plants, power lines, and other infrastructure, as illustrated in Figure 24. Much of this infrastructure is aging and still relies on technology from the 1960s (Source: *National Geographic*, July 2010). Rising domestic electricity consumption combined with high-tech, energy-efficient innovations in the built environment are leading governments and industry alike to devote resources toward the development of a next-generation, advanced power grid known as the "smart grid."

Figure 24

VISUALIZING THE U.S. ELECTRIC GRID: POWER PLANTS

Sized with respect to each plant's annual net power generation



Source: NPR's data from the U.S. EPA's eGRID database (www.npr.org/series/103281114/power-hungry-reinventing-the-u-s-electric-grid).

Smart energy management entails using digital technologies and computer intelligence to transform the existing power grid infrastructure into a smart grid. This next-generation power grid connects utility companies and consumers to devices on the grid, such as power lines, meters, transformers, and home appliances that have Internet Protocol (IP) addresses.

With this type of networking functionality, the components on the grid are capable of two-way communication, both receiving power and commands from the utility company as well as relaying information to the utility about energy usage, service interruptions, equipment failure, and other data.

If the U.S. power grid were just 5% more efficient, the energy savings could equate to eliminating the fuel and greenhouse gas emissions of 53 million cars.

While at present, a utility company may often only know about a service outage because a customer has reported it, in a smart grid, the utility would know immediately that service is interrupted because certain components (e.g., smart meters) stop sending data. This enables power companies to be proactive about maintenance and response times. Likewise, while utility workers have traditionally read meters in person, smart meters do not require meter readers as these devices automatically collect and send data to the power company. Receiving real-time data on energy usage, especially during peak use times, allows utilities to more efficiently manage power distribution.

The U.S. DOE has allocated billions of dollars for smart grid and related technology deployments.

Essentially, smart grid technologies are those that combine traditional power hardware with sensing and monitoring technology, information technology, and a communication network to enhance electrical grid performance and support additional services to consumers (Source: the Southern States Energy Board). By 2015, smart grid data analytics services are expected to generate $4.2 billion in annual revenue as utility companies prioritize more efficient energy management (Source: CNET, August 24, 2011). The market for smart products connected to the grid is also expanding, with 40 million U.S. homes forecast to have smart meters by 2015. Factors driving smart grid adoption are described below.

Government Support

In the past several years, the DOE has allocated billions of dollars to utilities deploying smart grids and the related technology developers, such as global smart grid solutions company, California-based Silver Spring Networks, Inc. (profiled on pages 51-52) (Source: *Forbes*, July 7, 2011). While not yet profitable, Silver Spring, which sells smart grid products and services to utility companies, reported revenues in 2010 of over $70 million, up from $3.3 million in 2009.

Specifically, in 2009, the U.S. government allocated $3.4 billion in smart grid investment grant awards as part of the American Reinvestment and Recovery Act, which were expected to be matched by industry funding for a total public-private investment in advanced power grid projects valued at over $8 billion (Source: *Wall Street Journal*, October 28, 2009).

Improved Energy Efficiency and Environmental Impact

Smart grid technologies are geared toward increasing the efficiency of the power grid. Using a smart grid to deliver electricity from suppliers to consumers via digital technology has been found to save energy, reduce costs, and increase reliability. For example, the DOE has estimated that if the U.S. power grid were just 5% more efficient, the energy savings could equate to permanently eliminating the fuel and greenhouse gas emissions of 53 million cars. Furthermore, a fully deployed national smart grid could reduce U.S. carbon emissions by 12% by 2030, representative of eliminating 66 power plants (Source: *Fast Company*, April 1, 2010).

Growth of Technology Providers

Silver Spring Networks, Inc., a company targeting the rapidly expanding smart grid space, filed for an IPO in July 2011.

Silver Spring is profiled on pages 51-52.

The smart data analytics space is composed of well-known companies, such as Accenture plc (ACN-NYSE), Hewlett-Packard Co. (HPQ-NYSE), IBM Corp. (IBM-NYSE), Microsoft Corp. (MSFT-NASDAQ), Oracle Corp. (ORCL-NASDAQ), SAP AG (SAP-NYSE), and Siemens, as well as newer specialty companies focusing primarily on software for smart energy management.

As the smart grid market builds momentum, these specialty companies have considerable growth potential, which may include IPOs, acquisition targets, or strategic partnerships with global firms. To this extent, Silver Spring Networks has already filed its registration statement with the SEC for an IPO potentially valued at $150 million.

In May 2011, Toshiba Corp. (6502-TSE) entered into a definitive sale agreement with global smart metering company, Landis+Gyr AG, under which Toshiba acquired Landis+Gyr for $2.3 billion in cash to build an integrated smart grid company. Similar transactions include Johnson Controls' July 2011 acquisition of smart grid company, EnergyConnect Group, Inc., for over $32 million, and Honeywell's May 2010 acquisition of California-based Akuacom, a supplier of automated demand response technology and services for the smart grid. Large-cap companies have also entered into partnerships with tech startups, such as Siemens' ongoing relationship with Tendril Networks Inc. (described on page 53) and Honeywell's supply agreement with EnergyHub Inc., under which Honeywell has integrated EnergyHub's home energy solutions into its energy management product portfolio.

Other industries may benefit from advanced energy management technologies as well. Toyota Motor Corp. (TM-NYSE), for example, intends to launch a smart electric power system for charging electric vehicles by 2012 (Source: U.S. Energy Information Administration's *International Energy Outlook* 2011).

Empowered Consumers Can Be Proactive at Reducing Energy Consumption

Because smart grid platforms capitalize on IP infrastructure, they have an added benefit for utilities of increasing the level of customer engagement, and thus, overall customer satisfaction, as utilities can implement new services to allow customers to better understand their home or property's energy usage. To this extent, the success of smart grid infrastructure has been found to be dependent upon consumer participation, which is increased when consumers are provided an intuitive user interface to view and control their energy use, such as that provided by Virginia-based Opower, Inc. (profiled on pages 55-56) (Source: CNET, August 24, 2011).

Opower, Inc., profiled on pages 55-56, is addressing the need for consumer engagement tools to manage buildings' energy consumption.

By empowering consumers to manage and understand their own energy consumption and by improving utilities' efficiencies, many countries are likely to emphasize modernizing the power grid as a method to address energy independence and environmental concerns (e.g., global warming and greenhouse gas emissions). As cited by TechTarget, a knowledge base for enterprise IT professionals, the DOE anticipates the following key technologies to continue driving the advancement of smart grids:

- integrated, automated communication between components of the electric grid;
- sensing and measurement technologies;
- automated controls for distribution and repairs; and
- improved management dashboards and decision support software.

Silver Spring Networks, Inc.

Silver Spring Networks, Inc.
555 Broadway Street
Redwood City, CA 94063
Phone: (650) 298-4200
or (866) 204-0200
Fax: (650) 251-4114
www.silverspringnet.com

Closely held Silver Spring Networks is a global smart grid solutions company, with corporate headquarters in California and international offices in Australia and Brazil. In July 2011, Silver Spring filed a registration statement for an IPO on the NYSE (under the symbol "SSNI") and anticipates raising up to $150 million.

Silver Spring functions as a bridge between utility companies and their customers, providing 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 reduce carbon emissions. A smart utility network facilitates communication between the utility and devices, including meters, load management controllers, and electric vehicle charging stations. Over time, Silver Spring's ability to quickly collect and manage energy consumption data and promptly spot and respond to outages or other problems in the electricity distribution network are expected to lead to lower operational costs for utility companies (Source: *Forbes*, July 7, 2011).

Believing that a smart grid should operate like the Internet, without proprietary networks built around single applications or devices, Silver Spring's Smart Energy Platform is an open, IP version 6 (IPv6)-based utility networking infrastructure that provides a foundation for the smart grid (which requires products/services from multiple technology providers to be interconnected). Silver Spring's smart grid initiatives are tailored to utility companies' project goals, service territory, terrain requirements, regulatory models, and operational structures.

For the first six months of 2011, Silver Spring reported revenue of over $115 million—significant growth from revenues of $70 million for the entirety of 2010.

The Smart Energy Platform includes intelligent endpoints and network infrastructure to collect and send information to the back office. Endpoints, such as the meter or distribution automation devices (e.g., **switches**), are configured with Silver Spring's Communications Module to relay information and quickly isolate and route around power failures. Silver Spring software also includes a customer interface, called the CustomerIQ™ web portal, for customers to view consumption and pricing and manage their 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.

In August 2011, Silver Spring announced that it was expanding its functionality from electric and gas metering into water meters as well, which follows the company's move earlier in August into the UK market through a partnership with Cable&Wireless Worldwide (CW-LSE). Silver Spring is now also integrating Freestyle Technology Pty. Ltd.'s smart water meter module with its Smart Energy Platform. The company anticipates that this combination can reduce meter reading costs, spot water leaks and backflow more quickly, cut estimated billings, and improve billing accuracy.

Since its inception in 2002, Silver Spring has been contracted to network more than 17 million Silver Spring-enabled devices that connect homes and businesses, of which eight million were completed as of June 30, 2011. The company has deployed its system to more than 16 utility companies globally, including Florida Power & Light Company (FPL) (a subsidiary of NextEra Energy, Inc. [NEE-NYSE]), Pacific Gas and Electric (PG&E) Company (PG&E Corp. [PCG-NYSE]), Public Service Company of Oklahoma (part of American Electric Power Company, Inc. [AEP-NYSE]), Australia's Western Power, and Baltimore Gas and Electric Company (BGE), among many others.

For the first six months of 2011 (ended June 30, 2011), Silver Spring reported revenue of over $115 million, up from $70 million for the entire year of 2010. At June 30, 2011, the company employed 593 individuals.

Silver Spring is led by a management team with decades of experience in diverse roles within the utilities and cleantech industries, complemented by individuals who come from venture capital and academic backgrounds. As summarized in Table 4, the business has received a number of awards and recognitions over the past several years for innovation and field deployments.

Table 4

A SELECTION OF SILVER SPRING NETWORKS' AWARDS AND RECOGNITIONS

- 2011 Global Cleantech 100 List
- Inaugural EMC Data Hero Award - Energy
- 2011 TR50 List of the World's Most Innovative Companies
- Think London - '100 Companies to Watch' list for 2011
- Frost & Sullivan's 2010 North American Technology Leadership of the Year Award
- 2010 Global Cleantech 100 Company
- CNBC 2010 Top 15 Green Tech Startups - #2
- The *Wall Street Journal's* Top 10 Venture-Backed, Clean Technology Companies
- Greentech Media's Top 50 VC-Funded Greentech Startups
- *Fast Company* - 2010 Most Innovative Companies: Energy
- 2010 GridVision Awards
- *CRO's* Responsible CEO of the Year
- The Carbon Trust: CleanTech 100
- Ernst & Young Entrepreneur of the Year
- Best of Green Winners
- AlwaysOn Global 250 Winners
- World Economic Forum's Technology Pioneer 2008
- Red Herring Top 100 Technology Company
- Greentech Media's Top Ten Startups
- Brilliant Innovations Award for Leadership in Sustainability
- AlwaysOn Going Green 100 Award for Energy Efficiency

Source: Silver Spring Networks, Inc.

Tendril Networks Inc.

Tendril Networks Inc.
5395 Pearl Parkway,
Ste. 100
Boulder, CO 80301
Phone: (303) 951-4360
Fax: (303) 926-1398
www.tendrilinc.com

Tendril is a closely held smart grid company operating out of Boulder, Colorado. The company has developed and launched a cloud-based energy platform called Tendril Connect™, an open, secure, scalable network to link energy service providers with customers.

The Tendril Connect™ energy management platform includes utility applications for demand response, load control, electric vehicles, and distributed generation. It also offers a novel interface for the customer's **home area network (HAN)**, which allows consumers to track energy costs and consumption by appliances, electronics, and household devices. Information collected by Tendril's HAN products (e.g., the Tendril thermostat, the Tendril Volt smart outlet) is accessible online via the Tendril web portal or through the company's iPhone and Android™ apps.

Tendril Connect™ is an open, standards-based network allowing interchangeable technology and third-party integration. To this extent, a range of companies from New York-based ThinkEco, Inc. (www.thinkecoinc.com) to Siemens have built upon Tendril's platform for energy services. To expose the platform to more developers, Tendril co-sponsored the Cleanweb Hackathon event in September 2011 in San Francisco, California, where software and app developers were given access to the Tendril Connect™ Application Programming Interfaces (APIs) in order to create new functionalities and products based on the platform (Source: CNET, August 24, 2011).

The company believes that its end-to-end consumer engagement products, software, applications, and services entail easy-to-integrate solutions for utility companies that can facilitate better energy decisions. Tendril aims to help 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 usage and costs.

To date, approximately 35 utility companies are deploying the Tendril Connect™ energy management platform.

As of October 2011, Tendril reported that its platform was in use by over 35 energy service providers, which provide power to roughly 70 million homes (Source: Tendril's October 18, 2011, Press Release). The company has forecasted reaching a million homes by the end of 2011, with the ability to ultimately reach 70 million households connected to a smart grid.

In October 2010, Tendril acquired Newton, Massachusetts-based GroundedPower, Inc. to augment the company's personalized energy management offerings. Also during October 2010, Tendril initiated a private placement for total proceeds between $20 million and $30 million. Tendril is backed by venture capitalists, namely VantagePoint Capital Partners, Siemens Venture Capital GmbH, Good Energies, RRE Ventures LLC, and GE. Subsequently, in June 2011, the company received funding from Siemens Venture Capital for an undisclosed amount.

Founded in 2004, Tendril employs over 130 people (as of June 2011) (Source: *Bloomberg BusinessWeek* and the *Boulder County Business Report*). As Tendril expands, it is hiring approximately 10 to 15 employees a month (Source: Greentech Media, Inc., September 5, 2011). In 2011, Tendril was included in the Global Cleantech 100 list for the third consecutive year. As a private company, Tendril's sales figures were not publicly available.

Serious Energy, Inc.

California company Serious Energy, which is profiled on pages 30-31 for its next-generation, energy-efficient window technologies, also offers the "SeriousEnergy Manager" for the smart microgrid—a localized grid such as is employed at a university campus or commercial facility. While not a public company, Serious Energy, which combines real-time building analytics with material science innovations, may become an IPO candidate during 2012.

SERIOUS ENERGY

Serious Energy, Inc.
1250 Elko Drive
Sunnyvale, CA 94089
Phone: (408) 541-8000
or (800) 797-8159
www.seriousenergy.com

The SeriousEnergy Manager entails a cloud-based enterprise software program using advanced algorithms for monitoring, optimizing, and controlling building energy use. It is a method of smart energy management that allows building managers to comprehensively evaluate overall energy consumption. The software supports building and quality standards, such as the newly released ISO 50001 (June 2011), and provides actionable recommendations for optimizing and reducing energy usage, thereby leading to reduced operating costs. The SeriousEnergy Manager can be employed by commercial office buildings, schools, university campuses, government facilities, retail operations, and property managers in support of smart microgrids.

Because it is a cloud-based approach, the SeriousEnergy Manager lowers upfront costs as there are no servers to install. As well, Serious Energy offers a long-term financing arrangement where building owners pay their energy bills to the company and the company pays the energy providers, dividing the savings with the building owners (Source: SmartGridNews.com, June 14, 2011). The company estimates that the payback time for establishing its smart energy technology is approximately 6 to 24 months.

Serious Energy is also pioneering new techniques to improve the energy efficiency and reduce the cost of windows.

See pages 30-31 for more information.

The SeriousEnergy Manager is designed as a total enterprise solution that goes beyond solely monitoring and managing energy operations, to include building analytics and adaptive learning functionalities. Use of this smart platform may lead to energy savings as well as tenant and occupant satisfaction; saved time compared to manual energy tracking, reporting, and budgeting; extended life of mechanical systems; better management of EPA benchmarking, carbon reporting, and ISO 50001 certification; and an improved ability to measure and track the return on investment of retrofit measures and capital investments; among other key benefits. Serious Energy estimates that the use of its software can reduce energy costs by up to 30%.

To date, the SeriousEnergy Manager has been employed in over 60 buildings. Worldwide, Serious Energy's products have been installed in over 70,000 projects, including the Empire State Building (as described on pages 11-12). Subsequently, Serious Energy was selected as part of Deloitte's 2011 Technology Fast 500™. In July 2011, the company released SeriousEnergy Manager 3.1, which enhances the prior version by including greater building intelligence reporting capabilities, advanced fault detection and diagnostics for heating, ventilation, and air conditioning (HVAC) equipment, and more sophisticated monitoring and analytics applications.

In November 2011, Serious Energy acquired Agilewaves, Inc., a building energy management technology firm, with plans to integrate Agilewaves' Building Optimization System (BOS) into Serious Energy's platform.

Opower, Inc.

Opower, Inc.
1515 N. Courthouse Rd.,
8th Floor
Arlington, VA 22201
Phone: (703) 778-4544
Fax: (703) 778-4547
www.opower.com

Opower, an energy information software company founded in 2007, has corporate headquarters in Virginia and West Coast offices in San Francisco, California. The company has developed a software platform that uses behavioral science and patent-pending analytics to drive energy efficiency gains on a large scale and provide targeted energy data and recommendations to utilities' customers.

Opower's core business is its customer-engagement tools, which are only available through utility companies. These include home energy reports; energy alerts; and an online portal. 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 2011, the company furthered its position in the smart grid market through the achievement of several business milestones, as summarized below.

- Opower's product and services deployment led to an estimated savings of over 400 gigawatt hours and over $50 million on consumers' energy bills as well as the abatement of more than 500 million pounds of CO_2.
- The company expanded into the UK market with the announcement of First Utility (www.first-utility.com) becoming its first UK utility partner.
- It was awarded smart grid contracts for major U.S. utility companies, Pacific Gas and Electric (PG&E) and Baltimore Gas and Electric (BGE).
- Opower was named as one of the U.S.'s Top 10 Clean-tech Companies by the *Wall Street Journal*, and was named to the 2011 Global Cleantech 100 list.
- The company was selected as one of five companies to lead in 2011 by the *Washington Post*.

Opower is partnered with Honeywell International, a leader in building management, for the joint development of new energy management tools for consumers.

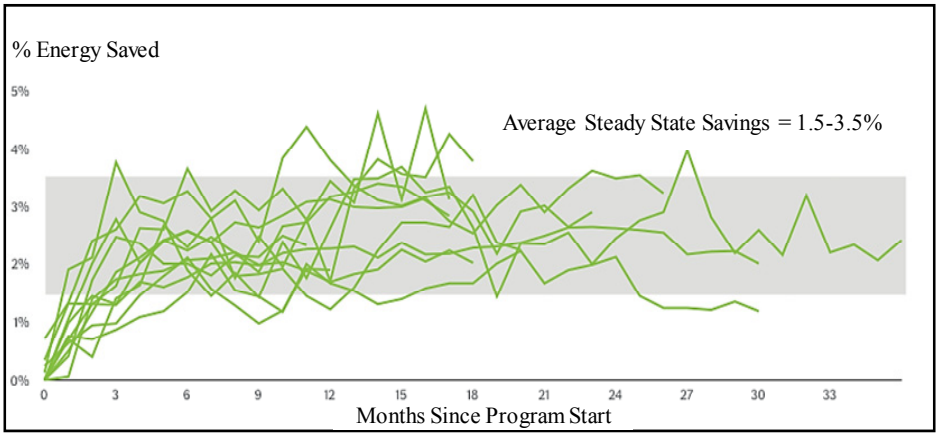
Honeywell is profiled on page 16.

As illustrated in Figure 25 (page 56), the company's information-based energy efficiency approach has shown to consistently result in energy savings in the realm of 1.5% to 3.5%, which can add up to significant numbers for a utility company under strain (Source: Opower). Opower reports that its data is independently verified by industry analysts, academics, and nonprofit organizations, such as the American Council for an Energy-Efficient Economy (ACEEE) and Environmental Defense Fund (EDF).

As of November 2011, Opower's platform reached over 10 million homes via more than 60 utilities, including eight of the U.S.'s ten largest utility companies. On September 13, 2011, the company announced a key partnership with Honeywell for the joint development of energy management tools for consumers. This relationship seeks to capitalize on Opower's expertise in energy data analytics and customer engagement techniques and Honeywell's residential automation and control systems knowledge. Initially, Opower and Honeywell plan to launch web-connected programmable thermostats. Through a web portal, customers can not only access their home or building's thermostat and view their energy usage but also view and automatically implement suggested cost-saving changes as well as view equivalent data from similar families in the same geography as a benchmark. Further, the company partnered with Facebook and the Natural Resources Defense Council (NRDC) to develop a new social energy application to raise awareness of energy consumption.

With over 200 employees, Opower is a closely held company backed by the following venture capital firms and angel investors, as listed on the company's website: Accel Partners, Founder Collective, Kleiner Perkins Caufield & Byers, MHS Capital, New Cycle Capital, New Enterprise Associates, and serial entrepreneurs, Ali and Hadi Partovi. The company has raised approximately $65 million in funding (Sources: *Wall Street Journal* [April 7, 2011] and CapitalIQ). However, as a private company, Opower's sales figures were not publicly available.

Figure 25
Opower, Inc.
COST-EFFECTIVE ENERGY SAVINGS: CONSISTENT, SUSTAINED SAVINGS ACROSS ALL GEOGRAPHIES



Source: Opower, Inc. (http://opower.com/utilities/results).

Water Treatment

Nanomaterials are being developed into effective and affordable water treatment systems.

The global market for water treatment equipment and supplies is projected to reach $38.2 billion by 2015, driven by increasing demand for fresh, potable water created by an expanding global population, as well as by needed repairs to aging existing infrastructure (Source: Global Industry Analysts' *Water Treatment Equipment and Supplies: A Global Strategic Business Report*, 2010).

There are multiple methods for purifying and treating water. Conventional techniques, such as filtration and ultraviolet (UV) disinfection, accounted for 76% of the market in 2010. However, newer distillation systems, such as membrane-based separation technologies, which can remove a broader range of contaminants compared to conventional filters, are expected to grow at a greater rate (Source: Freedonia Group's *Consumer Water Purification & Air Cleaning Systems to 2014*, 2011).

The global market for nanostructured products used in water treatment is forecast to reach $2.2 billion by 2015.

Nanomaterials are being developed with properties conducive to water filtration, in particular, small pore size, highly specific surface areas, and high permeability and porosity. Such initiatives could result in more effective, efficient, durable, and affordable approaches to removing pollutants than current methods (Source: *Critical Reviews in Microbiology* Vol. 36[1]:68-81, 2010). Several water treatment devices that incorporate nanotechnology are already being marketed, including nanofiltration membranes and active carbon and polymer filters, with more in development. For example, both nanofiltration and reverse osmosis (commonly used filtration methods) use membranes with pore sizes of less than 1 nm. The global market for nanostructured products used in water treatment was estimated at $1.4 billion in 2010, forecast to reach $2.2 billion by 2015 (Source: BCC Research's *Nanotechnology in Water Treatment*, 2011).

Moreover, nanomaterial-based water treatment technologies, either newly developed materials or existing materials refined on a nanoscale, may help solve the technical challenges faced by current water treatment processes, including biofouling. Biofouling occurs when a harmful biofilm of microorganisms, such as bacteria, fungi, and algae, forms on the filter or membrane surface, and impairs the filter's ability to operate. The unique characteristics of nanomaterials lend these technologies to the creation of membranes with improved permeability, selectivity, and resistance to fouling.

Calgon Carbon Corporation

Pennsylvania's Calgon Carbon (CCC-NYSE) is a global manufacturer and supplier of activated carbon and other innovative water and air treatment systems. Calgon Carbon's technologies are used in over 700 distinct market applications from purifying air, drinking water, food, and pharmaceuticals, to separating gas and removing mercury emissions from coal-fired power plants.

Calgon Carbon Corp.
P.O. Box 717
Pittsburgh, PA 15230
Phone: (412) 787-6700
Fax: (412) 787-6676
www.calgoncarbon.com

The company offers a range of products, services, and equipment for the purification, separation, and concentration of liquids, gases, and other media. Calgon Carbon operates in three business segments: (1) activated carbon and services; (2) equipment; and (3) consumers. Activated carbon is a porous material that removes organic compounds from liquids and gases in a process known as "adsorption." In adsorption, unwanted organic molecules are attracted and bound to the surface of the pores of the activated carbon as the liquid or gas passes through. With advanced R&D capabilities, in addition to 16 carbon manufacturing, reactivation, and fabrication facilities, Calgon Carbon is believed to be one of the world's largest manufacturers of activated carbon. The company has a presence across North America, Europe, and Asia.

Calgon Carbon's activated carbon business accounted for more than 88% of its revenues in 2010. The segment primarily consists of the production and commercialization of activated carbons in granular, powdered, or pellet form, as well as reactivation and field support services. Calgon Carbon manufactures activated carbon by crushing, sizing, and processing **bituminous coal** in low-temperature kilns followed by high-temperature furnaces. Through adjustments in the activation process, pores of the required size and number for a particular purification application are developed. Calgon Carbon's technological expertise in adjusting the pore structure in this process is one of a number of factors enabling it to develop specialized types of activated carbon.

Publicly traded Calgon Carbon reported more than $143 million in sales for the quarter ended Sept. 30, 2011—a 15.5% increase over the same quarter in 2010.

Other important components of this segment are optional services associated with the company's carbon products, including carbon supply, equipment leasing, installation, maintenance, and spent carbon reactivation. The central component of Calgon Carbon's service business is the reactivation and re-supply of spent carbon. In the reactivation process, the spent carbon is subjected to high-temperature re-manufacturing conditions that destroy the adsorbed organics and return the activated carbon to usable quality.

Along with providing activated carbon products, Calgon Carbon offers a portfolio of standardized, pre-engineered systems that can be delivered and installed at treatment sites. The company 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.

Calgon Carbon, founded in 1942, possesses a substantial body of technical knowledge and trade secrets, holding 69 U.S. patents and patent applications as well as 274 patents and patent applications in other countries as of February 2011. The company had 1,070 employees at December 31, 2010.

For the most recently reported quarter (ended September 30, 2011), Calgon Carbon had net sales of over $143 million, a 15.5% increase over the comparable period in 2010.

Specialty Materials/Situations

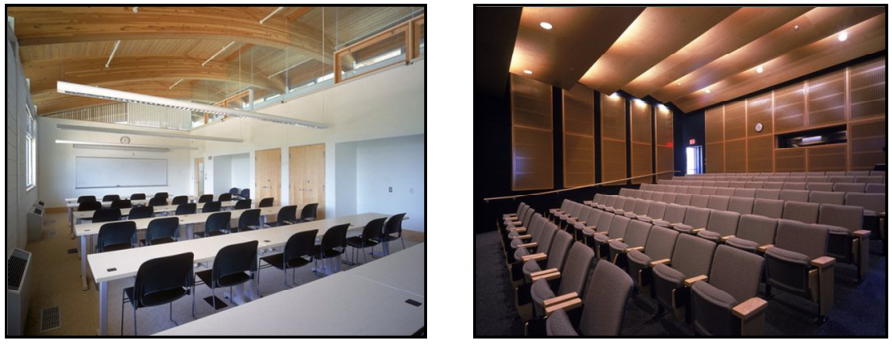
Next-generation building materials include stronger, lighter titanium, ecofriendly plastic additives, and many other new resources.

In addition to the advancements being made in traditional building products—for example, concrete, cement, and steel—nanotechnology has enabled the refinement of an array of other specialty materials. Some of these, such as titanium, have been employed in manufacturing for decades but are now being optimized for new uses in the built environment, among other sectors. Other materials, such as advanced polymers from FRX Polymers, Inc. (profiled on pages 64-65), have recently come into focus as innovative additives to improve the mechanical and flame-retardant properties of existing plastic products as well as to replace toxic chemicals that have previously been widely employed in plastics manufacturing. Figure 26 illustrates a classroom/auditorium at Oberlin College's Center for Environmental Studies in which recycled plastic chairs, sustainably harvested wood, and low-VOC paints and adhesives for improved indoor air quality have been employed. The accompanying pages detail several companies that are capitalizing on the use of next-generation nanotechnologies to create improved building products.

Figure 26

CLASSROOM/AUDITORIUM AT OBERLIN COLLEGE'S ADAM JOSEPH LEWIS CENTER FOR ENVIRONMENTAL STUDIES

Recycled plastic chairs, sustainably harvested wood, and low-VOC paints and adhesives for improved indoor air quality



Source: National Renewable Energy Laboratory.

Titanium Metals Corporation

Titanium Metals Corp.
5430 LBJ Freeway,
Ste. 1700
Dallas, TX 75240
Phone: (972) 934-5300
Fax: (972) 934-5345
www.timet.com

Texas-based Titanium Metals ("TIMET") (TIE-NYSE) is a global supplier of titanium metal products. The company is involved in every aspect of titanium supply, from research into next-generation properties to manufacturing, sales, and distribution. TIMET believes that it ranks among the world's largest titanium metal product suppliers. The company has world headquarters in Dallas, Texas, with additional corporate offices, R&D sites, and mill locations in Henderson, Nevada; Toronto, Ohio; Morgantown and Exton, Pennsylvania; England; South Wales; France; and Italy. It distributes titanium products directly from its mills as well as via international service centers.

Uses of titanium are widespread. The metal is employed for aerospace, industrial, and emerging applications. TIMET's target markets include industrial, aerospace, oil and gas, military armor, medical uses, sporting goods, architecture, and value chain applications for lean-driven OEM environments and longer-distance supply chains.

Among other partners and customers, TIMET has established a long-term titanium supply agreement with The Boeing Company (BA-NYSE). This supply agreement parallels other joint technology development agreements to specify mutual annual purchase and supply commitments, a global titanium scrap recycling program, and Boeing's use of TIMET's Global Service Center Network, as well as cooperative development efforts for new titanium alloys and processes.

TIMET produces titanium as its material of choice due to the metal's combination of strength, light weight, and resistance to corrosion, among other metallurgical properties. TIMET's plant in Henderson, Nevada, converts rutile ore—a black, yellowish, or reddish-brown mineral—to titanium sponge, which is a porous form of titanium that is created during the first stage of processing. The sponge undergoes further processing to remove impurities and is subsequently melted and combined with molten magnesium, iron aluminum, **vanadium** or **molybdenum** and **argon** in a very hot furnace to add strength and stability to the titanium sponge and create a pliable metal alloy. TIMET's Henderson plant has the capacity to melt up to 30 million pounds of **ingot** (a mass of metal) annually. The company's furnaces use **vacuum arc remelting (VAR)** technology, which TIMET has pioneered as triple VAR melting to produce titanium suitable for critical rotating jet engine quality specifications. The company continues to research new titanium production methods in order to develop new alloys to meet customer needs in the increasingly efficient and high-tech built environment.

Globally, TIMET operates other mills that specialize in additional types of titanium products. For instance, in Ohio, the company produces slabs, billets, and bars for strip and welded tube applications using what it believes is the only dedicated titanium strip rolling facility in the world. Similarly, TIMET maintains that its continuous vacuum **annealing** facility (a process of heating and slow cooling) is the only one of its type as well. In Pennsylvania, the company has integrated facilities for titanium scrap recycling and casting for specialty metals, such as for industrial and aerospace applications. A Welsh facility produces jet engine and medical titanium products that are used in some of the newest-technology jet engines.

TIMET was founded in 1950. As of December 31, 2010, the company had 2,385 employees. In 2010, full-year net sales totaled over $857 million, up from 2009 sales of $774 million.

In November 2011, TIMET reported net sales for the third quarter 2011 (ended September 30, 2011) of $262 million, up from $210 million in the corresponding prior year's period, driven by higher sales of melted and mill products.

Hexcel Corporation

Hexcel Corporation
281 Tresser Boulevard,
16th Floor
Stamford, CT 06901
Phone: (203) 352-6800
or (203) 969-0666
Fax: (203) 358-3993
www.hexcel.com

Headquartered in Connecticut, Hexcel (HXL-NYSE) is a global advanced composites company manufacturing lightweight, high-performance composites, including carbon fibers, reinforcements, pre-impregnated materials, honeycomb core, matrix systems, adhesives, and composite structures. These products are marketed for use in commercial aerospace, space, defense, and industrial applications, such as transport, sports equipment, alternative energy (notably, wind turbine blades), machinery, and tooling. Industrial markets, such as those that contribute to the built environment, are emerging opportunities for Hexcel.

The company seeks to supply advanced composite technologies for sectors where the technology significantly benefits the end user, which are often applications demanding high-performance engineering. Hexcel's manufacturing facilities are located in the U.S., Europe, and Asia, with sales offices in the U.S., Europe, Asia, Australia, and South America. Hexcel also holds 50% of a Malaysian composites manufacturer.

Hexcel emphasizes the continuous development of new technologies, capitalizing on nanotech to enhance the properties of materials used and created by the company. Hexcel states that it was the first to develop an adhesive for bonding metal to metal, and today continues to market novel adhesives, including Redux® Film Adhesives. Redux® encompasses epoxy, **phenolic**, and **bismaleimide** adhesives supplied as a film or roll for metal to metal and composite bonding. The bond formed by these adhesives is permanent, withstanding harsh environments and high temperatures. Primary Redux® applications are in the transportation, recreation, and construction industries.

Hexcel reported revenues of over $685 million for the first half of 2011—more than an 18% increase over the first half of 2010.

Additionally, Hexcel states that it was the first company to manufacture expanded honeycomb on a commercial scale. Honeycombs are a lightweight structural material made from a wide variety of materials, including **thermoplastic**, fiberglass, carbon, and aluminum mechanical papers. The company's HexWeb® honeycombs, of which Hexcel produces over 700 varieties, are designed for optimal stiffness and strength with little added weight. Honeycomb material can be used as an efficient energy absorber, for airflow control, sound attenuation, and **dielectric** applications.

The company is also known for its carbon fiber products, including HexTow® carbon fiber for composite tooling material, concrete reinforcement, and infrastructure repair. Due to the strength and performance capabilities of carbon fiber, this material holds new potential for energy generation and high-performance pressure vessels.

In July 2010, the company helped sponsor the Carbon 2010 conference held at South Carolina's Clemson University. The theme of the conference was to address advancements in nanocarbons that could lead to new applications of carbon materials, particularly in areas driving demand for these materials—energy and transportation. Hexcel showcased its HexTow® IM10 carbon fiber at the event, as this new product achieved over 1,000 ksi tensile strength performance, which the company believed represented the highest commercially available tensile strength.

Hexcel was founded in 1946. It had 4,043 employees at December 31, 2010, and revenues of nearly $1.2 billion. For the first half of 2011 (ended June 30, 2011), Hexcel reported net sales of over $685 million, an 18.4% increase from the first half of 2010.

Going forward, Hexcel plans to spend $150 million to $175 million on capital additions in 2011 as it prepares for anticipated growth (Source: Hexcel's Form 10-Q filed with the SEC on July 25, 2011).

A. Schulman, Inc.

With facilities across North and South America, Europe, Asia, and Australia, A. Schulman (SHLM-NASDAQ) is a multinational supplier of high-performance plastic compounds and resins used as raw materials in a variety of industries. The company's proprietary plastic compounds are custom formulated and include color concentrates and additives to improve the appearance and performance of plastic.

A. Schulman, Inc.
3550 West Market Street
Akron, OH 44333
Phone: (330) 666-3751
Fax: (330) 668-7204
www.aschulman.com

The company began as a processor of rubber compounds in 1928. Its initial focus was to create new formulations of existing rubber products in order to meet underserved market needs. By the 1950s, A. Schulman was capitalizing on newly emerging polymer science and has since expanded into Europe, Latin America, and Asia. Today, the company innovates new plastics technologies in order to expand upon the properties, production, and uses of existing plastic products.

A. Schulman believes that it holds the following competitive advantages: (1) products are tailored to customers' unique needs; (2) A. Schulman's global purchasing power enables it to formulate and sell products competitively; (3) it has roughly 35 manufacturing facilities worldwide for a global customer base; (4) the company has a reputation for product innovation and development driven by customer relationships and global technology centers; and (5) its financial position.

A. Schulman's core competency is its technology and manufacturing expertise in plastics and experience with resin additives and modifiers, which has enabled the company to enhance the performance, appearance, processing, customization, and production yields of plastic compounds. For the commercial and residential building and construction market, A. Schulman provides specialized, high-performance polymer compounds for both interior and exterior applications. Table 5 (page 63) summarizes the areas where the company's engineered plastics can be used in the built environment, as well as lists the key performance requirements that A. Schulman seeks to address with its novel plastic compounds.

Other markets targeted by A. Schulman include agriculture, appliance, coatings/adhesives, consumer and institutional products, electrical and electronics, energy, fluid management, industrial, lawn and garden, recreation, and transportation. The company holds several quality certifications, including ISO 9001, ISO 17025, ISO 14001, ISO/TS 16949, and ISO 18000.

For the fiscal year ended August 31, 2011, A. Schulman reported net sales of nearly $2.2 billion, up from $1.6 billion in fiscal 2010. Typically, a majority of the company's sales occur in markets outside of the U.S. The company employs approximately 3,000 people.

Table 5
A. Schulman, Inc.
BUILDING AND CONSTRUCTION USES OF SPECIALTY PLASTICS

Interior	
Key Performance Requirements	
▪ High strength and stiffness	▪ Resiliency (sealing performance)
▪ Low warping and CLTE	▪ Ability to be colored
▪ Heat resistance	▪ Low/high service temperature performance
▪ Creep and fatigue resistance	▪ Extrusion quality (no gels)
Applications	
▪ Blinds and shutters	▪ Residential and commercial glazings and seals
▪ Fan shrouds	▪ Expansion joints
▪ Blower wheels	▪ Window setting blocks
▪ Structural load-bearing components	▪ Door bulb seals

** CLTE = Coefficient of Linear Thermal Expansion (plastics property)*

Source: A. Schulman, Inc.

PURETi Inc.

PURETi Inc.
261 Fifth Avenue
New York, NY 10016
Phone: (212) 685-5400
www.pureti.com

Closely held PURETi Inc. is a U.S.-based enterprise that has patented and commercialized a series of ecofriendly, sustainable, surface treatments designed to self-clean, purify air, and eliminate odor. When applied to a surface, such as on a building, sign, solar panel, sidewalk, outdoor furniture, holding tank, boat, or plane, PURETi® treatments actively protect against the buildup of organic matter, including biofilms, bacteria, molds, and fungi. PURETi® water-based solutions air dry into clear, thin, durable coatings. PURETi Inc. states that the technology is supported by 13 international patents.

PURETi® is an aqueous solution holding nanoparticles of titanium dioxide (TiO_2) in a stable suspension (99% water, 1% TiO_2). The key to PURETi® coatings is that these surface treatments are powered by water-based ultraviolet photocatalysis (UV-PCO) technology. Thus, they use light, not chemicals, to create environmentally friendly, clean surfaces. The self-cleaning, air-cleansing, odor-eliminating properties of PURETi® are activated by UV light, including direct sunlight and ambient light as well as artificial fluorescent light.

The PURETi® solutions have been tested by an EPA-approved independent laboratory and were found to be free of toxicities, heavy metals, and volatile organic compound (VOCs). They have also been tested for cleaning effectiveness by the National Sanitation Foundation and other laboratories. These coatings are applicable to virtually any industry and are used by customers from automakers to vineyards. Target markets for PURETi® solutions include OEMs, transportation, building construction and restoration, and facility maintenance and operation.

The company maintains that its PURETi® products offer a range of benefits, including the following:

- surfaces need to be cleaned only half as often and cleaning is easier;
- cleaning maintenance costs are reduced by approximately 50% and the chemicals used in cleaning are considerably reduced;
- indoor and outdoor air quality is improved as smog, VOCs, and harmful greenhouse gases, such as methane, are reduced;
- organic malodors, such as tobacco smoke, fire damage, and human and agricultural waste, are removed;
- surface area repels water; and
- professional coatings that have shown long-term efficacy of up to three years in some instances.

The company offers different formulations based on the surface to be treated. PURETi Clean™ is intended for cement, stone, ceramic tile, painted walls, plastic, and metal. Light-activated PURETi Fresh can be applied to fabrics and textiles to help cleanse a room of objectionable organic odors and indoor air pollutants. Likewise, PURETi Clear can be used on any glass surface from OEM to aftermarket, including building windows, solar panels, LED screens, and residential glass fixtures.

The company is headquartered in New York with manufacturing operations in Michigan. PURETi is a member of the U.S. Green Building Council and can help building projects qualify for LEED credits. As a private company, PURETi's sales figures were not publicly available.

FRX Polymers, Inc.

Founded in 2007 after five years of R&D into flame-retardant plastics, Massachusetts-based FRX Polymers offers a line of fire-resistant plastics suited for use by consumer electronic, building and construction, and transportation markets. Additional customer bases for FRX's product lines are listed in Table 6 (page 65). The company has two operational pilot plants in Massachusetts and a pilot polymer plant in Switzerland that are producing at capacity.

In June 2011, closely held FRX raised over $15 million in a Series B equity financing. In addition to providing working capital, these funds were earmarked to partially finance deployment of the company's first commercial-scale manufacturing facility. FRX's investors include SAM Private Equity, Israel Cleantech Ventures, Capricorn Venture Partners, private investors from Western Canada, North Sky Capital, FRX's founders (including Triton Systems, Inc.), and company employees, among other groups.

FRX Polymers, Inc.
200 Turnpike Road
Chelmsford, MA 01824
Phone: (978) 244-9500
Fax: (978) 250-4533
www.frxpolymers.com

Table 6
A SELECTION OF MARKETS FOR FRX'S PRODUCTS

- Building/Construction
- Construction/Lighting
- Electrical/Electronic
- Textiles
- Transportation

Source: FRX Polymers, Inc.

The plastics created at FRX are durable and transparent with a high melt flow, which is a measure of the ease of flow of the melt of a thermoplastic polymer. Moreover, FRX's ecofriendly polymers are non-halogen, as the company intends for its products to represent an alternative to certain families of banned halogenated flame-retardant additives. Halogenated flame retardants are chemical compounds containing chlorine or bromine bonded to carbon that have been associated with human and animal toxicities and environmental concerns. Such halogenated chemicals have been shown to cause reproductive, thyroid, endocrine, developmental, and neurological disorders and present difficult and costly cleanup challenges. As a result, many of these chemicals, which have been used for decades as fire retardants in electronics, building insulation, polyurethane foam, wire, and cable, have been banned by various governments worldwide as well as the Stockholm Convention on Persistent Organic Pollutants.

FRX recently raised over $15 million in an equity financing, in part intended to finance deployment of the company's first commercial-scale manufacturing facility.

In contrast, FRX manufactures non-halogenated polymers that are inherently flame retardant due to a high phosphorous content. The company's products are sold both as additives and as standalone engineered plastics. When used as a plastic additive, these polymers have shown that they do not migrate out of the host plastic, due to their high molecular weight. As well, they are designed with novel properties (e.g., improved melt flow and fire resistance) that enhance the mechanical properties of the host plastic.

As of June 2011, FRX held 10 patents and approximately 50 patent applications. In 2008, the company received Frost and Sullivan's "Innovation of the Year" award and has since been featured on CNN and Fox Business News. FRX is led by an executive management team with decades of experience in product and business development, operations, manufacturing, sales, and marketing and skill working with polycarbonates.

Glossary

Admixture—Elements or ingredients that are added to a batch (typically as a minor ingredient) immediately before or during mixing. Admixture also can refer to a compound containing an admixture.

Alloys—Metallic substances composed of two or more metals, or of metals with nonmetal, in order to enhance the final product's properties, such as strength or resistance to corrosion.

Amorphous—Without a clearly defined shape or form.

Anasazi—A Native American civilization and culture of the southwestern U.S.

Annealing—A metallurgy treatment that entails heating a material, such as glass or metals, and allowing it to cool slowly in order to remove or prevent internal stress and enhance its properties, such as strength and hardness.

Argon—The chemical element of atomic number 18, an inert gaseous element and the most common noble gas.

Bismaleimide—Polyimides used in high-performance structural composites that require superior toughness and high-temperature resistance.

Bituminous Coal—A soft type of coal that burns with a smoky, yellow flame. Bituminous coal is the most abundant form of coal. When burned, it gives off sulfurous compounds that contribute to air pollution and acid rain.

Blast Furnace Slag—Formed when iron ore or iron pellets, coke (carbon fuel made by distilling coal), and a flux (either limestone or dolomite) are melted together in a blast furnace. When the metallurgical smelting process is complete, the lime in the flux has been chemically combined with the aluminates and silicates of the ore and coke ash to form a blast furnace slag.

Calcining—Heating a substance so that it will break down into small particles or into a powder or to drive off volatile substances.

Calcium Carbonate—A white, crystalline, water-insoluble powder occurring in nature in various forms as calcite, chalk, and limestone. It is used mainly in dentifrices, polishes, and in the manufacture of lime and cement.

CALGreen—The California Green Building Standards Code ("CALGreen") is a statewide building code that seeks to establish minimum green building standards for residential and commercial construction projects across California.

Cermet—A composite material made of ceramic and metal elements that is designed to combine the optimal properties of ceramics, such as temperature resistance and hardness, and metals, such as toughness.

Cladding—The process of bonding a metal coating onto another metal under high pressure and temperature.

Copper-Indium-Gallium-Diselenide (CIGS)—Semiconductor material composed of copper, indium, gallium, and selenium useful for the manufacture of solar modules. Due to CIGS' strong sunlight absorption capacity, solar cells only require thinner film of CIGS for full functionality.

Cradle to Cradle®—A certification from McDonough Braungart Design Chemistry that measures products manufacturing characteristics and ecological impact in order to create a sustainable society.

Dielectric—A substance that is a poor conductor of electricity, but an efficient supporter of electrostatic fields. Dielectrics can maintain an electric field with a minimum loss of power.

Ductility—The ability to undergo change of form without breaking, allowing the material to be molded or shaped. Also refers to the malleability of something that can be drawn into threads or wires or hammered into thin sheets.

Electrochromic—Pertaining to a substance that changes color when placed in an electric field, as in the liquid crystal display of many calculators.

Epitaxy—The growth of crystals on a crystalline substrate, a form of solid-state physics that is key to many next-generation product developments, including LED creation.

Epoxy—A class of resins derived by polymerization from epoxides, used chiefly in adhesives, coatings, electrical insulation, solder mix, and castings.

Flowability—Capability or ease with which a liquid or loose particulate solid move or flow.

Fly Ash—Fine particle ash residue resulting from the combustion of ground or powdered coal, discharged as an airborne emission or recovered as a byproduct for various commercial uses.

Gallium Nitride on Silicon (GaN-on-Si)—A semiconductor compound commonly used in bright light-emitting diodes. GaN-on-Si is a very hard material that displays special properties for applications in optoelectronic, high-power, and high-frequency devices.

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.

Gusset Plates—Thick sheets of steel used to connect beams and girders to columns or to connect truss members.

Heat Dissipation—Dissipation of heat causing temperature reduction. The process of becoming cooler.

Home Area Network (HAN)—A network contained within a residential unit or home that is used for communication between digital devices, usually personal computers and their peripheral devices.

IECC 2012—The International Energy Conservation Code (IECC®) code is a model energy building code that contains minimum energy efficiency provisions for residential and commercial buildings, as well as building envelope requirements for thermal performance and air leakage. The 2012 provision tightens the envelopes of buildings, raises the efficiency for mechanical equipment, and institutes testing and controls in homes and offices, measures expected to achieve a 30% increase in energy savings compared to the 2006 predecessor.

Ingot—A mass of metal cast in a form suitable for storage, shaping, remelting, or refining.

Leadership in Energy and Environmental Design (LEED)—An ecology-oriented building certification program run under the auspices of the U.S. Green Building Council. LEED concentrates its efforts on improving performance across five key areas of environmental and human health: energy efficiency, indoor environmental quality, materials selection, sustainable site development, and water savings.

Lithium-Ion—A rechargeable battery technology common in consumer and portable electronics that provides one of the best energy densities, no memory effect, and a slow loss of charge when not in use.

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

Lumens per Watt—A measure of the efficacy of a light source in terms of the light produced for the power consumed.

Model Energy Codes—National building energy codes developed through a public hearing process by national experts that provide states and local jurisdictions a blueprint for their own codes. For example, the IECC® 2012 is a model energy building code produced by the International Code Council® (ICC®).

Molybdenum—A hard, silvery-white metallic element (atomic number 42) used to toughen alloy steels and soften tungsten alloys.

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 well as an oxidizer in rocketry and in motor racing to increase the power output of engines.

Off-Grid—Refers to living in a self-sufficient manner without reliance on public utilities.

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.

Phenolic—A resin made of phenol and an aldehyde. It is commonly used to make moldings or insulation.

Photocatalytic—The acceleration of a photoreaction in the presence of a catalyst. In catalyzed photolysis, light is absorbed by an adsorbed substrate. This phenomenon enables a material to breakdown organic compounds on a surface using UV radiation.

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

Pilings—A column of wood, steel, or concrete that is driven into the ground to provide support for a structure.

Polyurethane—A synthetic resin in which the polymer units are linked by urethane groups that is used chiefly in paints and varnishes.

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.

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.

Solid-State—In a solid-state component, the current is confined to solid elements and compounds engineered specifically to switch and amplify it. Solid state refers to electronic components, devices, and systems based entirely on the semiconductor. The integrated circuit (IC), light-emitting diode (LED), and liquid-crystal display (LCD) have evolved as examples of solid-state devices.

Substrate—A substance or layer that underlies something, or on which some process occurs, in particular.

Supercritical Drying—A method for controlling the removal of liquid in aerogel manufacture.

Switches—Devices for making and breaking the connection in an electric circuit.

Tensile Strength—The resistance of a material to breaking under tension.

Thermoplastic—Denoting substances (especially synthetic resins) that become plastic on heating and harden on cooling and are able to repeat these processes.

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

Vacuum Arc Remelting (VAR)—A secondary melting process for the production of metal ingots with elevated chemical and mechanical homogeneity for highly demanding applications.

Vanadium—A hard gray metal used to make alloy steels.

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

Zinc Oxide—A pigment used in compounding rubber in the manufacture of plastics and in pharmaceuticals and cosmetics.

Company Index

RISKS AND DISCLAIMERS

Some of the information in this report relates to future events or future business and financial performance. Such statements can only be predictions and the actual events or results may differ from those discussed. For a summary of risk factors specific to the businesses mentioned in this report, please contact each respective company directly or consult their publicly available documents, including their statements on forms filed with the U.S. Securities and Exchange Commission (SEC), Annual Reports, or other documents and releases filed from time to time.

The content of this report has been compiled from information available to the public released in news releases, Annual Reports, SEC filings, and other publicly available information and has not been independently verified by Crystal Research Associates or Livingston Securities. Certain summaries of activities have been condensed to aid the reader in gaining a general understanding.

Investors should carefully consider the risks and information described below. Investors should not interpret the order in which these considerations are presented as an indication of their relative importance. As well, additional risks and uncertainties not presently known may materialize and adversely affect the businesses referenced in this report, the nanotechnology sector, or the green building industry as a whole. If any such risks and uncertainties develop, the business, financial condition, and results of operations could be materially and adversely affected for such reference companies and the value of an investor's share could decline.

This report is published solely for information purposes and is not to be construed as an offer to sell or the solicitation of an offer to buy any security in any state. Past performance does not guarantee future performance.

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.

Intentionally Blank.

Jeffrey J. Kraws and Karen B. Goldfarb
Phone: (609) 306-2274
Fax: (609) 395-9339
Email: eio@crystalra.com
Web: www.crystalra.com