



CENTRAL UPSTATE NEW YORK'S
GREEN INDUSTRY SECTOR:

Opportunities and Prospects

Prepared For:

Metropolitan Development Association of Syracuse
and Central New York and Creative Core's
Regional Green Team

Prepared By:

Battelle
Technology Partnership Practice

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CENTRAL UPSTATE NEW YORK'S GREEN INDUSTRY SECTOR: OPPORTUNITIES AND PROSPECTS

Final Report

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EXECUTIVE SUMMARY

Introduction

The Central Upstate New York region recognized that it had key assets in environmental and energy systems (E&ES) more than ten years ago; and the region's business, government, and academic leaders have worked to grow this industry cluster. (See Appendix A for a map of key E&ES assets in the region.) In Vision 2010, the Metropolitan Development Association (MDA) of Syracuse and Central New York targeted seven industry clusters, including "Environmental Systems". Indoor Environmental Quality (IEQ) was chosen as an initial focus, and the New York Indoor Environmental Quality (NYIEQ) Center, Inc., was established in 2000. NYIEQ was an independent, nonprofit organization created to foster industry-university collaborative research, technology transfer and commercialization, and outreach to advance human health and performance in urban and built environments by creating products and services to enhance indoor environmental quality. In 2001, Syracuse University (SU) partnered with the MDA and NYIEQ to create a Strategically Targeted Academic Research (STAR) Center for Environmental Quality Systems. Syracuse University was awarded \$15.9 million for the STAR Center in 2001 and another \$22 million to establish a Center of Excellence in Environmental Systems in 2002. In 2004, the focus of the Center of Excellence was expanded to include energy systems.

The region's public, private, and academic leaders came together again in 2006 to form a coalition with the mission of expanding and marketing the region's green (environmentally sound) and sustainable assets, and thus accelerating the growth of the E&ES industry sector. MDA and its partner organizations engaged Battelle's Technology Partnership Practice (TPP) to conduct a market analysis and competitive assessment of the E&ES sector in the Central Upstate New York region. Battelle's TPP, which includes leading analysts and practitioners in technology-based economic development, helps clients develop, implement, and evaluate technology strategies, policies, and programs.

Project Goals

This project was designed to

- Understand the market potential of the E&ES cluster and the components that make up the cluster,
- Identify leading and emerging firms within this sector,

Project Goals

- ▶ Understand market potential of E&ES cluster
- ▶ Identify leading and emerging firms within this sector
- ▶ Assess Central Upstate New York's competitive position
- ▶ Identify potential actions to develop E&ES cluster and brand the region as center of green industry

- Assess Central Upstate New York’s competitive position in the E&ES sector, and
- Identify potential actions that could further develop the E&ES cluster and brand Central Upstate New York as a center of green industry development.

Project Methodology

Market Analysis

Battelle prepared a market analysis that examined market trends and drivers for four major industries and their subsectors within the broader E&ES area (Table ES-1).

Table ES-1: Environmental and Energy Systems Industry Sector

Core Industries	Subsectors
Indoor Environmental Quality	<ul style="list-style-type: none"> ▪ Air Filtration, Ventilation, Conditioning, and Other Treatment Technologies ▪ Air Sensors and Air Analysis/Monitoring Instrumentation
Renewable Energy	<ul style="list-style-type: none"> ▪ Biomass ▪ Wind ▪ Solar ▪ Fuel Cells, Including Portable/Micro-Fuel Cells
Green Buildings/Sustainable Design	<ul style="list-style-type: none"> ▪ Green Structural and Exterior Finish Materials ▪ Green Interior Systems, Surface and Finish Materials
Water Quality and Water Resources	<ul style="list-style-type: none"> ▪ Water Filtration, Purification, Desalination, and Other Treatment Technologies ▪ Water Sensors and Analysis/Monitoring Instrumentation ▪ Water Engineering and Watershed/Resource Management Consulting

For each industry subsector, data were collected to provide an overview and to identify technology trends, challenges, and key market opportunities. Battelle also developed a list of current market leaders and identified smaller, emerging firms for each industry subsector.

Competitive Analysis

Battelle examined Central Upstate New York’s E&ES sector and compared it with a number of other regions. The Battelle team interviewed firms and organizations involved in the E&ES sector in the region to gain an understanding of the region’s key assets and to identify any gaps that need to be addressed to further grow this sector. Battelle identified, using the North American Industrial Classification System (NAICS), those industries that make up the E&ES sector and its subsectors. Employment and establishment data were developed to examine the size, concentration, and growth rate of each subsector.

Project Tasks

- ▶ Market Driver and Trend Analysis
- ▶ Identification of Market Leaders and Emerging Firms
- ▶ Competitive Assessment
- ▶ Gap Analysis
- ▶ Potential Actions

Using the input from the interviews, the examination of employment data, and the regional profiles, Battelle identified potential actions that could be undertaken to accelerate the growth of Central Upstate New York's green economy.

Understanding the E&ES Market

Significant opportunities exist for the growth of the indoor environmental quality (IEQ) industry, and Central Upstate New York is well positioned to grow this sector. Increased interest in improving the energy efficiency of IEQ systems, recognition of black mold threats, financial and real estate concerns regarding sick building syndrome, and the need to protect against airborne attacks are all factors that are driving growth of the IEQ market (Table ES-2). The global expansion of high-tech manufacturing and research, increased demand for home indoor air quality (IAQ) instrumentation, and expansion of the residential air filtration market are examples of areas of market opportunity. There also exists a growing market for IAQ monitors and for specialty instrumentation measuring volatile organic compounds (VOCs), gases, and particles.

Central Upstate New York has significant assets in the IEQ area. Pall Corporation, a billion dollar company and world leader in the filtration industry, has a facility in Cortland NY; and Carrier, a leading global company in air filtration, conditioning, ventilation, and treatment technologies, has located one of its 16 design centers in Syracuse. The focus of this design center is on IEQ. The region also is home to a number of small innovative IEQ firms, such as Air Innovations and NuClimate.

Approximately 2,400 people were employed in the IEQ sector in Central Upstate New York in 2005. This is a much larger employment base than that found in any of the competitor regions, all of which had less than 400 total employees. The region experienced a 42.7 percent decline in IEQ employment from 2001 until 2005; a result, in part, of the loss of 1,200 jobs when Carrier Corporation closed two plants at its Syracuse site in 2003. At the same time, however, the number of IEQ establishments increased by approximately 23 percent, suggesting that the number of small, start-up IEQ firms is increasing. Accelerating the growth of these companies would provide additional employment opportunities in the region.

Central Upstate New York also has research strengths in IEQ. Significant investments have been made in the region's universities to support the development of the E&ES sector through the Syracuse Center of Excellence in Environmental and Energy Systems (Syracuse CoE), which includes a focus on IEQ, and its partner Centers, which include the Clarkson Center for Air Resources Engineering and Science, the EQS STAR Center, and SU's Building, energy and Environmental Systems Lab. Through these Centers, the region has received capital equipment and research funding from the Environmental Protection Agency (EPA). These resources could be used to attract companies and to help existing companies with new product development; but, it must be recognized that there is competition from other regions.

California is clearly the leader in both indoor and outdoor air quality. University Centers, such as the Berkeley Center for the Built Environment, Carnegie Mellon's Center for Building Performance and Diagnostics, and Penn State University's In-

door Environment Center, are established programs, with which the Syracuse CoE must compete.

Actions that could further build this cluster include strengthening industry-university partnerships and aligning the research focus of Syracuse CoE with areas of interest to the region’s companies, which will require greater resources that can be dedicated to both operating expenses and focused research and development (R&D). Attracting IEQ companies to the region will require that the Center and its partner institutions continue to build its critical mass of world-class researchers in the IEQ area.

Table ES-2: Key Drivers of IEQ Sector

Indoor Environmental Quality: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • Security against airborne attacks • Recognition of black mold threats • Financial and real estate concerns regarding sick building syndrome • Cost-efficient technologies for urban asset enhancements • Increasing interest in improving energy efficiency of IEQ systems • Presence or absence of legislatively mandated regulatory standards
Economic Development Drivers	<ul style="list-style-type: none"> • Federal, state, and local funding for homeland security • Advances in multidisciplinary research • Improved R&D capabilities
Firm Locational Requirements	<ul style="list-style-type: none"> • Firms need partnerships with university researchers, but they don’t necessarily need to be located next to them • Scientists and other professionals with skills relevant to environmental industry cluster • Business climate that is attractive to mature industries <ul style="list-style-type: none"> - Skilled workforce - High-quality K-20 education - Family-friendly quality of life
Key Market Opportunities	<ul style="list-style-type: none"> • Global expansion of high-tech manufacturing and research • Demand for home indoor air quality (IAQ) instrumentation and expansion of residential air filtration market • Growth for market in energy recovery ventilation systems • Growth of office building remediation market • Growing market for IAQ monitors • Growing market for specialty instrumentation measuring VOCs, gases, and particles

The renewable energy sector is poised for growth, and Central Upstate New York has opportunities in the production of biomass energy and the development of fuel cell technology. A range of external factors shapes and influences the future direction of the market for renewable energy and the technologies that produce it (Table ES-3). Such factors may be technological, regulatory, or based on consumer preferences. Technological factors include large shifts in research funding and the development of innovative technologies by industry leaders who can affect the market. The extent of these technology breakthroughs is dependent in large part on R&D funding. Regulatory factors include various financial incentives and policies that can alter demand for traditional and alternative sources of energy. Finally, increasing desire for a sustainable economy, rising electric power needs, environmental concerns, and moral pressures are among the factors influencing the preferences of energy consumers.

Table ES-3: Key Drivers of Renewable Energy Sector

Renewable Energy: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • National R&D budgets and financing for energy technologies • Public policies, government subsidies, and incentive programs • Goals, mandates, targets, and standards • Increased nationwide support for a secure and sustainable economy • Growing global and domestic energy demand • Concerns over global warming/climate change • Consumer tastes and preferences going green
Economic Development Drivers	<ul style="list-style-type: none"> • Access to inputs and supporting infrastructure • Forward-thinking policy making at local, state, and federal levels • Willingness of existing utilities to partner with renewable energy companies • Pursuit of alternative energy investors and businesses
Locational Requirements	<ul style="list-style-type: none"> • Access to energy sources • Availability of incentives • Supportive regulatory and public policy environment
Key Opportunities	<ul style="list-style-type: none"> • Worldwide market for biofuels • Offshore wind turbine design/wind energy consulting services, small wind turbine design, energy storage systems • On-grid solar applications, consumer and industrial PV markets, non-silicon-based thin-film PV technologies • Portable personal electronics, portable power systems, small off-road transportation

The renewable energy sector includes industries engaged in a variety of activities from producing biomass energy to manufacturing fuel cells, wind turbines, and solar cells. Central Upstate New York has a relatively modest number of jobs in the renewable energy sector with just 378 in 2005. The number of establishments, however, increased 28 percent between 2001 and 2005, suggesting that new firms are being created. The region has a high concentration of renewable power generation jobs and its job totals exceed that of the comparison regions; however, total employment in the renewable power generation sector is just over 400 jobs, the majority of which are in hydroelectric power generation, a sector that lost almost half its total employment between 2001 and 2005. Opportunities within the various subsectors of renewable energy are discussed below.

Biomass

Among the various sources of renewable energy, biomass—plant matter and other biodegradable materials—is receiving a great deal of attention as a source of energy. Conversion of biomass into “biofuels” such as ethanol, biodiesel, biobutanol, and biogas is a major focal point of today’s economy due to the potential to relieve dependence on foreign oil and to reduce greenhouse gas emissions.

The ethanol and biodiesel markets are growing rapidly—ethanol at roughly 15 percent and biodiesel at 85 percent in recent years—and continued rapid growth of these markets both worldwide and in the United States is anticipated.

A number of projects to produce energy from biomass are underway in Central Upstate New York, including the following:

- **Northeast Biofuels** is developing an ethanol production plant at the site of the former Miller Brewing Company in Fulton NY. The plant will initially use corn as its feedstock but hopes to be able to produce cellulosic ethanol in the future. This facility will be the first ethanol production plant in New York State and in New England.
- **Catalyst Renewables Corporation** is working with the State University of New York College of Environmental Science and Forestry (SUNY-ESF) to develop a pilot cellulosic ethanol plant in Lyonsdale NY.
- **SUNY–Morrisville** is developing a **green biofuel blending facility** that will convert soy to biodiesel.
- **ND Fusion** is a small company in Potsdam NY that uses process intensification to provide green processing of chemicals, pharmaceuticals, and alternative energy.
- **ZeroPoint Clean Tech, Inc.**, also in Potsdam, is a renewable energy company that has developed a highly efficient gasification process for converting biomass into renewable gas, electricity, or liquid fuels.

Clearly, Central Upstate New York has university expertise in biomass energy and private sector firms that have been created to exploit this technology. At the moment, however, emerging biomass energy firms are concentrated in California and Massachusetts; no leading biomass energy firms were identified in New York.

Wind Energy

The market for and production of wind power are experiencing rapid growth both nationally and in the Central Upstate New York region. Technological advances along with government investment incentives and the desire to use sustainable, green energy sources are leading to rapid installation of wind turbines. Wind power can be an effective driver of economic development. Wind farms boost the local tax base, provide direct benefits to local farmers and landowners, and create jobs in the production supply chain for wind turbines and related goods.

Companies in Europe, Germany in particular, dominate the wind energy market; but, the United States has a number of emerging companies in the wind energy sector focused primarily on developing new types of wind turbines. Central Upstate New York is home to one such company, Vento Tek, which is developing “smart blades,” devices that control the flow of air around blades. Vento Tek is a spin-off of Clarkson University. Clarkson researchers are working with Warner Energy to develop more efficient, small wind turbines. Central Upstate New York has expertise in sensors, engineering, and materials that position it to develop technology to improve wind energy production. The region has several wind farms operating or under development.

Solar Energy

Electricity generation from solar energy has increased rapidly, growing annually by an average of approximately 20 percent for the past decade. The solar photovoltaic (PV) industry is one of the world’s fastest growing industries with a growth rate of approximately 40 percent in recent years. Solar PV capacity is concentrated in Germany, Japan, and the United States. In Germany and Japan, generous government subsidies have stimulated demand spurring most of this development. In the United States, a few states—primarily California—have passed major solar initiatives resulting in a broad range of installed projects. Because of its chip industry, California is the ideal setting for the development of new materials and technologies for solar cells. Not surprisingly, California is home to a majority of the emerging solar firms identified in this analysis.

The State of New York and Central Upstate New York do not have an established solar industry. Central Upstate New York’s materials expertise could be applied to the development of materials for solar cells, and the Center for Future Energy at Rensselaer Polytechnic Institute (RPI) includes a focus on high-end III-V high-efficiency cells and thermal solar. If incentives were provided to promote the use of solar energy, the increased demand that would result could be used to attract or encourage the creation of companies to meet that demand.

Fuel Cells, Including Portable/Micro-Fuel Cells

Global demand for portable electronic devices is driving growth of the micro-fuel cell (MFC) sector. MFCs have the potential to replace lithium ion batteries as an energy source providing up to 10 times the energy of existing battery technology. The low emissions and greater efficiency to be gained with fuel cells are preferable to recharging batteries using electrical power supplies. The global market for fuel cells is expanding rapidly. The market for micro-fuel cells is estimated at \$12 million in 2006 and projected to reach \$112 million by 2011 (Innovative Research and Products).¹

New York has a strong academic and industry base in fuel cells. On the university side, Central Upstate New York is home to the following:

¹ Key sources used in the analysis of each of the four major industries in the E&ES market are listed at the end of this report and in Appendix A.

- The **Cornell Fuel Cell Institute (CFCI)**, a research center with world-class expertise in materials science that focuses on overcoming challenges to commercial fuel cell production rooted in fundamental materials limitations. CFCI faculty members collaborate with leading commercial fuel cell companies, such as Ford, GM, Sumitomo Finance, Primet, and UTC Fuel Cells; and a number of small start-up companies have been created to commercialize technology developed by CFCI researchers.
- **Clarkson University’s Center for Advanced Materials Processing**, which develops innovations in advanced materials processing in collaboration with industry and also has a focus on fuel cells.
- **Alfred University’s Center for Advanced Ceramic Technology**, which conducts research on the use of ceramic materials in fuel cells.

The region is also home to a number of small start-up fuel cell companies. It must be recognized, however, that only a small number of leading-edge companies actually have products on the market (one of which is Albany-based MTI MicroFuel Cells) and that most emerging companies are still in the R&D, testing, and prototype development stage. Central Upstate New York clearly has assets that can be used to attract companies to the region and to grow companies around technology developed at the region’s research institutions; but, this sector will likely take some time to develop.

The green building materials market is underdeveloped in Central Upstate New York; but, this could change with projects underway at Cornell, the CoE, and Destiny. Demand for green building products and sustainable design is being driven largely by consumer preferences and the decline in the cost differential between green and traditional products (Table ES-4). Advocacy groups at the national, state, and local levels, such as the U.S. Green Building Council that promotes LEED® certification², have also played an important role in building support for green development.

Multiple solar panel manufacturers located in the Chicago area after the City of Chicago established a 25 percent renewable energy usage goal.

The demand for green building products and practices offers opportunities for existing companies to develop new product offerings in areas such as green furniture, cabinetry, and fixtures or to make products from composites that incorporate recycled material. All else being equal, green building product companies gravitate toward regions that exhibit potential for strong local demand for green products. This potential can be exhibited through income characteristics (e.g., more

affluent consumers), coordinated efforts toward renewing the housing stock, or significant planned developments that will create demand. Additionally, a strong driver

² LEED (Leadership in Energy and Environmental Design) certification is a recognized standard for measuring building sustainability. The LEED green building rating system is designed to promote design and construction practices that increase profitability while reducing negative environmental impacts of buildings and improving occupant health and well-being.

for locational decisions for “footloose” green building product companies (i.e., those not tied to a regional asset) is to be located where the demand for building products is most robust. Historically, these are areas of the country experiencing significant population growth. They also tend to be areas of the country with a citizenry that is committed to sustainability.

Table ES-4: Key Drivers of Green Buildings/Sustainable Design

Green Buildings/Sustainable Design: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • Commercial and consumer interest in green buildings • Decline in cost differential for green buildings • Adoption and implementation of LEED standards
Economic Development Drivers	<ul style="list-style-type: none"> • Advocacy and education by nonprofit organizations • Customer demand • Development of standards
Locational Requirements	<ul style="list-style-type: none"> • Strong local demand for green building materials, products, and components • Easy access to product inputs • Buy-in from local designers, architects, builders, etc. • Green-friendly location • Access to research, testing, and certification capabilities • LEED-based tax incentives
Key Market Opportunities	<ul style="list-style-type: none"> • Offers opportunity for existing companies to develop new product offerings • Wood plastic composites that incorporate recycled materials is a fast-growing market opportunity • Federal, state, and local legislation and policy have created strong demand for high-performance roofing • Untapped market for green roofs that incorporate vegetation • Rehabilitation of older buildings using green building practices • Opportunities to develop green furniture, cabinetry, and fixtures

A number of initiatives are underway in Central Upstate New York that could drive demand for green building products and sustainable design. Cornell University, SU and SUNY-ESF are implementing campus-wide sustainability initiatives; the Syracuse CoE is being built to LEED standards; the City of Syracuse has adopted LEED standards; and the Destiny project, which involves a significant expansion of Carousel Mall, is being developed with green building products and practices and using renewable energy sources. These projects will create demand for green products; but, they can also be used to showcase green and sustainable development and encourage greater use of green products throughout the region.

The region also has research and education strengths in the green products and sustainable design area. These include the following:

- SUNY-ESF’s Construction Management and Wood Products Engineering Program, which includes a focus on green materials
- SU’s Building, Energy and Environmental systems Lab
- Cornell’s Center for Materials Research, which includes a focus on composites and chemistry, biodegradable and renewable materials. Several start-up companies have been formed to commercialize technology developed at the Center.

Central Upstate New York has slightly more than 2,500 workers employed in the green building and sustainable design sector, although this sector lost nearly 16 percent of its employment base between 2001 and 2005. This decline generally

reflects weakness in the overall U.S. manufacturing sector in which these green building activities are included. While the national green building sector contracted, two of the comparison communities, Sacramento, CA and Fort Collins, CO added jobs in this sector since 2001.

Water quality and water resources is a growing market that could be tapped by the region’s water resources consulting and engineering firms; but, at present, there is insufficient alignment between the region’s research base and its industry base. Water treatment, long considered a mature industry in the United States and other developed countries, is experiencing a revival due to increasing global demand for freshwater, depletion of groundwater resources, competing demands by users of freshwater, concerns with regard to the security of public water systems, and new regulations. All of these factors are driving the water quality and water resources market (Table ES-5).

Table ES-5: Key Drivers of Water Quality and Water Resource Sector

Water Quality and Water Resources: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> Increasing global demand for freshwater Competing demands for freshwater for agriculture, power, and industry Depletion of groundwater resources Concern with regard to the management of water resources Aging drinking and wastewater infrastructure Concerns regarding security of public water systems
Economic Development Drivers	<ul style="list-style-type: none"> Proximity to strong programs in electrical engineering, environmental engineering, and materials science Access to suitable experimental settings
Locational Requirements	<ul style="list-style-type: none"> Local demand for water testing and related services Local demand for supersterile water or water treatment technologies to meet needs of specific industries, such as pharmaceutical companies or computer chip manufacturers
Key Opportunities	<ul style="list-style-type: none"> Integrated approaches to wastewater treatment will be a growth area Need to meet freshwater needs in California, Florida, and Texas International demand for freshwater Need to mitigate impact of household chemicals and drugs in water supply Government policies requiring new detection and monitoring systems

The Central Upstate New York region has developed strengths in technologies related to water purification, sensing, and monitoring, and consulting services due to the scope of the Onondaga Lake restoration project. As a result, the region’s employment is 88 percent more concentrated in water quality and resources than is the nation. More than 1,500 people were employed in water quality and resources in 2005 in Central Upstate New York, although this employment level is down 10 percent from 2001.

Companies involved in water filtration, purification, desalination, and other treatment technologies tend to grow in areas in need of additional water supply. The largest markets for such systems in the United States include Florida, California, and Texas. Not surprisingly, California and Florida are home to many emerging water treatment firms. California also leads in the emerging water sensor and analysis/monitoring instrumentation market.

Water quality and water resource firms also are likely to grow in proximity to research institutions with a focus in this area. While Central Upstate New York has research institutions with strengths in understanding, assessing, and managing watersheds—including SUNY-ESF, which has a focus on water quality and water resource planning; the Upstate Freshwater Institute, which focuses on understanding how ecosystems work; the Syracuse Center of Excellence, which focuses on sensors and monitoring watersheds; and the Center for Integrated Watershed Studies at SUNY Binghamton—the R&D being conducted on watersheds and water resources has not translated into creating companies and insufficient alignment exists between areas of research and the industry base.

Assessing Central Upstate New York's Competitive Position

Central Upstate New York is not the only region trying to grow its E&ES industry cluster. Multiple regions across the country are branding themselves as locations for green businesses and implementing policies and actions to promote the use of green building practices, renewable energy, and practices that promote environmental quality. Battelle conducted an analysis to assess the competitiveness of Central Upstate New York's environmental and energy sector and to identify policies and programs that are being used to promote this sector in other regions of the country.

Competitor Regions

- ▶ Eugene, OR
- ▶ Fort Collins, CO
- ▶ Grand Rapids, MI
- ▶ Pittsburgh, PA
- ▶ Sacramento, CA

Central Upstate New York was compared with the following five regions: Eugene, OR; Fort Collins, CO; Grand Rapids, MI; Pittsburgh, PA; and Sacramento, CA.

Key Findings

- For the most part, the initiatives to grow the E&ES sector are being driven by a citizenry that values sustainability and sees the industries that make up this sector as compatible with maintaining the region's quality of life.
- Most of these communities have adopted public policies aimed at promoting green practices and businesses. These include setting goals for the use of renewable energy, adopting green building practices for municipal buildings, committing to purchase sustainable products and technologies, and providing incentives for businesses that use sustainable practices.
- Communities are trying to build their E&ES industry sectors by (1) encouraging the growth of start-up companies, (2) helping to create a market for green products by conducting education and outreach activities, and (3) encouraging existing companies to offer new green products or enter new markets. Attracting E&ES companies from outside the region is much less common; although, in Sacramento, some international firms are opening operations to meet the demand for renewable energy, which has developed as a result of state policy actions.

- The competitor communities have put their money where their mouth is, so to speak. They can show, for example, that they have a significant percentage of buildings constructed to green performance standards.
- In some instances, including in Fort Collins and Pittsburgh, the presence of university centers focused on specific aspects of the E&ES sector is fostering the growth of E&ES businesses. Colorado State University is in fact driving the region's Clean Energy Cluster. In other regions, such as Sacramento, the region has not been able to engage the university in its efforts to grow this industry sector.
- The most common tool used to help grow the E&ES industry is to promote networking and the formation of cluster initiatives.
- The focus on promoting the growth of green industry sectors is at an early stage of development, and it will take time to see where the industry takes hold and what types of incentives are effective in accelerating its growth.

Growing Central Upstate New York's E&ES Sector

Table ES-6 identifies a number of approaches that could be undertaken to grow Central Upstate New York's E&ES industry sector and suggests actions that have been taken elsewhere that might apply in this region.

Table ES-6: Objectives and Possible Actions to Grow E&ES Industry Sector and Examples From Other Regions

Objective	Possible Actions	Examples of Initiatives in Other Regions
Stimulate the market for green products and practices	Adopt green procurement standards	In 2006, Columbus City Council changed City's procurement code to include a preference for environmentally preferable bidders, vendors, and contractors
	Adopt renewable energy goals	Grand Rapids committed to buying 20% of power from renewable sources by 2008 Eugene, OR plans to purchase 25% wind power for all existing general fund buildings
	Commit to building green buildings	City of Columbus is requiring that all new public buildings be developed to LEED certification
	Offer tax incentives to individuals and businesses that employ green technologies	City of Columbus is targeting its tax incentives to green businesses Portland OR offers municipal incentives for installation of solar power Austin offers rebates for installation of solar energy
	Educate the public on the value of using renewable energy and green building products and practices	Rochester's Greenprint proposes a public relations and education campaign, including public service announcements to increase citizen awareness about green products and practices
	Create a program to certify green businesses	San Francisco's Green Business Program promotes, recognizes, and supports firms that operate in an environmentally conscientious way
Raise profile of E&ES industry cluster in Central Upstate New York	Organize a media campaign featuring articles, op eds, and columns on the region's green companies	Northern Colorado Clean Energy Cluster, a network of 350 members with \$1.5 million budget, paid staff, and Web presence, is seeking to brand the region as a center for clean tech
	Continue to attract flagship green events to region, such as 2009 International Conference & Exhibition, "Healthy Buildings." Take advantage of opportunity to showcase companies and activities in region	Pittsburgh's Green Building Alliance is working to position region's building product manufacturers to take advantage of growth in green building products and practices
	Expand number of E&ES firms profiled on Essential Connections Web site	

Table ES-6: Objectives and Possible Actions to Grow E&ES Industry Sector and Examples From Other Regions (Continued)

Objective	Possible Actions	Examples of Initiatives in Other Regions
Provide business development resources to emerging green businesses	Create locations to house both start-up and established E&ES companies to encourage greater networking and partnering	A Green Building Fund has been created within CL Fund, a community development loan fund servicing greater Pittsburgh. GBF will provide loans ranging from \$200,000 to \$400,000 to help developers obtain LEED certification, and Pittsburgh Urban Redevelopment Authority makes low-interest loans for green construction
	Explore option of using Carrier's marketing channels to sell products of emerging IEQ companies	CleanStart in Sacramento provides coaching and mentoring for clean tech companies
	Provide commercialization assistance to start-up and emerging companies	New York City's Environmental Economic Development Assistance unit helps companies identify NYC programs that can support green tech companies
	Expand Emerging Business Competition to include award for Emerging Green Business	
Continue to build region's E&ES research base and link it to industry	Seek additional sources of operating funds and R&D funding that can be directed to industry needs for CoE	Colorado State University has grown its clean energy cluster to include 80 faculty who have attracted \$9.2 million in clean tech R&D funding
	Continue and possibly expand Grants for Growth program	

Conclusion

Central Upstate New York clearly has an opportunity to promote the growth of its E&ES industry sector by expanding and marketing the region's green and sustainable assets. To do so, the region's public and private organizations need to commit to practicing sustainability and encouraging the adoption of green products and practices by the community at large.

The market for E&ES is growing both nationally and globally. Central Upstate New York is a leader in IEQ and is thus poised to grow this sector locally. The Syracuse CoE can be an important contributor, but only if increased and sustained funding is obtained to support the Center's operations. Funds have been provided for equipment through the STAR program and for a state-of-the-art building through the Centers of Excellence program; but, relatively limited funds are available to hire technicians and graduate students to operate equipment or to support industry-university research collaborations.

Central Upstate New York also has opportunities in the renewable energy sector. A number of pilot projects are underway that, if commercially successful, will pave the way for the region to become a leader in the production of energy from biomass sources, including forests and agricultural crops. The Central Upstate New York region is a leader in fuel cell development with world-class expertise in both

academia and industry. The CFCI already is both attracting firms and spinning out companies based on CFCI technologies. Central Upstate New York should investigate ways to work collaboratively with Albany and Rochester, which have considerable assets in fuel cells, to support the development of this sector.

Growing the green buildings/sustainable design, solar energy, and wind energy sectors will require stimulating demand within the region and encouraging existing companies to introduce new products and services in response to this demand. Lastly, Central Upstate New York should look for ways in which to build upon the technologies developed to address IEQ, in the areas of sensors and controls, for example, and identify opportunities to apply those technologies to energy systems and water quality monitoring.

The green business sector is at an early stage of development, and most efforts to encourage it in a particular region are also in early development, making it difficult to determine best practices. Central Upstate New York can realize the opportunity to grow this sector if the region's public and private sector leaders and citizenry commit to sustainability and undertake a long-term collaborative initiative to build New York's "Creative Core" around green technologies and renewable energy.

INTRODUCTION

The Central Upstate New York region recognized that it had key assets in environmental and energy systems (E&ES) more than ten years ago; and the region's business, government, and academic leaders have worked to grow this industry cluster. (See Appendix A for a map of key E&ES assets in the region.) In Vision 2010, the Metropolitan Development Association (MDA) of Syracuse and Central New York targeted seven industry clusters, including "Environmental Systems". Indoor Environmental Quality (IEQ) was chosen as an initial focus, and the New York Indoor Environmental Quality (NYIEQ) Center, Inc., was established in 2000. NYIEQ was an independent, nonprofit organization created to foster industry-university collaborative research, technology transfer and commercialization, and outreach to advance human health and performance in urban and built environments by creating products and services to enhance indoor environmental quality. In 2001, Syracuse University (SU) partnered with the MDA and NYIEQ to create a Strategically Targeted Academic Research (STAR) Center for Environmental Quality Systems. Syracuse University was awarded \$15.9 million for the STAR Center in 2001 and another \$22 million to establish a Center of Excellence in Environmental Systems in 2002. In 2004, the focus of the Center of Excellence was expanded to include energy systems.

The region's public, private, and academic leaders came together again in 2006 to form a coalition with the mission of expanding and marketing the region's green (environmentally sound) and sustainable assets, and thus accelerating the growth of the E&ES industry sector. MDA and the Green Team engaged Battelle's Technology Partnership Practice (TPP) to conduct a market analysis and competitive assessment of the E&ES sector in the Central Upstate New York region. Battelle is recognized worldwide for technology development, management, and commercialization, as well as for the development of industry, academic, and government partnerships. Battelle's TPP, which includes leading analysts and practitioners in technology-based economic development, helps clients develop, implement, and evaluate technology strategies, policies, and programs.

Project Goals

This project was designed to

- Understand the market potential of the E&ES cluster and the components that make up the cluster,
- Identify leading and emerging firms within this sector,
- Assess Central Upstate New York's competitive position in the E&ES sector, and
- Identify potential actions that could further develop the E&ES cluster and brand Central Upstate New York as a center of green industry development.

Project Goals

- ▶ Understand market potential of E&ES cluster
- ▶ Identify leading and emerging firms within this sector
- ▶ Assess Central Upstate New York's competitive position
- ▶ Identify potential actions to develop E&ES cluster and brand the region as center of green industry

Project Methodology

Market Analysis

Battelle prepared a market analysis that examined market trends and drivers for four major industries and their subsectors within the broader E&ES area (Appendix B). The major industries and subsectors analyzed include the following:

Indoor Environmental Quality

- Air Filtration, Ventilation, Conditioning, and Other Treatment Technologies
- Air Sensors and Air Analysis/Monitoring Instrumentation

Renewable Energy

- Biomass
- Wind
- Solar
- Fuel Cells, Including Portable/Micro-Fuel Cells

Green Buildings and Sustainable Design

- Green Structural and Exterior Finish Materials
- Green Interior Systems, Surface and Finish Materials

Water Quality and Water Resources

- Water Filtration, Purification, Desalination, and Other Treatment Technologies
- Water Sensors and Analysis/Monitoring Instrumentation
- Water Engineering and Watershed/Resource Management Consulting

For each industry subsector, data were collected to provide an overview of the sector and to identify technology trends, challenges, and key market opportunities. Battelle also developed a list of current market leaders and identified smaller, emerging firms for each industry subsector (Appendix C).

Competitive Analysis

Battelle examined Upstate Central New York's E&ES sector and compared it with a number of other regions. The Battelle team interviewed firms and organizations involved in the E&ES sector in the region to gain an understanding of the region's key assets and to identify any gaps that need to be addressed for further growing this sector. Battelle identified, using the North American Industrial Classification System

Project Tasks

- ▶ Market Driver and Trend Analysis
- ▶ Identification of Market Leaders and Emerging Firms
- ▶ Competitive Assessment
- ▶ Gap Analysis
- ▶ Proposed Actions

(NAICS), those industries that make up the E&ES sector and its subsectors. Employment and establishment data were developed to examine the size, concentration, and growth rate of each subsector.

To assess Central Upstate New York's competitive position, the project steering committee selected five regions that are seeking to grow their green economy. Battelle prepared profiles of these regions (Appendix D) and compared Central Upstate New York's employment in E&ES industry sectors with these regions.

Using the input from the interviews, the examination of employment data, and the regional profiles, Battelle proposed a recommended set of actions that could be undertaken to accelerate the growth of Central Upstate New York's green economy.

The results of both the market and competitive analyses are presented in this report.

UNDERSTANDING THE E&ES MARKET

The broad market for E&ES, green, or other environmentally oriented sectors is driven by a unique set of factors and trends. While similar in some respects, market drivers of each major subsector of this market are generally as diverse as the technologies and applications themselves. Drivers of the market for indoor environmental quality (IEQ) technologies and products tend to be vastly different from those of the market for renewable and alternative energy. For this reason, it is appropriate to separate these major groups in a market study to more clearly delineate critical drivers and trends. However, it should be recognized that intrinsic links often exist between these major groups as firms develop technologies and solutions to market demands (e.g., solar-based air heating systems; energy-efficient user-controlled lighting systems; sound-absorbing wall treatments made of renewable materials; etc.).

Significant factors driving the E&ES sector were determined by examining existing literature and market research studies as well as Web sites of companies, organizations, and governments. In this research, particular effort was made on pinpointing specific needs and requirements unique to the E&ES or related green sector companies. What became immediately clear was that the industries comprising the E&ES sector are both unique and similar to existing, more mature industries.

E&ES industries are unique, in part, because they are only recently being thought of collectively as a potential for local market and economic development. Hence, available market research and economic development programs are extremely limited with respect to the specific needs of green companies and drivers and the locational requirements of the broader green industries. These firms and industries are also unique in that the owners/entrepreneurs behind many emerging companies, while seeking appropriate financial returns for their activities, are often initially motivated by more personal green thinking and ambitions. This characteristic may drive a decision to locate or conduct business in regions with a relatively green mind-set or established green infrastructure and support. While this may sound somewhat trivial from an economic perspective, it nonetheless influences locational decision making according to personal preference or non-traditional business factors other than (or in addition to) more traditional economic development factors (such as availability of space and infrastructure, low costs, or low taxes).

Beyond working to appeal to these personal preference or community factors (programmatically and through marketing, branding, and image development), existing economic development efforts may often suffice with these firms (though ensuring applicability and robustness is still an issue). However, as with more traditional industries, local demand often spurs related economic development. For example, following the City of Chicago's establishment of a 25 percent renewable energy usage goal, multiple solar panel manufacturers established operations in the area.

Multiple solar panel manufacturers located in the Chicago area after the City of Chicago established a 25 percent renewable energy usage goal.

Indoor Environmental Quality

IEQ has a significant impact on occupant health and comfort, and is increasingly understood to play an important role in worker productivity. The definition of IEQ, according to the Federal Facilities Council (FFC), is not tightly defined in a universally accepted and measurable manner. However, the FFC has described the building-related factors that affect IEQ as follows:

“the amounts and components of air pollution (indoors and outdoors); sources and rates of ventilation (i.e., outdoor air supply); temperature and humidity ranges; levels and sources of lighting; noise and vibration; building and furnishing materials; and operations and maintenance practices.”³

In this project, the Battelle team focused on the drivers and markets related to what is traditionally referred to as indoor air quality (IAQ), but also examined issues of noise and lighting to some degree. These non-air aspects are also strongly related to building materials; hence, drivers and markets in the subsequent section on Green Buildings and Sustainable Design will also be important to the overall view of IEQ.

The National Institute for Occupational Safety and Health (NIOSH), which has conducted over 1,500 Health Hazard Evaluations of indoor environments since 1971, has found that inadequate ventilation is the leading cause of poor IAQ in more than 50 percent of the cases. Contaminants from indoor and outdoor sources affect IAQ even in cases where the quality of ventilation is reasonably adequate. Indoor spaces contain a number of pollutants or contaminants such as pesticide residues, tobacco smoke, cleaning material residues, and fumes from copy machines. Commonly used building and furnishing materials can also release contaminants as a result of normal use as well as gradual decomposition. Microbial contaminants, radon, and toxic mold are the other sources of contamination that compromise IAQ.

There is greater public concern over the impact of air quality on employee productivity and wellness. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has recently established minimum standards for IAQ in commercial and industrial settings. The World Health Organization (WHO) in a recent study of IAQ concluded that airborne contaminants kill more people than automobile accidents.

Additionally, poor IAQ has a significant economic impact. A study conducted by the U.S. Department of Energy (DOE) and Lawrence Berkeley Laboratory in 1997 concluded that the total financial impact on the U.S. economy of poor IAQ could be as high as \$158 billion. The report estimated that the cost of allergy and asthma treatment ranged from \$7 billion to \$23 billion a year, and placed productivity losses at more than \$12 billion a year.

³ Key sources used in the analysis of each of the four major industries in the E&ES market are listed at the end of this report and in Appendix A.

Noise has traditionally been recognized as a health hazard in industrial and open workspaces, with federal and state laws on occupational safety substantially addressing this problem. However, noise in office environments has become a matter of significant concern only since the mid-1990s (although the problem has been a subject of research since the early 1970s). Motivated by these concerns, the American Society of Interior Designers (ASID) and four of the leading manufacturers of building materials created a partnership to study the problem of office noise and develop strategies for improving acoustic comfort levels in offices. The study team found that noise had become a significant concern among office workers and was the single largest negative factor impacting office productivity. In a survey of office workers, conducted as part of the study, it was found that 71 percent of workplace distractions were traced to noise, compared with 20 percent for air quality and 9 percent for lighting. Ambient noise levels were found to be a significant factor in perceptions and attitudes related to productivity in the workplace, with 81 percent of the respondents expressing the opinion that they could be more productive if the workplace were quieter.

The quality of lighting, though perhaps posing a lesser impact, is also a determinant of office productivity and represents an untapped area for improving business performance. This is particularly important considering the increasing share of services in corporate revenues; as a result, office improvements have become key facilitators of revenue generation.

In an experimental study conducted with human subjects in an office setting, the Light Right Consortium found that employee persistence and vigilance declined during the course of the day when personal lighting controls were not provided. However, when personal controls were provided, there was no change during the course of the day. The most preferred lighting design, which was rated as comfortable by 91 percent of the participants, provided a combination of direct and indirect lighting, wallwashing, and occupant dimming controls.

The Consortium also found that lighting technology affects employee health and productivity:

- Published literature indicates that there is a lower incidence of headaches when electronic ballasts are used instead of magnetic ballasts.
- Office workers who reported being satisfied with the lighting in their personal work rated the space as more attractive, and reported being happier and satisfied with their workspace.
- Workers reported that the presence of personal lighting controls increased motivation and allowed them to work longer and be more accurate on difficult tasks.

Technology Market Drivers and Trends

The following six major market factors drive the IEQ sector:

- **Security against airborne attacks.** The terrorist attacks of September 11, 2001, and the anthrax attacks that followed have changed the nature of business for IAQ manufacturers. Concerns over the consequences of chemical and

biological terrorism are driving the market for the development of new air filtration and other air quality technologies and products that not only can handle routine, everyday air quality requirements but also can meet these extreme circumstances.

- **Recognition of black mold threats.** Increased media attention has made the presence of mold in interiors a matter of concern, much in the way concerns over radon and asbestos occurred in past decades. These concerns have affected strategy formulation and policy making in fundamental ways, changing the way the IAQ sector does business.
- **Financial and real estate concerns regarding Sick Building Syndrome (SBS).** The Environmental Protection Agency (EPA) estimates that the U.S. working population spends 90 percent of its time indoors. The NIOSH has in its evaluations over the years found that 20 to 30 percent of non-industrial workspaces had poor IAQ. SBS is a term used to describe a variety of symptoms exhibited by users of non-industrial workspaces. Symptoms include afflictions of the respiratory system such as nose irritation and sneezing, and others such as headache, nausea, fatigue, and dizziness. The symptoms have been traced to multiple causative agents. Building-related illnesses with more serious consequences include legionnaire's disease, asthma, and pneumonitis. Studies by the EPA and professional trade associations such as the National Contractors Association reveal that a significant number of office buildings have IAQ-related problems.
- **Cost-efficient technologies for urban asset enhancements.** The increasing recognition of the importance that IEQ plays in worker productivity and satisfaction is becoming a financial inducement (for both building owners and tenants) to ensure that existing building assets are able to meet ever-higher IEQ thresholds. The availability of cost-efficient technologies, both off-the-shelf and in some instances customized, to improve the quality of existing buildings' working environments will be necessary to maintain the viability of older urban buildings. Tenants left with no choice will seek newer (often suburban) construction to meet these IEQ thresholds.
- **Increasing interest in improving energy efficiency of IEQ systems.** High energy costs in the 1970s led many heating, ventilation, and air conditioning (HVAC) system designers to sacrifice air quality in favor of energy efficiency, as dense filters used at the time were found to impede air flow and increase energy consumption. Today's HVAC filtration systems must meet multiple objectives—protect internal machinery (compressors, blowers, and motors) and deliver high air quality—without causing a significant increase in energy consumption. Additionally, improvements in lighting systems (e.g., personal control, low-level ambient lighting, etc.) are often shown to compensate for additional up-front costs through energy-efficiency-based cost savings.
- **Presence or absence of legislatively mandated regulatory standards.** In the United States, although no single federal agency has mandated IAQ standards, the EPA, the Occupational Safety and Health Administration (OSHA), and a few other industry associations, notably ASHRAE, have issued new guidelines.

The Indoor Environments Division of the EPA implements a voluntary (nonregulatory) program that addresses IAQ with standards regarding pollutants, radon mitigation, asthma triggers, and other air toxics. State legislation with respect to toxic mold further drives the IAQ market from a regulatory standpoint. However, a **lack** of standards in some areas also impacts the IAQ/IEQ market because the claims of a number of manufacturers of stand-alone devices are unverifiable. Increased public interest and more information are expected to drive demand in the residential sector.

From an economic development perspective, some factors that influence the location of IEQ firms include the following:

- **The presence of active homeland security operations and/or significant research efforts focused on homeland security.** Given the events of 9/11 and the related concerns over bioterrorism, there has been an increased interest in the role IAQ equipment can play in the safety of building occupants. Significant resources have been targeted at research and development (R&D) efforts to improve the efficacy of IAQ sensors, monitoring, and systems controls. Access to or involvement with these government implementation and research funds encourages firms to locate in regions with significant efforts.
- **Access to broad, multidisciplinary research.** The technologies and sophisticated components associated with the entire spectrum of IAQ equipment require access to a base of complementary research and facilities in a broad range of disciplines. These disciplines include areas such as fluid dynamics, electronic engineering, information technology, and materials science/nanotechnology.
- **Access to academic and industrial R&D facilities.** Given the dominance of large firm players in the IEQ marketplace, it is difficult for smaller and/or start-up firms to make all the infrastructure investments necessary to develop new, niche technologies. The ability for these firms to leverage substantial academic or industrial R&D facilities and expertise can potentially be an attractive locational feature for a region.
- **Access to a skilled workforce.** IEQ firms need access to scientists and professionals with skills relevant to this industry cluster, including civil engineers, environmental engineers, architects, and various other scientists.
- **Quality-of-life considerations.** Of the four industry segments examined, IEQ consists of a larger set of more mature companies. These more mature firms often prioritize community characteristics that attract and benefit workers, such as a strong and supportive business climate, high-quality K-20 education, and overall family-friendly lifestyle, over more technology- or segment-specific requirements.

Table 1 summarizes the key drivers of the IEQ sector.

Table 1: Key Drivers of IEQ Sector

Indoor Environmental Quality: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • Security against airborne attacks • Recognition of black mold threats • Financial and real estate concerns regarding sick building syndrome • Cost-efficient technologies for urban asset enhancements • Increasing interest in improving energy efficiency of IEQ systems • Presence or absence of legislatively mandated regulatory standards
Economic Development Drivers	<ul style="list-style-type: none"> • Federal, state, and local funding for homeland security • Advances in multidisciplinary research • Improved R&D capabilities
Firm Locational Requirements	<ul style="list-style-type: none"> • Firms need partnerships with university researchers, but they don't necessarily need to be located next to them • Scientists and other professionals with skills relevant to environmental industry cluster • Business climate that is attractive to mature industries <ul style="list-style-type: none"> - Skilled workforce - High-quality K-20 education - Family-friendly quality of life
Key Market Opportunities	<ul style="list-style-type: none"> • Global expansion of high-tech manufacturing and research • Demand for home IAQ instrumentation and expansion of residential air filtration market • Growth for market in energy recovery ventilation systems • Growth of office building remediation market • Growing market for IAQ monitors • Growing market for specialty instrumentation measuring VOCs, gases, and particles

Central Upstate New York Assets

Central Upstate New York has significant assets in IEQ because of the investments that have been made during the past decade and the presence of major corporate leaders in this field. The region can provide firms with access to both university and private industry R&D expertise. The region is home to the following:

- **The Center of Excellence in Environmental and Energy Systems (Syracuse CoE)**. While housed at the University of Syracuse, the Syracuse CoE includes all of the region's universities and many private sector firms. IEQ is a major focus of the Syracuse CoE, and its partner universities have leading researchers in various aspects of IEQ. The Syracuse CoE received capital funding from the State of New York's Centers of Excellence program and is in the process of completing a new building with state-of-the-art laboratory space in downtown Syracuse. Partner centers include:
 - **Clarkson Center for Air Resources Engineering and Science (CARES)**. CARES brings together researchers from various New York universities to focus on measuring, modeling, and implementing strategies to improve IEQ in homes, hospitals, and commercial manufacturing facilities.

- **STAR Center for Environmental Quality Systems (STAR EQS Center).** The STAR EQS Center seeks to advance knowledge on intelligent systems that enhance human health and performance, reduce lifecycle costs and improve quality of urban ecosystems and their built environments.
- **Building Energy and Environmental Systems Lab (BEESL) at SU.** BEESL seeks to advance science and develop technologies in areas of IEQ, building energy efficiency and building protections.
- **Pall Corporation.** A billion-dollar company and world leader in the filtration industry, Pall Corporation has a facility in Cortland NY.
- **Carrier Corporation.** A leading global company in air filtration, conditioning, ventilation, and treatment technologies, Carrier has located its IAQ Key Competency Group in Syracuse.
- **Numerous small innovative IEQ companies.** These include Air Innovations and NuClimate.

These resources could be used to attract companies and to help existing companies with new product development.

Challenges

For the region's IEQ companies to grow, they must be able to tap into an expanding market; for such a market to exist, consumers must understand the need for IEQ technologies. Yet, the first concern for many consumers is cost. Educating the marketplace will have to go hand in hand with encouraging the development of new technologies and products.

There is also a disconnect between Central Upstate New York's IEQ research base and its IEQ companies. University researchers tend to focus on areas for which funding is readily available. Since much of this funding comes from the federal government, they tend to do basic research or research that addresses the missions of these federal agencies. On the company side, many small firms are not focused on next-generation products; others do not know what to ask for in terms of research. Greater interaction between the companies and researchers and access to larger amounts of funding for collaborative university-industry projects would help to ensure that the region is able to leverage the academic research base to achieve greater economic development.

Lastly, Central Upstate New York is not the only region seeking to build an IEQ cluster. California is clearly the leader in both indoor and outdoor air quality. University Centers, such as the Berkeley Center for the Built Environment, Carnegie Mellon's Center for Building Performance and Diagnostics, and Penn State University's Indoor Environment Center, are established programs, with which the Syracuse CoE must compete.

Opportunities for Central Upstate New York

Industry and university leaders in the region suggested the following areas of opportunity for Central Upstate New York’s IEQ firms:

- **Tie IEQ to health and human performance.** This is already being done with projects underway in developing new sensor and filtration systems, new building materials that reduce airborne contaminants, and innovations that allow individuals to control their personal microenvironment.
- **Build on the presence of Carrier Corporation to support the growth and development of the region’s emerging IEQ companies.** It may be possible for the region’s small companies to market new products through Carrier’s distribution channels. Carrier may also have specialized equipment that could be made available to start-up and emerging companies.
- **Seek applications** for technologies developed for IEQ in sensing, monitoring, and filtration in the **healthcare** and **homeland security** markets.

Actions that could be taken to further build the region’s IEQ cluster include strengthening industry-university partnerships and aligning the research focus of the CoE with areas of interest to the region’s companies, which will require greater resources that can be dedicated to both operating expenses and focused R&D. Attracting IEQ companies to the region will require that the Center and its partner institutions continue to build its critical mass of world-class researchers in the IEQ area. Table 2 provides an overview of Central Upstate New York’s IEQ sector.

Table 2: IEQ Sector in Central Upstate New York

Indoor Environmental Quality: Central Upstate New York	
Key Assets	<ul style="list-style-type: none"> • Syracuse Center of Excellence, although limited by lack of operating and R&D funding • STAR EQS equipment • Capital equipment and research funding received from EPA • Clarkson CARES (STAR EQS node) • Great strengths in area of ultrafine particles: Jianshun Zhang, Syracuse University; Phil Hopke, Clarkson; University of Rochester; and Upstate Medical • Expertise in sensors • Presence of Carrier’s Design Team with focus on IEQ
Industry Base	<ul style="list-style-type: none"> • Region has a number of innovative IEQ firms such as Air Innovations, NuClimate • NYS has lost a significant number of air quality companies: <ul style="list-style-type: none"> - Loss of Carrier’s manufacturing operations - Purchase of Rupprecht & Patashnick by Thermo Electron—moving from Albany to MA
Key Challenges	<ul style="list-style-type: none"> • Lack of an educated market • May be difficult to attract large companies such as Johnson Controls, Honeywell, who have established relationships with major universities • California is clearly the leader in both indoor and outdoor air quality • Competitors, Berkeley and Pittsburgh, have very strong university assets in this area • For most customers, first consideration is still cost • Disconnect between research agenda and relevance to companies
Key Opportunities	<ul style="list-style-type: none"> • Tie IEQ to health and human performance • Sell products of small companies through Carrier’s marketing channels • Carrier could provide access to specialized equipment/ space for start-up companies • Tap into homeland security market • Access healthcare market

Renewable Energy

A range of external factors shapes and influences the future direction of the market for renewable energy and the technologies that produce it. Such factors may be technological, regulatory, or based on consumer preferences. Technological factors include large shifts in research funding and the development of innovative technologies by industry leaders who can affect the market. The extent of these technology breakthroughs is dependent in large part on R&D funding. Regulatory factors include various financial incentives and policies that can alter demand for traditional and alternative sources of energy. Finally, increasing desire for a sustainable economy, rising electric power needs, environmental concerns, and moral pressures are among the factors influencing the preferences of energy consumers.

Market forces driving growth of the renewable energy sector include the following:

- **National R&D budgets and financing for energy technologies.** Changes in R&D budgets in both public and private sectors drive the identification rate of solutions to current technology barriers. Increased R&D budgets yield accelerated research, firm entrance, and, ultimately, falling costs for alternative energy technologies. In addition, as oil and natural gas prices rise, excess capital normally directed to traditional energy companies is rerouted to company-level venture capital funds, many of which are investing in various alternative energy technologies.
- **Public policies, government subsidies, and incentive programs.** Political and financial instruments, such as R&D incentives, tax credits, or fees, can spur R&D, production, consumption, and market competition. For example, the Energy Policy Act of 2005 provides tax incentives to consumers who can keep their energy consumption at or below specific levels and mandated an ethanol production increase to 7.5 billion gallons per year by 2012. The 2005 Investment Tax Credit (ITC) gave a boost to industry efforts toward commercialization of fuel cells by encouraging the purchase of fuel cells for both residential and business use. The Renewable Energy Production Tax Credit (PTC) is helping to lower the costs of wind power by encouraging new firm investments.
- **Goals/mandates, targets, and standards.** A growing number of states and countries have enacted policies designed to increase the use of energy derived from renewable resources. Renewable portfolio standards (RPSs) are a key driver of U.S. renewable energy utilization and production. At present, 22 states and the District of Columbia have enacted RPSs. In August 2007, the U.S. House of Representatives voted to require investor-owned electric utilities nationwide to generate at least 15 percent of their electricity from renewable energy sources. Countries of the European Union have adopted a goal of deriving 20 to 30 percent of their total energy demand from renewable resources by 2020.
- **Increased nationwide support for a secure and sustainable economy.** The security and reliability of traditional sources of energy, such as oil, are questionable given current geopolitical crises and related concerns around the globe. Rising and fluctuating fossil fuel costs and the threat of foreign fuel supply inter-

ruptions are the primary contributors to a growing nationwide demand for development of domestic fuel sources.

- **Growing global and domestic energy demand.** The world is experiencing a rising demand for energy and electric power, a trend that is resulting in increased global competition for energy resources. The energy requirements of China and India have increased sharply for their rapidly growing economies. U.S. growth in high-tech equipment and personal electronics is also contributing to increased energy use; domestic energy consumption per capita is expected to rise 17 percent through 2025.
- **Concerns over global warming/climate change.** Mounting scientific evidence of global climate warming due to greenhouse gas emissions has produced a convergence of political and public opinion that reduction of fossil-fuel generated greenhouse gases is imperative.
- **Consumer tastes and preferences going green.** Many energy consumers are increasingly demanding alternative sources of energy; and, if given a choice between traditional and alternative energy supplies at a similar cost, many consumers are opting for the cleaner alternatives.

In addition to the market, the following economic factors drive the growth and location of renewable energy companies:

- **Access to inputs and supporting infrastructure.** As with any siting decision, availability of key inputs and a distribution network are critical. Renewable energy production plants require proximity to abundant natural resources—wind, sunlight, biomass feedstock, or water (as a renewable source of hydrogen). Access to transmission lines for the distribution of electricity to the main grid or to consumers is also needed. Access to traditional university-centered research could also be advantageous, particularly if strong programs in environmental engineering, materials science engineering, plant genetics, and/or biochemistry are in place and research clusters can be developed around broad renewable energy themes.

Certain types of capital may be designated specifically for investment in renewable energy projects. “Green funds”—funds that invest in environmentally progressive companies—or “green energy grants”—competitive grants that support renewable energy R&D or deployment at the consumer or corporate level—are potential sources of capital for new or growing renewable energy companies.

- **Forward-thinking policy making at local, state, and federal levels.** States are using increasingly aggressive and ambitious Renewable Portfolio Standards (RPS) to spur economic development and to create a reliable and diversified supply of electricity, as well as to reduce greenhouse gas emissions and conventional pollutants. Twenty-two states and the District of Columbia have implemented an RPS.
- **Willingness of existing utilities to partner with renewable energy companies.** While states with RPS’ in place require utilities serving their state to obtain a specific percentage of retail electricity from renewable resources, new or

growing renewable energy companies can only benefit from these standards if the existing utilities are willing to partner with them rather than obtain renewable energy generated outside of the state off of the grid or build their own solar, wind, biofuel, or hydropower facilities.

- **Pursuit of both alternative energy investors and businesses.** A meaningful, earnest pursuit of both new alternative energy firms and venture capital firms (and other early-stage investors) is attractive to a company as it chooses its location for operations. At the same time, if a state or local government takes a strong, pro-environmental policy stance, businesses will look favorably to the region as a potential site.

Table 3 summarizes the key drivers of the renewable energy sector.

Table 3: Key Drivers of Renewable Energy Sector

Renewable Energy: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • National R&D budgets and financing for energy technologies • Public policies, government subsidies, and incentive programs • Goals, mandates, targets, and standards • Increased nationwide support for a secure and sustainable economy • Growing global and domestic energy demand • Concerns over global warming/climate change • Consumer tastes and preferences going green
Economic Development Drivers	<ul style="list-style-type: none"> • Access to inputs and supporting infrastructure • Forward-thinking policy making at local, state, and federal levels • Willingness of existing utilities to partner with renewable energy companies • Pursuit of alternative energy investors and businesses
Locational Requirements	<ul style="list-style-type: none"> • Access to energy sources • Availability of incentives • Supportive regulatory and public policy environment
Key Opportunities	<ul style="list-style-type: none"> • Worldwide market for biofuels • Offshore wind turbine design/wind energy consulting services, small wind turbine design, energy storage systems • On-grid solar applications, consumer and industrial PV markets, non-silicon-based thin-film PV technologies • Portable personal electronics, portable power systems, small off-road transportation

Central Upstate New York’s potential in the various renewable energy subsectors is discussed below.

Biomass

Among the various sources of renewable energy, biomass—plant matter and other biodegradable materials—as a source of energy is receiving a great deal of attention. Conversion of biomass into “biofuels” such as ethanol, biodiesel, biobutanol, and biogas is a major focal point of today’s economy due to the potential to relieve dependence on foreign oil and to reduce greenhouse gas emissions.

The two most common types of biofuels are ethanol and biodiesel. Typically, ethanol is made by fermenting starches and sugars in corn and other plants such as sugar cane; but, cellulosic plant matter such as corn cobs, husks, and agricultural waste offer greater energy potential and less controversy regarding the use of feedstock to meet energy needs. Hardwoods are an especially abundant source of cellu-

lose and represent the largest biomass energy resource today. Therefore, major research initiatives are being directed toward collection, treatment, digestion, and fermentation of cellulosic materials to produce ethanol. Biodiesel is produced through a different method altogether (transesterification) using crops, waste, or microbes with high oil content.

Technology Market Drivers and Trends

The ethanol and biodiesel markets are growing rapidly—ethanol at roughly 15 percent and biodiesel at 85 percent in recent years—and continued rapid growth of these markets both worldwide and in the United States is anticipated (Renewable Energy Policy Network of the 21st Century). While much of the focus in achieving national or state goals in biofuel production is on corn-based ethanol and biodiesel, interest in cellulosic-based ethanol, algae-based biodiesel, biobutanol, and biopropane is escalating.

Key opportunities for development of biomass energy will result from the following:

- **Rapid growth in the worldwide market for biofuels.** The worldwide market for biofuels was \$20.5 billion in 2006 and is expected to reach \$80.9 billion by 2016 (Clean Edge). Growth in the biofuels sector will come from new commercial and industrial biomass power plants; distributed production in pulp/paper mills; wholesale power generation; solid-waste conversion to energy; and farm, landfill, and wastewater treatment projects. The worldwide market for cellulosic biofuels is projected to reach \$10 billion by 2012 (Shell).
- **Growth in U.S. demand for ethanol and other transportation fuels.** The U.S. ethanol industry is the one of the fastest-growing energy industries in the world. Ethanol demand is driven by replacement of gasoline additive MTBE with ethanol; government-mandated production targets; air quality issues; tax credits and other financial incentives; and reducing dependence on foreign oil (BCC Research). U.S. demand for transportation biofuels for cars and trucks will double to 6 percent of all road fuels by 2010. Road fuels currently represent a \$28.4 billion market (Cambridge Energy).
- **Growing markets for biorefinery products.** Biomass can also be used to produce chemicals and materials currently generated from fossil sources, further increasing the efficiency and economic value of bio-based technologies. The variety of products that can be generated is diverse, ranging from adhesives and paint to nutraceuticals and animal feed.

Opportunities for Central Upstate New York

New York has a number of assets that make it an attractive location for the production of biomass energy. The region has a very large, available supply of biomass feedstock, both wood and agricultural products. The region's universities have developed expertise and technologies that could be used to convert these resources into energy. SUNY-ESF, which houses the SUNY Center for Sustainable and Renewable Energy, has expertise and technology to convert cellulosic biomass into biofuels, bioplastics, and bioenergy. Clarkson University's CARES is conducting research

on biodiesel, and SUNY-Morrisville is investigating using various agricultural products to produce biofuels and other products.

A number of projects to produce energy from biomass are underway in Central Upstate New York, including the following:

- **Northeast Biofuels** is developing an ethanol production plant at the site of the former Miller Brewing Company in Fulton NY. The plant will initially use corn as its feedstock but hopes to be able to produce cellulosic ethanol in the future. This facility will be the first ethanol production plant in New York State and in New England.
- **Catalyst Renewables Corporation** is working with SUNY-ESF to develop a pilot cellulosic ethanol plant in Lyonsdale NY.
- **SUNY–Morrisville**, in conjunction with Empire AgriFuel, is developing a **green biofuel blending facility** that will convert soy to biodiesel.
- **ND Fusion** is a small company in Potsdam NY that uses process intensification to provide green processing of chemicals, pharmaceuticals, and alternative energy.
- **ZeroPoint Clean Tech, Inc.**, also in Potsdam, is a renewable energy company that has developed a highly efficient gasification process for converting biomass into renewable gas, electricity, or liquid fuels.

Clearly, Central Upstate New York has university expertise in biomass energy and private sector firms that have been created to exploit this technology. But, it should be recognized that, with the exception of ethanol from corn, biomass fuels from other sources have not yet been produced on a commercial scale. New York has demonstration pilot programs underway; but, these new technologies will need to be proven and deployed before this industry becomes a driver of economic development.

It is also the case that many regions are focusing on the development of biomass energy. Many think the key will be to develop biofuels and other products from locally available feedstocks; if so, this industry may become regional than national or international. At the moment, emerging biomass energy firms are concentrated in California and Massachusetts; no leading biomass energy firms were identified in New York. Table 4 provides an overview of Central Upstate New York's biomass energy sector.

Table 4: Biomass Energy Sector in Central Upstate New York

Biomass: Central Upstate New York	
Key Assets	<ul style="list-style-type: none"> • Supply of biomass feedstock—state has 18.5 million acres of forest land/potential for 20 million tons of biomass, also has agricultural products that could be used • Key strengths in cellulosic material and process engineering • ESF expertise in cellulosic biomass for biofuels, bioplastics, and bioenergy <ul style="list-style-type: none"> - Working with Xerox, Welch Allyn, and Tessy Plastics on bioplastics - Working with Constellation Energy, NY Power, and others to use wood and wood residues as feedstocks to generate electric energy or steam - Working with Johnson Controls on gasification of biomass to produce syn gas • Clarkson CARES (est. through STAR grant)—biodiesel • SUNY Center for Sustainable and Renewable Energy at ESF
Industry Base	<ul style="list-style-type: none"> • Northeast Biofuels (Under development) • Catalyst Renewables Corp. working with ESF to develop a cellulosic ethanol pilot plant in Lyonsdale • SUNY–Morrisville developing a biofuel facility in conjunction with Empire AgriFuel • ND Fusion • ZeroPoint Clean Tech, Inc.
Key Challenges	<ul style="list-style-type: none"> • With the exception of corn to ethanol, technology has not been demonstrated that can produce biomass fuels on a commercial scale that is competitive • Other regions such as Canada and Maine also have large supplies of biomass and closed pulp and paper mills • Regions that received major DOE awards are likely to become leaders <ul style="list-style-type: none"> - Oak Ridge National Lab - University of Wisconsin - Lawrence Berkeley Lab and University of California at Berkeley
Key Opportunities	<ul style="list-style-type: none"> • Closed pulp and paper mills could be converted into biorefineries producing a suite of products • Opportunities to meet regional demand for biofuels • Technology and processes developed in the region could be exported for use elsewhere

Wind Power

As one of mankind’s oldest sources of power generation, harnessing wind energy to produce electricity can be seen as a natural and logical fit today when 6 billion people have ever-increasing demands for electricity. Whether powering sailboats for transportation or windmills for production, humans have utilized wind for centuries. Today, wind generates electricity by converting the mechanical energy of rotating turbine blades into an electrical current.

Wind energy is produced in both large- and small-scale operations. Large-scale wind farms produce for the electrical grid and require energy storage devices to compensate for the variability in output associated with wind (i.e., wind does not occur at a constant rate). On a smaller scale, individual wind turbines are capable of providing electricity for off-the-grid locales and might similarly utilize power storage systems, often batteries.

Market Trends, Challenges, and Opportunities

The market for and production of wind power is experiencing rapid growth both nationally and in the Central Upstate New York region. Technological advances along with government investment incentives and the desire to use sustainable, green energy sources are leading to rapid installation of wind turbines. Wind power can be an effective driver of economic development. Wind farms boost the local tax base,

provide direct benefits to local farmers and landowners, and create jobs in the production supply chain for wind turbines and related goods.

Wind energy is the fastest-growing energy sector. Worldwide, installed capacity of wind power from 2004 to 2005 increased nearly 24 percent, pushing global wind generation capacity to 60 gigawatts for 2005. For the first time since 1992, the United States was the leader in additions to wind power in 2005. Global added capacity helped total sales of wind power reach nearly \$18 billion in 2006. Some projections have this sales total reaching over \$60 billion by 2016.

U.S. consumption of wind power grew fivefold from 1990 through 2005 to 149,490 billion BTUs (British thermal units). This level of current national consumption translates to about 0.4 percent of U.S. energy consumption—a share that is growing rapidly. The American Wind Energy Association forecasts that by 2020, wind power will rise to meet 6 percent of U.S. electricity needs. Texas overtook California in 2006 as the top U.S. state with respect to installed wind energy—Iowa, Minnesota, and Washington round out the top five.

Companies in Europe, Germany in particular, dominate the wind energy market; but, the United States has a number of emerging companies in the wind energy sector focused primarily on developing new types of wind turbines.

These trends suggest numerous viable market opportunities for private companies to pursue, namely:

- Offshore wind turbine design including specialized anchoring methods and offshore-specific technologies to reduce costs and boost efficiency.
- Wind energy consulting services including optimal site selection; regional economic development potential and assessments; environmental impacts on birds and noise reduction; advising on government policy and optimizing tax credits.
- Small wind turbine design for residential and other small-scale applications and the ability to improve payback time through grid connections for surplus electricity. As a subset, these include new opportunities in micro, building-integrated wind turbines installed on buildings in urban environments.
- Energy storage systems R&D to determine best fits for storing intermittent and surplus wind energy.

Table 5 summarizes the key drivers of the wind energy sector.

Table 5: Key Drivers of Wind Energy Sector

Wind: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • National R&D budgets and financing for energy technologies • Public policies, government subsidies, and incentive programs • Goals, mandates, targets, and standards • Increased nationwide support for a secure and sustainable economy • Growing global and domestic energy demand • Concerns over global warming/climate change • Consumer tastes and preferences going green
Economic Development Drivers	<ul style="list-style-type: none"> • Wind power seen as a source of rural economic development • Cost of generating wind power has decreased substantially in recent years because of new technologies and economies of scale
Locational Requirements	<ul style="list-style-type: none"> • Sufficient wind power • Electricity distribution system able to distribute wind power
Key Opportunities	<ul style="list-style-type: none"> • Offshore wind turbine design • Wind energy consulting services • Small wind turbine design for residential and other small-scale applications • Energy storage systems

Opportunities for Central Upstate New York

Like hydroelectricity, wind energy is inherently tied to regions that have certain natural features of topography and climate to make wind a reasonable source of energy. It is estimated that New York could be one of the top 10 wind energy-producing states in the United States. Central Upstate New York already has several wind farms operating or under development. While the production of wind energy will be an important factor in meeting renewable energy goals and decreasing greenhouse gases, it is unclear the extent to which it will become an economic driver for regions, although wind energy can provide an important source of income for landowners in rural areas.

The manufacturing of wind turbines, blades, etc., is already well established in many countries. Turbine equipment production has largely been captured by Europe as virtually all parts of wind turbines can be transported anywhere in the world. Currently, there is no particular reason why wind energy equipment needs to be manufactured near the site of installation.

There are opportunities in producing innovative wind energy equipment, and Central Upstate New York has strengths that could position the region to grow this sector. The region is home to an emerging company, Vento Tek, which is developing “smart blades,” devices that control the flow of air around blades. Vento Tek is a spin-off of Clarkson University. Clarkson researchers are working with Warner Energy to develop more efficient, small wind turbines. Central Upstate New York has expertise in sensors, engineering, and materials that position it to develop technology to improve wind energy production.

The wind energy consulting market also offers an opportunity for the region's many environmental consulting firms. Table 6 provides an overview of Central Upstate New York's position in wind energy.

Table 6: Wind Energy Sector in Central Upstate New York

Wind: Central Upstate New York	
Key Assets	<ul style="list-style-type: none"> • Expertise in sensors • Engineering and materials expertise
Industry Base	<ul style="list-style-type: none"> • Region has several wind farms operating or under development, but no companies building turbines • Warner Energy working with researchers at Clarkson to develop more efficient, small wind turbines; construction underway on full-scale 2.5 kilowatt prototype windmill
Key Challenges	<ul style="list-style-type: none"> • Europe has captured the wind turbine production market, although there are companies in the U.S. pursuing innovative designs
Key Opportunities	<ul style="list-style-type: none"> • New York state could be one of top 10 wind producers • Wind energy could provide income for the region's agricultural sector • Region's environmental consulting firms could provide wind energy consulting services

Solar Energy

Solar power is derived by converting energy from sunlight into heat or electricity. Solar energy technologies can be found in a range of applications from the micro level (e.g., mobile power generators) to the macro level (e.g., skyscrapers). Solar power can be divided into two principal categories: photovoltaic (PV) and solar thermal systems.

PV cells convert sunlight directly into electricity. They are semiconductor devices that almost always consist of silicon crystals doped with impurities, a combination that in the presence of sunlight generates free electrons and thus an electric current. The three main types of PV cells are (1) single-crystal, (2) multi- or polycrystal, and (3) thin-film (amorphous silicon). Crystalline cells account for the vast majority of the PV cell market. Thin-film solar cells do not absorb light as well as crystalline cells, but are far thinner, smaller, and weigh less. A system of lenses or mirrors can be used to focus sunlight onto a small area of PV cells, increasing the amount of sunlight absorbed. Anti-reflective coatings on PV cells also increase absorption.

Solar thermal systems produce heat or hot water for buildings or industrial processes. They can also generate electricity by operating heat engines or by producing steam to spin electric turbines in solar thermal electric power plants. Solar thermal systems may be concentrating or nonconcentrating. Concentrating solar power systems use various configurations of lenses or mirrors to convert sunlight into heat and then into electricity. The amount of power generated by a concentrating solar power plant depends on the amount of direct sunlight. These systems possess high solar-to-electric conversion efficiencies, and some are equipped with thermal storage capacity for use during low-sun periods. Nonconcentrating systems do not use lenses or mirrors to focus sunlight and thus are less efficient thermodynamically.

Electricity produced by solar energy systems is either stored in batteries or is fed into the electricity grid using grid-connected PV systems called inverters.

Technology Market Drivers and Trends

Electricity generation from solar energy has increased rapidly, growing annually by an average of approximately 20 percent for the past decade. The solar PV industry is one of the world's fastest-growing industries, with a growth rate of approximately 40 percent in recent years. The global solar energy market is currently valued at \$11 billion (*Business 2.0 Magazine*) and is projected to reach \$69.3 billion by 2015 (Clean Edge, Inc.). Since 2002, revenues in the solar market have grown at 47 percent on an annual compounded basis (Clean Edge, Inc., 2006).

Solar PV capacity is concentrated in Germany, Japan, and the United States. In Germany and Japan, generous government subsidies have stimulated demand spurring most of this development. In the United States, a few states—primarily California—have passed major solar initiatives resulting in a broad range of installed projects. Because of its chip industry, California is the ideal setting for the development of new materials and technologies for solar cells. Not surprisingly, California is home to a majority of the emerging solar firms identified in this analysis.

Major technology research goals in solar energy lie in three areas:

1. **Making solar cells cheaper and more efficient.** Approaches include lowering costs related to the manufacturing of silicon crystals, increasing the conversion efficiency of silicon-based solar cells, and using systems of mirrors and lenses to focus sunlight directly onto cells. Also, new manufacturing techniques such as “printing” solar cells on plastic sheets instead of silicon chips are helping to drive down costs.
2. **Developing new solar cell architectural designs.** Approaches include restructuring—particularly nanostructuring—the surface to reduce reflection loss, using a pyramid-shaped structure so that incoming light hits the surface multiple times, and using tandem or stacked cells that absorb a wide spectrum of radiation.
3. Almost 90 percent of PV cells contain silicon, yet there is a limited supply of it worldwide. Therefore, an important research goal is to **develop new materials** for absorbing light and carrying charge. Materials under investigation include gallium arsenide (GaAs), cadmium telluride (CdTe), and copper indium diselenide (CuInSe₂).

Key market opportunities are found in the following areas:

- Alternative (non-silicon-based) thin-film PV technologies.
- On-grid applications market (in which solar power is used to supplement electricity obtained from the utility network), which is the fastest-growing segment of the solar power systems market.
- Consumer PV markets including installations for use in residential grid-tie systems, water pumping, recreational vehicle and marine applications, and remote home systems.

- Industrial PV markets including the employment of PV technology in communications, oil and gas industries, traffic safety, railroad applications, lighting systems, rural development, installations in commercial grid-tie systems, and defense-related applications for the government.
- Solar nanotech (tiny solar cells can be printed onto flexible, very thin light-retaining materials, bypassing the cost of silicon production). NanoMarket’s projections indicate that printed PV could be a \$1 billion market by 2011.
- Hybrid power systems incorporating PVs such as generators, batteries, etc.
- Rooftop solar—once solar panels are smaller and lighter, they can be incorporated directly into roofing material.

Table 7 summarizes the key drivers of the solar energy sector.

Table 7: Key Drivers of Solar Energy Sector

Solar: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • National R&D budgets and financing for energy technologies • Public policies, government subsidies, and incentive programs • Goals, mandates, targets, and standards • Increased nationwide support for a secure and sustainable economy • Growing global and domestic energy demand • Concerns over global warming/climate change • Consumer tastes and preferences going green • Solar PV industry is one of the world’s fastest-growing industries • But very concentrated in three countries: Germany, Japan, and U.S.
Economic Development Drivers	<ul style="list-style-type: none"> • Development spurred by government subsidies • Major U.S. investments in PV in the U.S.—three of the largest technology IPOs in 2005 were for solar companies
Key Locational Requirements	<ul style="list-style-type: none"> • Adequate sunlight • Local demand • Supporting public policies • Government subsidies and incentives
Key Opportunities	<ul style="list-style-type: none"> • Market for on-grid applications • Growing consumer PV market • Growing industrial PV market

Opportunities for Central Upstate New York

The State of New York and Central Upstate New York do not have an established solar industry. Central Upstate New York’s materials expertise could be applied to the development of materials for solar cells, and the Center for Future Energy at Rensselaer Polytechnic Institute (RPI) includes a focus on high-end III-V high-efficiency cells and thermal solar. If incentives were provided to promote the use of solar energy, the increased demand that would result could be used to attract or encourage the creation of companies to meet that demand. Table 8 provides an overview of Central Upstate New York’s solar energy sector.

Table 8: Solar Energy Sector in Central Upstate New York

Solar: Central Upstate New York	
Key Assets	<ul style="list-style-type: none"> Center for Future Energy (NYSTAR CAT) at RPI includes focus on high-end III-V high-efficiency cells and thermal solar Region has materials expertise
Industry Base	<ul style="list-style-type: none"> No firms involved in the solar energy market
Key Challenges	<ul style="list-style-type: none"> NY is far behind in the development of a solar energy market Few incentives for solar energy use U.S. has lost leadership to Germany and most recently China
Key Opportunities	<ul style="list-style-type: none"> Technologies based on thin-film materials

Fuel Cells, Including Portable/Micro-Fuel Cells

Fuel cells are electrochemical devices that use hydrogen and oxygen to produce electricity with the only by-products of the reaction being water and heat. By emitting only these “clean” by-products, fuel cells offer a promising alternative in which to convert energy that does not pollute the environment. Fuel cells have tremendous potential to replace a variety of energy conversion devices including gas turbines at power plants, gas engines in automobiles, and batteries in portable electronic devices like computer laptops. While these cells represent a proven technology and would ideally begin to replace traditional devices now, several obstacles remain that make them difficult to fully integrate into these energy-intensive applications.

Fuel cell technology, in basic terms, positions hydrogen and oxygen separated by a catalyst. Within the cell, a chemical reaction inside the catalyst generates electricity. As long as hydrogen is supplied as the input, the fuel cell will continue to generate power. Because the conversion of the fuel to energy occurs via an electrochemical process, not by combustion, the process is clean, quiet, and highly efficient compared with traditional combustion of fossil fuels. In fact, fuel cells are two to three times as efficient as burning fossil fuels.

Different fuel cells incorporate different chemistry and are categorized by their operating temperature and the type of electrolyte used. The major types include polymer exchange membrane fuel cell (PEMFC), solid oxide fuel cell (SOFC), alkaline fuel cell (AFC), molten-carbonate fuel cell (MCFC), phosphoric acid fuel cell (PAFC), and direct methanol fuel cell (DMFC). The PEMFC is the most promising candidate for use in automotive transportation. This type of fuel cell operates at a relatively low temperature (140 to 176 degrees Fahrenheit), which means it does not take long to warm up. The SOFCs are best suited for powering large stationary generators for towns or large factories. DMFCs are proving to be optimal for micro-fuel cell applications.

Micro-fuel cells (MFCs) are small fuel cells used to power small, portable electronic devices such as cellular phones, PDAs (personal digital assistants), digital cameras and camcorders, and notebook PCs (personal computers). While there is no strict definition of an MFC, the term generally describes a small fuel cell that produces fewer than 50 watts of power.

Market Drivers, Trends, and Opportunities

According to Clean Edge research, the market for fuel cells and distributed hydrogen is projected to grow from \$1.4 billion (mostly in research contracts and test units) to nearly \$16 billion over the coming decade. The Worldwide Fuel Cell Industry Survey, a joint information gathering effort by leading national fuel cell industry associations in the United States, Canada, Europe, and Japan, has been conducted annually for the past 4 years. According to the 2006 survey (reporting 2005 data), global industry sales increased by 7 percent from 2004 to 2005 to \$353 million.

Global demand for portable electronic devices is driving growth of the MFC sector. MFCs have the potential to replace lithium ion batteries as an energy source providing up to 10 times the energy of existing battery technology. The low emissions and greater efficiency to be gained with fuel cells are preferable to recharging batteries using electrical power supplies. The global market for micro-fuel cells is expanding rapidly. The market for micro-fuel cells is estimated at \$12 million in 2006 and projected to reach \$112 million by 2011 (Innovative Research and Products).

In general, fuel cells are a proven technology, converting energy for an array of applications. Achieving widespread usage and commercial scale, however, is proving to be a challenge on a number of fronts. While MFCs have greater energy density than batteries and allow for a significant power upgrade for portable electronic devices, developing fuel cells for these small electronics has posed several research and engineering challenges such as the following:

- High energy density requires that the “rest of the system” be miniaturized. This challenge is being addressed by incorporation of new and emerging MEMS (microelectromechanical systems) technology.
- Electronic products themselves must have a high-efficiency design to support the fuel cell system.
- Safety is a major concern with an MFC system, specifically with regard to fuel storage and handling.
- Generally, the major challenges facing researchers are achieving a viable cost-to-power ratio and a weight-to-power ratio (energy density).

Table 9 summarizes the key drivers of the fuel cell sector.

Table 9: Key Drivers of Fuel Cell Sector

Fuel Cells: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • National R&D budgets and financing for energy technologies • Public policies, government subsidies, and incentive programs • Goals, mandates, targets, and standards • Increased nationwide support for a secure and sustainable economy • Growing global and domestic energy demand • Concerns over global warming/climate change • Consumer tastes and preferences going green • Global demand for and use of portable electronic devices • High energy requirements of handheld electronics
Economic Development Drivers	<ul style="list-style-type: none"> • Government R&D funding <ul style="list-style-type: none"> - U.S. DOE Hydrogen, Fuel Cells and Infrastructure Technologies R&D Initiative - Major defense investments • Focus of U.S. auto industry
Locational Requirements	<ul style="list-style-type: none"> • Strong R&D base • Support for R&D and prototype development
Key Opportunities	<ul style="list-style-type: none"> • Tremendous potential to replace a variety of energy conversion devices including gas turbines, gas engines, and batteries • MFCs that would be used in small, portable electronic devices such as cellular phones, PDAs, digital cameras, and notebook PCs represent mass market commercial opportunities • Use in portable power systems • Use in small, off-road transportation

Central Upstate New York's Opportunities

New York has a strong academic and industry base in fuel cells. On the university side, Central Upstate New York is home to the following:

- The **Cornell Fuel Cell Institute (CFCI)**, a research center with world-class expertise in materials science that focuses on overcoming challenges to commercial fuel cell production rooted in fundamental materials limitations. CFCI faculty members collaborate with leading commercial fuel cell companies, such as Ford, GM, Sumitomo Finance, Primet, and UTC Fuel Cells; and a number of small start-up companies have been created to commercialize technology developed by CFCI researchers.
- **Clarkson University's Center for Advanced Materials Processing**, which develops innovations in advanced materials processing in collaboration with industry and also has a focus on fuel cells.
- **Alfred University's Center of Advanced Ceramic Technology**, which conducts research on the use of ceramic materials in fuel cells.

The region is also home to a number of small start-up fuel cell companies. It must be recognized, however, that only a small number of leading-edge companies actually have products on the market (one of which is Albany-based MTI MicroFuel Cells) and that most emerging companies are still in the R&D, testing, and prototype development stage. Central Upstate New York clearly has assets that can be used to attract companies to the region and to grow companies around technology developed at the region's research institutions; but, this sector will likely take some

time to develop. Table 10 provides an overview of Central Upstate New York’s fuel cell sector.

Table 10: Fuel Cell Sector in Central Upstate New York

Fuel Cells: Central Upstate New York	
Key Assets	<ul style="list-style-type: none"> • Cornell Fuel Cell Center • - Focus on materials, specifically PEM fuel cells • - Working with major industry players including: GM, Ford, Sumitomo Finance, Primet and TUC Fuel Cells • Clarkson’s Center for Advanced Materials Processing (NYSTAR CAT) includes focus on fuel cells
Industry Base	<ul style="list-style-type: none"> • Antek Corporation (start-up company) • IN PEM (polymer exchange membrane) of 5 leading companies, two are in NY, Plug and Play (Capitol region) and General Motors Fuel Cell in Rochester • MTI MicroFuel Cells in Albany • GE, Corning • Delphi (in Rochester) • Primet moved from MD to be near the Cornell Center • Spin-outs from Cornell include: Novamer, I2E and firm started by Ule Weiser
Key Challenges	<ul style="list-style-type: none"> • Competition from other regions including Connecticut, Ohio and Canada (Ballard and Hydrogenics) • Keeping new companies in NY, not allowing them to be attracted to other regions
Key Opportunities	<ul style="list-style-type: none"> • If you include Rochester, Southern Tier and Hudson Valley NY has a strong cluster of firms • Companies will locate in and around Ithaca to have access to new IP • Build on academic strengths

Green Buildings and Sustainable Design

The green buildings and sustainable design sector is a newly evolving industry sector that involves products that are

- Manufactured from recycled, salvaged, waste, or readily renewable inputs;
- Manufactured in a sustainable fashion that is resource efficient, conserves energy and water, and minimizes waste and pollutants;
- Beneficial to the built environment by conserving or reducing the use of energy or water and reducing or eliminating indoor pollutants; and
- Largely recyclable at end-of-useful life.

The reduction or elimination of indoor pollutants combined with efforts in IEQ provides the basis for “healthy buildings.” Therefore, by their nature, green building technologies and products improve, or at worst are neutral toward, indoor air/environmental quality. Historically, building materials including exterior/structural materials, carpets, paints, ceiling tiles, and furniture often emit particles or volatile organic compounds (VOCs) into the indoor environment or potentially leach toxic elements into the outdoor environment. The green building segment is targeted at changing these outcomes for overall environmental improvement.

Unlike other industry-technology segments, much of the structured development of this segment has occurred due to the advocacy, education, policy development, and standards development of a nonprofit organization—the U.S. Green Building Council (USGBC). The USGBC is composed of leaders from every sector of the building in-

dustry and works to promote buildings that are healthy places to live and work and building practices that are environmentally responsible and profitable. The USGBC's LEED® (Leadership in Energy and Environmental Design) Green Building Rating System is the nationally accepted standard for green buildings. Beyond LEED, other standards programs such as the EPA's ENERGY STAR, the GREENGUARD Environmental Institute's GREENGUARD certification, or other indoor air requirements are also integral in developing green and healthy buildings.

Technology Market Drivers and Trends

Specific market forces driving the growth of the green building and sustainable development sector include the following:

- **Commercial and consumer interest in green building.** A recent study by the American Institute of Architects found that 34 percent of the architectural firms surveyed characterized some of their current efforts as green and these efforts accounted for 14 percent of their revenues. Additionally, over 20 percent of these firms have recently completed a green new construction or remodeling project. The National Association of Home Builders and McGraw-Hill Construction predict that green building will reach somewhere between \$19 billion and \$38 billion by 2010. This will amount to a 10 percent residential penetration by 2010, up from current estimates of 2 percent.
- **Decline in cost differential for green technologies.** A decade ago, the construction cost premium for green buildings was as much as 20 percent; today, it ranges between 1 percent and 9 percent, with a 2005 study estimating that the average premium was 2.42 percent. Research into green or high-performance building practices and technologies, however, represents only 0.2 percent of federally funded R&D—averaging slightly more than \$190 million per year from 2002 to 2005. This amount represents only 0.02 percent of the estimated value of all building construction in the United States.
- **Adoption and implementation of LEED standards.** To date, 11 federal agencies, 22 states, and 55 individual municipalities require buildings to meet either local green standards or those set by the USGBC. Of the commercial space falling under these requirements, according to the USGBC, over 1 billion square feet of space is currently LEED registered or certified with 884 LEED-certified projects. Because LEED standards have a growing influence on materials used by building product manufacturers, LEED is rapidly becoming the nation's de facto green building code.

Economic factors that influence the location of green and sustainable businesses include the following:

- **Green-friendly location.** The owners/leadership of most green/healthy building companies entered this market in part because of their own personal beliefs and interest in providing environmentally sustainable products. To foster the development of these firms, regions need to have the “look and feel” of an environmentally conscious region. Examples include strong consumer and commercial recycling programs, an environmentally aware business press, will-

ingness to try new products, and a zoning and building permit infrastructure that allows for construction materials that are outside of traditional building norms.

- **Access to research, testing, and certification capabilities.** As a truly emerging area, green/healthy building products are being developed and deployed at an increasingly faster pace. For smaller firms, having the ability to easily and readily tap into either regional academic or industrial research and testing capabilities for product development, confirming specifications, and measuring performance (including the outgassing of VOCs) would be an extremely attractive locational factor. However, given the wide-ranging nature of green building products, these capabilities would need to be broad in scope. Additionally, local capabilities to certify performance of green/healthy building products against national and international standards would also be an extremely positive locational factor.
- **Strong local demand for green building materials, products, and components.** All else being equal, green building product companies will gravitate toward regions that exhibit the potential for strong local demand of green products. This potential can be exhibited through income characteristics (e.g., more affluent consumers), coordinated efforts toward renewing the housing stock, or significant planned developments (either private or public sector oriented) that will provide a strong demand component. Additionally, a strong driver for locational decisions for “footloose” green building product companies (e.g., those not strongly tied to a regional asset) is to be located where the demand for building products is most robust. Historically, this has followed population growth and migration trends with the South and West seeing the most profound residential building growth rates. Indeed, the Southwest is currently the fastest-growing region in the country in terms of both population growth and increases in the new housing stock.
- **Lower buzz, but still strong investment interest.** According to Forbes, despite the relatively low sex appeal of the green building materials market (as compared with renewable energy investments, etc.), investors—both individual and institutional—will undoubtedly position themselves at a competitive advantage by aggressively seeking out companies that produce sustainable building products as they see significant consumer and commercial markets beginning to emerge.
- **Easy access to product inputs.** Whether the product is manufactured locally or sourced internationally, green building product companies require easy and seamless access to their supply chain. Sourcing natural materials and other raw materials locally is an extremely important driver in some segments (e.g., fly ash for “green concrete”).
- **Strong green architectural and design firms.** A key market driver for green/healthy building companies is the ability to develop close working relationships with local architectural and design firms with strong green/LEED orientations. These relationships can drive both market demand (as design firms specify products that they know well from local relationships) and enhanced

product development (strong ties to consumer requirements and integral product feedback).

- **LEED-based tax incentives.** Development of LEED standards has allowed for more precise and applicable tax incentives to be developed—cities and states are using LEED certification to implement a wide variety of energy conservation and green building tax incentives as well as property tax abatements. Additionally, other cities are encouraging LEED development and certification by reducing permitting fees for green buildings.

The demand for green buildings products and practices offers opportunities for existing companies to develop new product offerings in areas such as green furniture, cabinetry, and fixtures or to make products from composites that incorporate recycled material. Table 11 summarizes the key drivers of the green buildings and sustainable design sector.

Table 11: Key Drivers of Green Buildings and Sustainable Design Sector

Green Buildings/Sustainable Design: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • Commercial and consumer interest in green buildings • Decline in cost differential for green buildings • Adoption and implementation of LEED standards
Economic Development Drivers	<ul style="list-style-type: none"> • Advocacy and education by nonprofit organizations • Customer demand • Development of standards
Locational Requirements	<ul style="list-style-type: none"> • Strong local demand for green building materials, products, and components • Easy access to product inputs • Buy-in from local designers, architects, builders, etc. • Green-friendly location • Access to research, testing, and certification capabilities • LEED-based tax incentives
Key Market Opportunities	<ul style="list-style-type: none"> • Offers opportunity for existing companies to develop new product offerings • Wood plastic composites that incorporate recycled materials is a fast-growing market opportunity • Federal, state, and local legislation and policy have created strong demand for high-performance roofing • Untapped market for green roofs that incorporate vegetation • Rehabilitation of older buildings using green building practices • Opportunities to develop green furniture, cabinetry, and fixtures

Opportunities for Central Upstate New York

The green building materials market is underdeveloped in Central Upstate New York; but, a number of initiatives are underway that could drive demand for green building products and sustainable design. Cornell University, SU and SUNY-ESF are all implementing campus-wide sustainability initiatives; the Syracuse CoE is being built to LEED standards, the City of Syracuse has adopted LEED standards, and the Destiny project, which involves a significant expansion of Carousel Mall, is being developed with green building products and practices and using renewable energy sources. Each of these projects will create demand for green products but they can also be used to showcase green and sustainable development and encourage greater use of green products throughout the region.

The region also has research and education strengths in the green products and sustainable design area, including the following:

- SUNY-ESF’s Construction Management and Wood Products Engineering Program, which includes a focus on green materials
- Syracuse University’s BEESL
- Cornell’s Center for Composite Materials, which includes a focus on composites and chemistry and biodegradable and renewable materials. Several start-up companies have been formed to commercialize technology developed at the Center.

Table 12 provides an overview Central Upstate New York’s green buildings and sustainable design sector.

Table 12: Green Buildings and Sustainable Design Sector in Central Upstate New York

Green Buildings/Sustainable Design: Central Upstate New York	
Key Assets	<ul style="list-style-type: none"> • ESF’s Construction Management and Wood Products Engineering Program focuses on green materials • Cornell’s Center for Materials Research <ul style="list-style-type: none"> - Focus on composites and chemistry, biodegradable and renewable materials - Has had a number of spin-off companies
Industry Base	<ul style="list-style-type: none"> • Few contractors experienced in constructing sustainable buildings • Few companies focused on producing green building products • New start-up e2e—based on technology developed by Cornell for fully biodegradable, reinforced composite
Key Challenges	<ul style="list-style-type: none"> • Clients, architects, and engineering still learning about LEED • Few LEED-certified buildings • Developing supply chain—need to get ag producers thinking in a new way
Key Opportunities	<ul style="list-style-type: none"> • Cornell undertaking campus-wide sustainability initiative—this opportunity cuts across all of the E&ES sectors • CoE and Destiny projects • Wealth of university talent • Help small companies produce green products

Water Quality and Water Resources

Business activity that involves water as a resource or its supply and consumption as a service or product consists of the following four sectors:

1. Water utilities—entities that collect water from surface or ground sources, purify it, and distribute it to water consumers and their residential, commercial, industrial, and agricultural customers
2. Wastewater treatment and water reuse/recycling facilities
3. Water distribution and purification equipment and chemicals companies
4. Water systems engineering and consulting companies.

The global water services and equipment industry segment is estimated to be a \$40 billion business growing annually at 6 percent. Water treatment has been a mature business in the United States and other developed countries, but is now experiencing a revival because of new regulations, prompting large water users to turn to water treatment companies for complete solutions and contracted services.

The global market has seen the emergence of consolidated water service companies, such as France's Veolia Environnement, which operates in all four sectors of the water industry.

The overall U.S. water industry (including sales/distribution of water) achieved total revenues of approximately \$86 billion in 2000, and business volume has continued to grow.

Market Drivers, Trends, and Opportunities

The following factors are driving the growth of the water treatment sector:

- **Increasing demand for freshwater.** WHO estimates that over 50 percent of the world's population lacks access to clean water and sanitation. Water-borne diseases account for nearly 80 percent of all infections affecting people in the developing world. Freshwater is also essential for agriculture, transportation, electricity generation, wildlife, and recreation. The ultimate sources of freshwater are snow and rain, and the natural climatic cycle ensures that much of the freshwater consumed is recycled through the evaporation-precipitation cycle. As long as the rate of withdrawal is balanced by the rate of replenishment, freshwater resources remain in balance. However, the doubling of the world's population since 1960 from 3 billion to 6 billion has strained these resources. In 2000, global water withdrawals were roughly 1,000 cubic miles, representing 30 percent of the world's total accessible freshwater resources. In 2020, withdrawals are expected to represent 70 percent of the total accessible resources.
- **Competing demands for freshwater.** The daily withdrawal of freshwater in the United States is on the order of 346 billion gallons. The farm sector, including irrigation, aquaculture, and livestock operations, accounts for 40 percent of the total water withdrawn. Thermoelectric power stations account for 39 percent of the total freshwater withdrawn; but, a considerable amount of the water used by this sector is returned to its source. Public water supply works account for 11 percent of freshwater consumption while independent domestic users of surface water and ground water account for 1 percent. Mining and industrial users of water, at 1 percent and 5 percent respectively, are relatively minor users of water. However, their impact on the quality of water is not insignificant.
- **Source depletion and accessibility to water concerns.** The depletion of groundwater resources is a serious problem. The Central Plains' Ogallala aquifer, which covers an area of 174,000 square miles across eight states and sustains 30 percent of U.S. agricultural output, has been under strain due to severe over-use for the past few decades with withdrawals exceeding the rate of natural recharge. To complicate matters, disagreements over the sharing of water resources have cropped up in a number of states.
- **Management of water resources.** The Twenty-First Century Water Commission Bill that is currently in Congress seeks to establish a national commission to devise a long-term strategy for the management of water resources. The Water Science and Technology Board of the National Research Council's report *Envisioning the Agenda for Water Resources Research in the Twenty-first Century*

(NRC 2001) identifies 43 research priority areas spanning the biological, physical, and social sciences and calls for setting up a national-level water research entity.

- **Initial interest in sustainable water treatment, reuse, and recovery technologies.** Integrated approaches to wastewater treatment will likely become a significant growth area. An inventory of water resources conducted in accordance with the Clean Water Act in 2000 revealed that 39 percent of river and stream miles, 45 percent of lake surface area, and 78 percent of the Great Lakes shoreline miles do not meet ambient water quality standards. In developing countries, as much as 85 percent of all wastewater is discharged untreated into surface water bodies. Many of the modern methods of water treatment, such as reverse osmosis, desalination, and performance chemicals-based purification, are either too energy-intensive or too dependent on an efficient wastewater treatment infrastructure to be administered effectively. Thus, a contemporary global water resources agenda would include the following elements:
 - Address issues related to water quantity and quality in the developed world, and facilitate a transfer of process and policy development know-how to developing countries
 - Develop new technologies for improving water quality that are energy efficient or powered by alternative sources of energy such as solar and wind power
 - Develop more environmentally friendly industrial processes with a reduced “water footprint,” such as zero discharge processes and water recycling.
- **Aging drinking water and wastewater infrastructure.** The American Society of Civil Engineers, quoting reports by the EPA, estimates that rebuilding the national drinking water and wastewater infrastructure will require an annual investment of \$11 billion and \$19 billion, respectively, over the next 20 years.
- **Security of public water systems.** Following the terrorist attacks of 2001, the security of the nation’s water resources became a major concern. The EPA and the National Homeland Security Research Center have developed an action plan for research focused on studying the following elements:
 - Water security threats with the greatest likelihood and their potential consequences
 - Response and recovery capacity, risk reduction, and consequence mitigation
 - Prioritization of new technologies based on cost, usefulness, and maintenance requirements.
- **Significant corporate expansion and merger and acquisition activity.** The water treatment business has attracted the attention of large corporations with significant global reach and market penetration whose reach now includes segments previously considered to be “public utilities.” Examples include the following:

- General Electric, which has been expanding its water treatment portfolio and acquired several companies since it formed its water business group in 2001
- Large private sector companies such as Veolia and Suez, both of France, which entered the U.S. water utilities market and provide water management services to several medium-sized utilities on a contractual basis
- Siemens, which bought USFilter, originally an independent company and the largest player in the U.S. water treatment market, from Veolia in 2004
- Dow Chemicals, which announced the formation of Dow Water Solutions, a water treatment business group.

The following factors are driving the location of water treatment firms:

- **Local demand for water testing and related services.** Some regions may demand water testing, treatment, and related services for local bodies of water. Communities engaged in water restoration projects such as Chesapeake Bay and Onondaga Lake are examples of regions that are likely to consume technologies related to water purification, sensing, and monitoring, as well as consulting services targeting the sustainable management of water-related resources.
- **Local demand for supersterile water or water treatment technologies.** Certain industries such as biopharma, computer chips, and surgical devices require exceptionally clean water as part of their manufacturing or testing processes. Siting new or growing firms operating in the water quality market within reach of industries that demand treated water or water treatment technologies on a large-scale, continual basis could be advantageous from both an economic and logistical perspective.
- **Proximity to strong programs in electrical engineering, environmental engineering, materials science.** Proximity of new or growing firms to academic centers of excellence or strong programs in traditional, university-centered research in particular fields—namely, environmental research, hydrology or limnology, computational modeling, electrical engineering, and materials science engineering—could yield partnerships or other beneficial outcomes such as knowledge transfer or IP licensing. In addition, development of a critical mass of both public- and private-sector organizations in any technology area is likely to attract support from policy and economic development officials as well as significant capital investment.
- **Access to suitable experimental settings.** While appropriate manufacturing infrastructure, distribution networks, and skilled labor are each critical economic development drivers, one non-obvious driver is access to locations where water testing or sensing technologies can be evaluated on a large, if not community-wide, scale. Deployment of innovative water purification technologies or remote sensing or monitoring instruments into public water supplies is a contentious issue that requires permission from municipal water district authorities.

Table 13 summarizes the key factors driving the development of the water quality and water resources sector.

Table 13: Key Drivers of Water Quality and Water Resource Sector

Water Quality and Water Resources: Key Drivers	
Market Trends and Drivers	<ul style="list-style-type: none"> • Increasing global demand for freshwater • Competing demands for freshwater for agriculture, power, and industry • Depletion of groundwater resources • Concern with regard to the management of water resources • Aging drinking and wastewater infrastructure • Concerns regarding security of public water systems
Economic Development Drivers	<ul style="list-style-type: none"> • Proximity to strong programs in electrical engineering, environmental engineering, and materials science • Access to suitable experimental settings
Locational Requirements	<ul style="list-style-type: none"> • Local demand for water testing and related services • Local demand for supersterile water or water treatment technologies to meet needs of specific industries, such as pharmaceutical companies or computer chip manufacturers
Key Opportunities	<ul style="list-style-type: none"> • Integrated approaches to wastewater treatment will be a growth area • Need to meet freshwater needs in California, Florida, and Texas • International demand for freshwater • Need to mitigate impact of household chemicals and drugs in water supply • Government policies requiring new detection and monitoring systems

Opportunities for Central Upstate New York

The Central Upstate New York region has developed strengths in technologies related to water purification, sensing, and monitoring, and consulting services due to the scope of the Onondaga Lake restoration project. As a result, the region’s employment is 88 percent more concentrated in water quality and resources than is the nation. More than 1500 people were employed in water quality and resources in 2005 in Central Upstate New York, although this employment level is down 10 percent from 2001.

Companies involved in water filtration, purification, desalination, and other treatment technologies tend to grow in areas in need of additional water supply. The largest markets for such systems in the United States include Florida, California, and Texas. Not surprisingly, California and Florida are home to many emerging water treatment firms. California also leads in the emerging water sensor and analysis/monitoring instrumentation market.

Water quality and water resource firms also are likely to grow in proximity to research institutions with a focus in this area. While Central Upstate New York has research institutions with strengths in understanding, assessing, and managing watersheds—including SUNY-ESF, which has a focus on water quality and water resource planning; the Upstate Freshwater Institute which focuses on understanding how ecosystems work; the Syracuse Center of Excellence, which focuses on sensors and monitoring watersheds; and the Center for Integrated Watershed Studies at SUNY Binghamton—the R&D being conducted on watersheds and water resources has not translated into creating companies and insufficient alignment exists between areas of research and the industry base. With more of this alignment, the

region's water resources consulting and engineering firms could tap into the growing water quality and water resources market.

Clearly, all four sectors examined—IEQ, renewable fuels, green buildings and sustainable design, and water quality and water resources—offer opportunities for development in Central Upstate New York. The next section of this report examines the region's existing industry base in each of these areas and assesses Central Upstate New York's competitive position vis-à-vis a set of peer or competitor communities.

ASSESSING CENTRAL UPSTATE NEW YORK'S COMPETITIVE POSITION

Central Upstate New York is not the only region trying to grow its E&ES industry cluster. Multiple regions across the country are branding themselves as locations for green businesses and implementing policies and actions to promote the use of green building practices, renewable energy, and practices that promote environmental quality. Battelle conducted an analysis to assess the competitiveness of Central Upstate New York's E&ES sector and to identify policies and programs that are being used to promote this sector in other regions of the country.

Competitor Regions

- ▶ Eugene, OR
- ▶ Fort Collins, CO
- ▶ Grand Rapids, MI
- ▶ Pittsburgh, PA
- ▶ Sacramento, CA

Central Upstate New York was compared with the following five regions: Eugene, OR; Fort Collins, CO; Grand Rapids, MI; Pittsburgh, PA; and Sacramento, CA. Battelle examined the existing employment bases in six industry sectors that make up the E&ES sector and reviewed policies and programs undertaken to accelerate the growth of these industry sectors. The six industry sectors examined included E&ES consulting, green buildings and sustainable design, IEQ, renewable energy, renewable power generation, and water quality and resources. The results of this analysis are discussed below.

E&ES Industry Sector

Central Upstate New York has a large employment base in the overall E&ES sector with more than 10,000 regional jobs in 419 individual business establishments. Regional jobs in this sector, however, declined by almost 28 percent during the 2001 to 2005 period. Nationally, the E&ES sector declined by 5.6 percent during this time period. While the Central Upstate New York region added jobs in the E&ES consulting subsector, it shed jobs in each of the remaining five subsectors. E&ES consulting has now surpassed both the IEQ and green building subsectors in the region and, in 2005, stands as the largest employer among all subsectors. Average earnings in the region's E&ES sector were \$54,000, slightly below the national average earnings of \$59,000 in 2005 (Table 14).

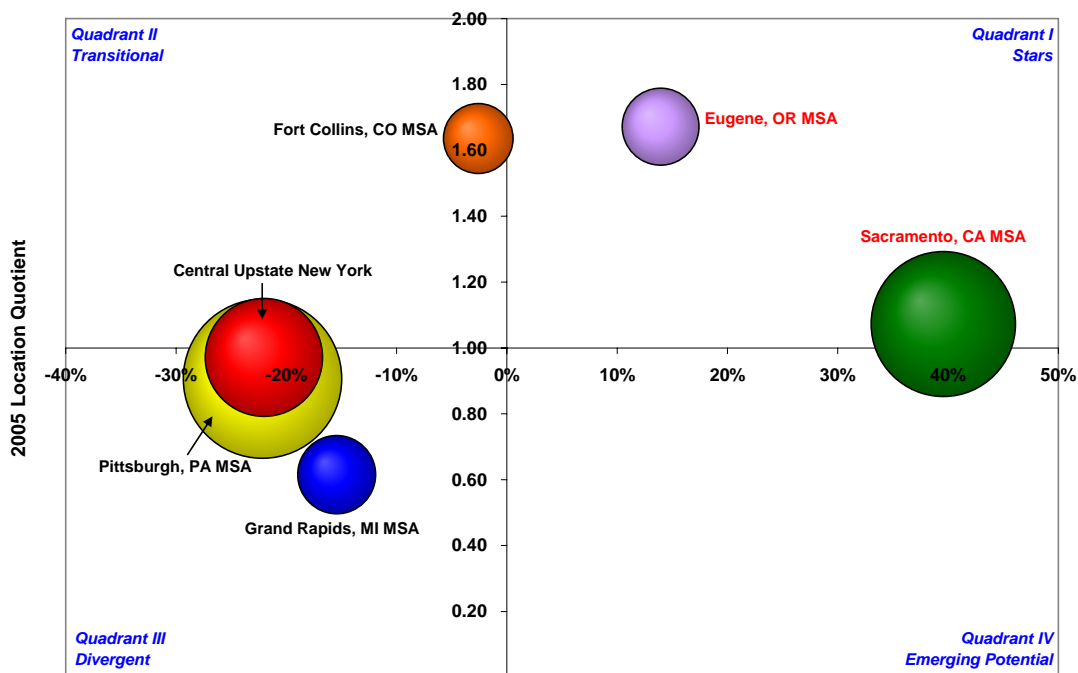
Table 14: Establishments, Employment, and Wages in Total E&ES Sector by Region, 2005

Region/ Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employ- ment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Total E&ES Sector						
Central Upstate New York	419	0.7%	10,290	-27.6%	0.97	\$54,222
Eugene, OR MSA	182	-10.7%	4,394	8.4%	1.67	\$48,333
Fort Collins, CO MSA	306	7.4%	3,626	-8.2%	1.64	\$54,796
Grand Rapids, MI MSA	279	-24.7%	4,553	-21.0%	0.62	\$52,841
Pittsburgh, PA MSA	1,039	-8.2%	18,769	-27.7%	0.91	\$59,697
Sacramento, CA MSA	1,158	39.8%	15,552	34.0%	1.07	\$59,381
United States, Total	140,747	10.7%	2,388,397	-5.6%	1.00	\$58,627

Source: Battelle analysis of Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

The Central Upstate New York region’s concentration of E&ES sector jobs nearly matches the national average with a location quotient (LQ) of 0.97 for 2005. This compares with the smaller but specialized E&ES sector regions in Eugene (LQ is 1.67) and in Fort Collins (LQ is 1.64). Eugene has exhibited overall growth, adding 8 percent to its job base since 2001. Sacramento has seen very large job growth, up 34 percent since 2001, and has increased its LQ to 1.07. Figure 1 presents E&ES sector employment data as a bubble chart, in which the size of each bubble corresponds to the amount of employment in that region. Regions with higher LQs and faster growth rates than the nation are found in the upper right-hand quadrant.

Figure 1: Total E&ES Sector Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job growth.

Employment Growth Relative to the U.S. (2001-05)

Each of the E&ES subsectors is discussed below.

E&ES Consulting Services

The U.S. E&ES consulting services sector experienced strong job growth during 2001 to 2005, adding 9 percent to its base and reaching more than 985,000 (Table 15). Among all the major E&ES sectors in this study, this consulting sector employs the most across the nation. The majority of these jobs (84 percent) are in the engineering services component. The sector's nearly 94,000 business establishments grew their numbers by 20 percent.

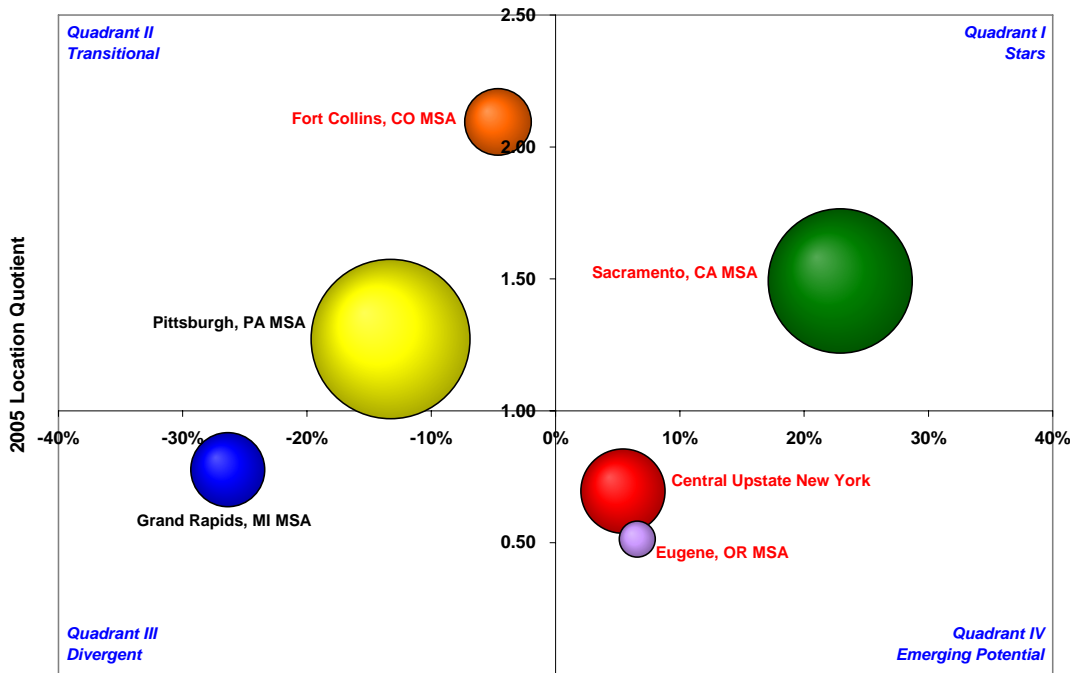
Table 15: Establishments, Employment, and Wages in E&ES Consulting Services Sector by Region, 2005

Region/Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
E&ES Consulting Services						
Central Upstate New York	248	1.4%	3,043	14.4%	0.70	\$68,262
Eugene, OR MSA	90	1.1%	557	15.6%	0.51	\$49,309
Fort Collins, CO MSA	244	22.6%	1,916	4.4%	2.09	\$53,945
Grand Rapids, MI MSA	179	-10.3%	2,371	-17.4%	0.78	\$60,195
Pittsburgh, PA MSA	707	-0.6%	10,873	-4.3%	1.27	\$64,245
Sacramento, CA MSA	853	56.5%	8,931	31.9%	1.49	\$64,337
United States, Total	93,592	20.0%	985,884	9.0%	1.00	\$67,252

Source: Battelle analysis of BLS QCEW data from IMPLAN.

In E&ES consulting, the Central Upstate New York region compares favorably and might be considered “emerging” with respect to the bubble chart in Figure 2. The Central Upstate New York region outperformed the United States with its 14 percent job growth in this key technical consulting sector. Its relative employment concentration (LQ of 0.70) does not match the specialized LQs in Fort Collins, Sacramento, and Pittsburgh; but, its impressive growth is noteworthy. In Central Upstate New York, this sector pays very high average wages, in fact, more than in any of the other benchmark regions or the United States. The average consulting services worker earned more than \$68,000 in Central Upstate New York, \$1,000 more than his or her counterparts across the nation.

Figure 2: E&ES Consulting Services Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Note: Size of bubble represents employment. Subsectors in Red had positive absolute job growth. **Employment Growth Relative to the U.S. (2001-05)**

Green Buildings and Sustainable Design

National sectors associated with green building materials and sustainable design shed jobs during 2001 to 2005, with the sector’s employment base down 7.8 per cent (Table 16). This generally reflects weakness in the overall manufacturing sector in which these green building activities are included.

Table 16: Establishments, Employment, and Wages in Green Buildings and Sustainable Design Sector by Region, 2005

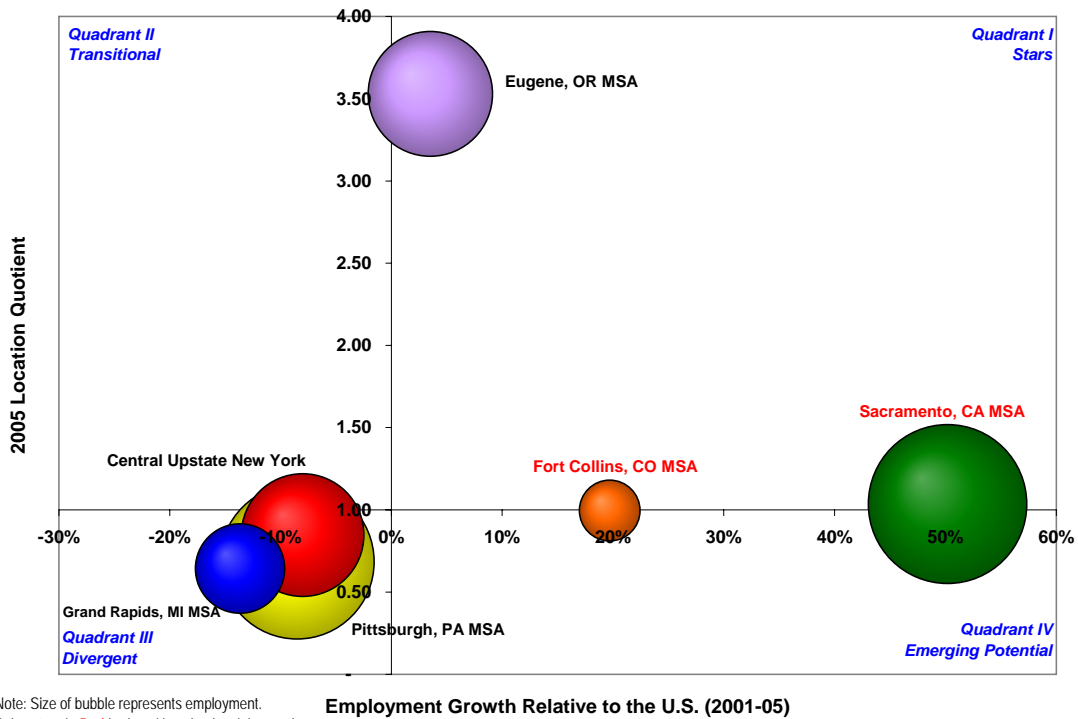
Region/Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Green Buildings & Sustainable Design						
Central Upstate New York	82	-5.8%	2,552	-15.8%	0.85	\$33,658
Eugene, OR MSA	77	-21.8%	2,639	-4.2%	3.53	\$42,561
Fort Collins, CO MSA	42	-36.4%	628	11.9%	1.00	\$34,833
Grand Rapids, MI MSA	67	-17.7%	1,353	-21.4%	0.64	\$41,176
Pittsburgh, PA MSA	178	-32.5%	4,034	-16.3%	0.68	\$52,345
Sacramento, CA MSA	188	-5.3%	4,272	42.4%	1.04	\$35,053
United States, Total	29,806	-5.9%	679,703	-7.8%	1.00	\$36,876

Source: Battelle analysis of BLS QCEW data from IMPLAN.

Central Upstate New York has seen job losses in its green buildings and sustainable design sector in the early to mid-2000s. The regional sector has lost nearly 16 per cent of its employment base in recent years, but remains above 2,500 jobs in 2005.

This base exceeds current totals for the smaller sectors in Grand Rapids and Fort Collins. With the national green building sector contracting, only two benchmark regions have added jobs since 2001—Sacramento (up 42 percent) and Fort Collins (up 12 percent) (Figure 3).

Figure 3: Green Buildings and Sustainable Design Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Indoor Environmental Quality

The U.S. IEQ sector has experienced a 17 percent job loss since 2001. The national employment decline translated into regional job losses for most of the benchmark regions considered here. Only Eugene and Fort Collins added jobs, but these were on very small employment bases (Table 17).

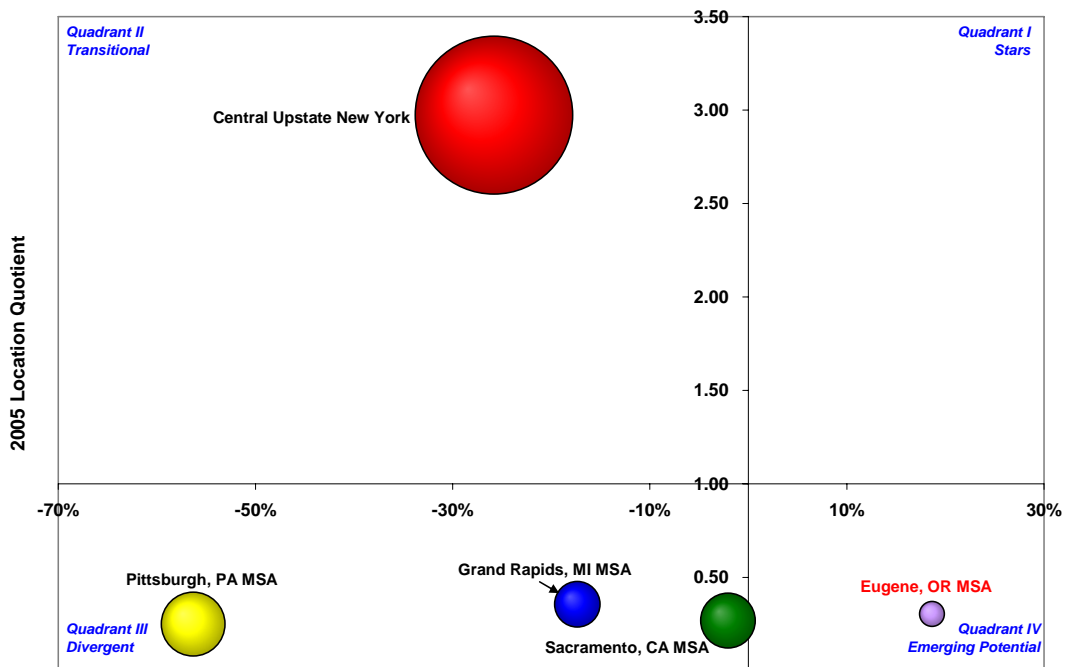
Table 17: Establishments, Employment, and Wages in IEQ Sector by Region, 2005

Region/Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Indoor Environmental Quality						
Central Upstate New York	16	22.8%	2,364	-42.7%	2.97	\$57,863
Eugene, OR MSA	5	25.0%	60	1.7%	0.30	\$29,488
Fort Collins, CO MSA	2	20.0%	10	577.0%	0.06	\$48,669
Grand Rapids, MI MSA	8	-9.1%	198	-34.3%	0.36	\$47,839
Pittsburgh, PA MSA	13	-43.8%	388	-73.3%	0.25	\$57,351
Sacramento, CA MSA	20	28.0%	286	-19.0%	0.26	\$52,497
United States, Total	2,548	-7.2%	179,257	-16.9%	1.00	\$44,167

Source: Battelle analysis of BLS QCEW data from IMPLAN.

Approximately 2,400 people were employed in the IEQ sector in Central Upstate New York in 2005. This is a much larger employment base than that found in any of the competitor regions, all of which had less than 400 total employees. The region experienced a 42.7 percent decline in IEQ employment from 2001 to 2005, illustrated in Figure 4 where Central Upstate New York is shown as “transitional.” But, this decline was most likely owing to the loss 1,200 jobs when Carrier closed two plants at its Syracuse site and the fact that the IEQ sector declined 17 percent nationally during this time period. At the same time, however, the number of IEQ establishments increased by approximately 23 percent, suggesting that the number of small, start-up IEQ firms is increasing. Accelerating the growth of these companies would provide additional employment opportunities in the region.

Figure 4: IEQ Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Note: Size of bubble represents employment. Subsectors in Red had positive absolute job

Employment Growth Relative to the U.S. (2001-05)

Renewable Energy

The U.S. renewable energy sector includes industries engaged in a variety of activities, from producing biomass energy from ethanol to manufacturing fuel cells, wind turbines, and solar cells. Employment in these activities, though often embedded with numerous other production activities, declined across the United States from 2001 to 2005. The overall sector was down more than 20 percent (Table 18).

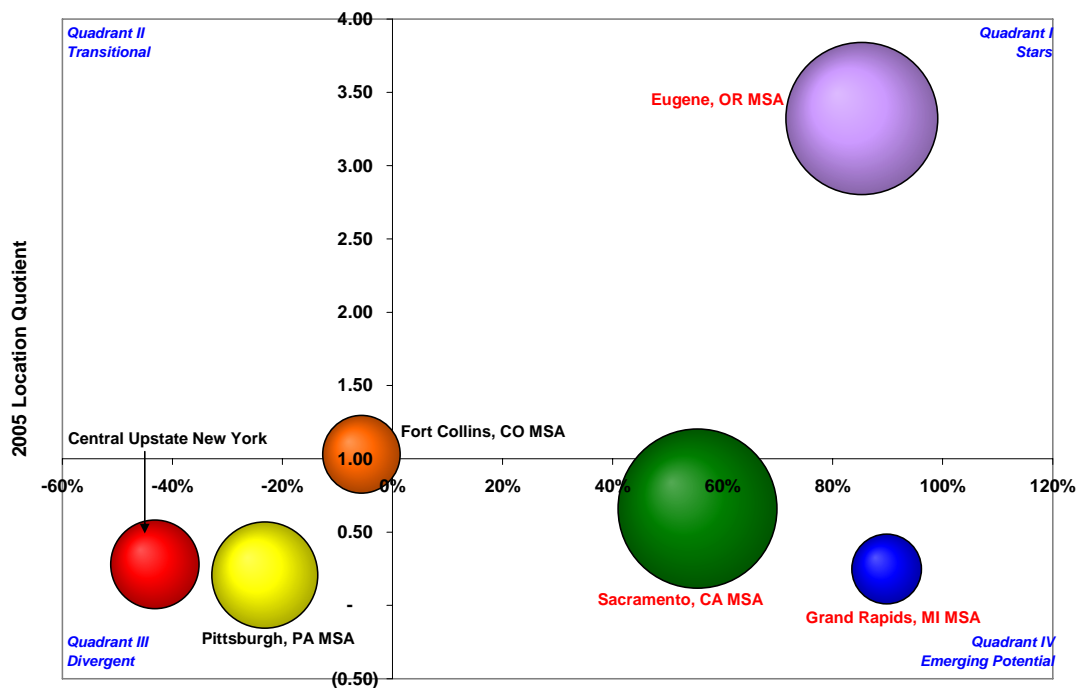
Table 18: Establishments, Employment, and Wages in Renewable Energy Sector by Region, 2005

Region/Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Renewable Energy						
Central Upstate New York	13	28.0%	378	-64.3%	0.28	\$57,051
Eugene, OR MSA	3	0.8%	1,111	64.2%	3.32	\$62,782
Fort Collins, CO MSA	9	55.5%	291	-26.7%	1.03	\$95,782
Grand Rapids, MI MSA	3	-42.0%	234	68.7%	0.25	\$60,761
Pittsburgh, PA MSA	24	3.9%	544	-44.3%	0.21	\$57,828
Sacramento, CA MSA	39	180.2%	1,218	34.3%	0.66	\$105,811
United States, Total	3,405	4.9%	303,951	-21.1%	1.00	\$86,704

Source: Battelle analysis of BLS QCEW data from IMPLAN.

Central Upstate New York has a relatively modest job total in the renewable energy sector with just 378 total in 2005. The regional establishment total is up, however, and may indicate some smaller entrepreneurial activity. Eugene has a highly specialized sector with more than 1,100 jobs and strong recent job growth. This metropolitan area might therefore be considered a “star” in the employment growth and concentration context (Figure 5).

Figure 5: Renewable Energy Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Note: Size of bubble represents employment. Subsectors in Red had positive absolute job

Employment Growth Relative to the U.S. (2001-05)

Renewable Power Generation

Power generation from “renewable” sources characterizes this E&ES sector. The United States saw an overall employment decline in the industry since 2001 with employment down by one-third. The sector has high average annual wages at more than \$85,000 nationally in 2005 (Table 19).

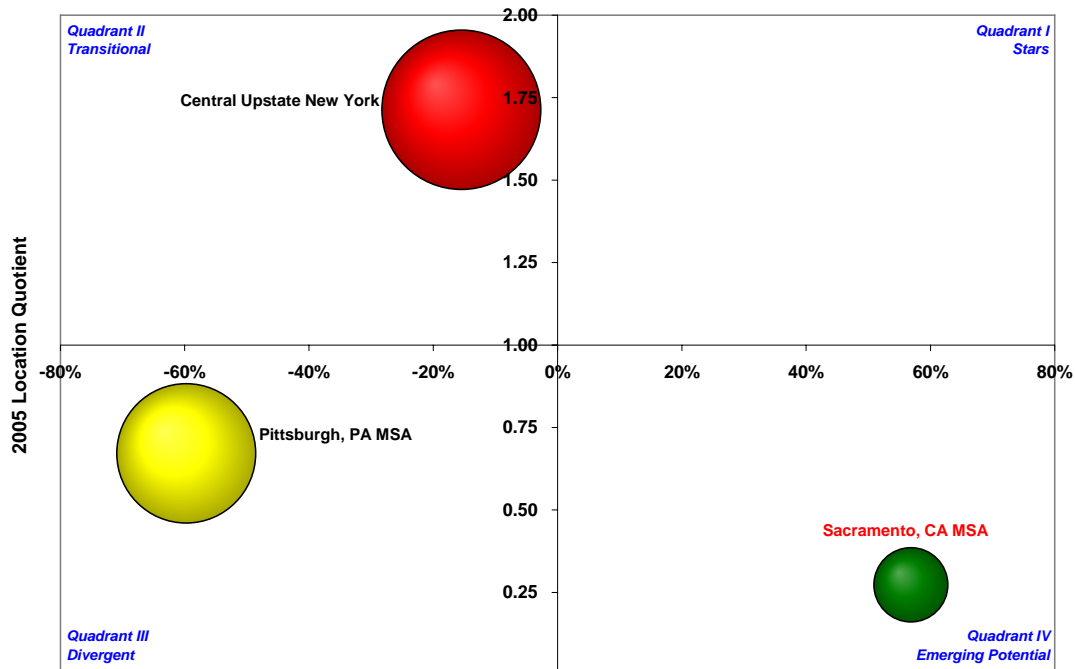
Table 19: Establishments, Employment, and Wages in Renewable Power Generation Sector by Region, 2005

Region/Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Renewable Power Generation						
Central Upstate New York	36	10.4%	414	-48.6%	1.71	\$64,459
Eugene, OR MSA	1	-31.2%	1	-91.1%	0.02	\$63,031
Fort Collins, CO MSA	1	-	33	-	0.64	\$59,391
Grand Rapids, MI MSA	2	-60.5%	1	-85.8%	0.01	\$42,073
Pittsburgh, PA MSA	9	-8.2%	318	-92.9%	0.67	\$73,629
Sacramento, CA MSA	2	-77.8%	90	23.7%	0.27	\$49,742
United States, Total	1,766	-4.8%	54,532	-33.2%	1.00	\$85,403

Source: Battelle analysis of BLS QCEW data from IMPLAN.

With just over 400 regional jobs, the Central Upstate New York region exceeds job totals in the renewable power generation sector compared with each of the benchmark regions. The majority of these jobs are in hydroelectric power generation. The Central Upstate New York region has a high concentration of renewable power jobs, with 71 percent more than the national average (LQ is 1.71). Despite this regional specialization, local sector jobs have been cut in half since 2001 (Figure 6.)

Figure 6: Renewable Power Generation Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Note: Size of bubble represents employment. Subsectors in Red had positive absolute job

Employment Growth Relative to the U.S. (2001-05)

Water Quality and Water Resources

National employers engaged in activities associated with water quality and water resources employ more than 185,000 (Table 20). This employment base in 2005 is down 10 percent from its level in 2001. This sector includes technologies associated with water filtration, purification, desalination, and other treatments. In addition, it includes the production of water sensors and monitoring instrumentation.

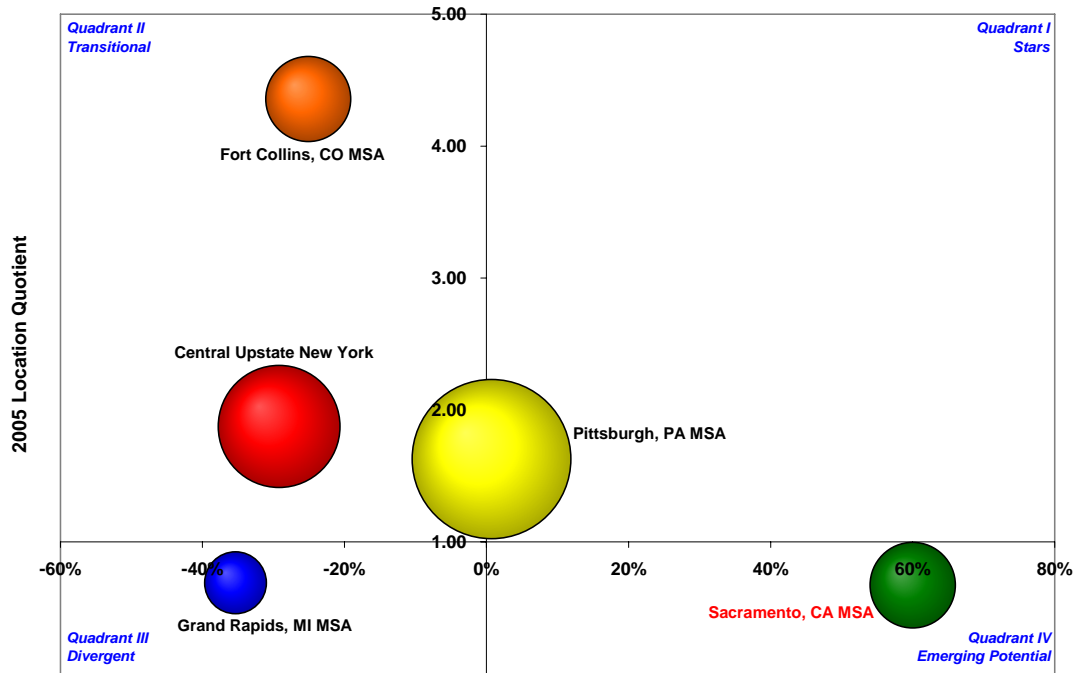
Table 20: Establishments, Employment, and Wages in Water Quality and Water Resources Sector by Region, 2005

Region/Metropolitan Statistical Area (MSA)	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Water Quality & Water Resources						
Central Upstate New York	23	-16.9%	1,539	-39.2%	1.88	\$51,514
Eugene, OR MSA	6	-23.1%	26	-63.6%	0.13	\$38,754
Fort Collins, CO MSA	8	-34.8%	748	-35.1%	4.36	\$57,693
Grand Rapids, MI MSA	20	-71.7%	395	-45.4%	0.69	\$46,507
Pittsburgh, PA MSA	108	6.3%	2,614	-9.3%	1.63	\$51,172
Sacramento, CA MSA	56	21.3%	755	50.0%	0.67	\$67,289
United States, Total	9,630	0.2%	185,070	-10.0%	1.00	\$52,563

Source: Battelle analysis of BLS QCEW data from IMPLAN.

Figure 7 shows a Central Upstate New York water quality and resources sector in transition. The sector can be considered regionally specialized with a high LQ of 1.88 in 2005. Its job loss in recent years, however, is transitioning this sector away from specialization as it loses some ground with respect to the labor market. Pittsburgh has a larger employment sector, although it is a much larger region and thus has a slightly lower LQ than Central Upstate New York. Sacramento's water quality and resources sector is modest in size but has shown rapid growth since 2001.

Figure 7: Water Quality and Water Resources Employment by Region, Degree of Specialization, and Growth Relative to the United States, 2001–2005



Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job

Employment Growth Relative to the U.S. (2001-05)

Summary

From an employment perspective, the area in which Central Upstate New York is most competitive is E&ES consulting, which experienced 15 percent growth in employment between 2001 and 2005. The region has a much larger IEQ employment base than all of the benchmarks with employment three times as concentrated in this sector as in the national economy. But, employment in Central Upstate New York’s IEQ sector declined significantly from 2001 to 2005. The increase in the number of IEQ establishments, however, bodes well for stemming the decline in jobs if younger, smaller establishments are able to grow. The region currently has some activity in renewable power generation but very little employment in the renewable energy sector.

Assessment of Policy Initiatives

Sacramento and Eugene stand out among the regions examined as experiencing significant employment growth in much of their E&ES industry base. Indeed, Sacramento exceeded national growth rates in every subsector with the exception of IEQ. Eugene exceeded national growth rates in renewable energy, E&ES consulting and green buildings. Grand Rapids’ renewable energy sector is growing faster than the nation’s as is Fort Collins’ green buildings sector. The only one of the comparison regions that did not show above average growth in any of the sectors was Pittsburgh.

Battelle examined each of these communities to identify the policies and actions that they have undertaken to promote the growth of the E&ES sector. A summary of its findings follows. A profile of each region can be found in Appendix D.

Key Findings

- For the most part, the initiatives to grow the E&ES sector are being driven by a citizenry that values sustainability and sees the industries that make up this sector as compatible with maintaining the region's quality of life.
- Most of these communities have adopted public policies aimed at promoting green practices and businesses. These include setting goals for the use of renewable energy, adopting green building practices for municipal buildings, committing to purchase sustainable products and technologies, and providing incentives for businesses that use sustainable practices.
- Communities are trying to build their E&ES industry sectors by (1) encouraging the growth of start-up companies, (2) helping to create a market for green products by conducting education and outreach activities, and (3) encouraging existing companies to offer new green products or enter new markets. Attracting E&ES companies from outside the region is much less common; although, in Sacramento, some international firms are opening operations to meet the demand for renewable energy, which has developed as a result of state policy actions.
- The competitor communities have put their money where their mouth is, so to speak. They can show, for example, that they have a significant percentage of buildings constructed to green performance standards.
- In some instances, including in Fort Collins and Pittsburgh, the presence of university centers focused on specific aspects of the E&ES sector is fostering the growth of E&ES businesses. Colorado State University is in fact driving the region's Clean Energy Cluster. In other regions, such as Sacramento, the region has not been able to engage the university in its efforts to grow this industry sector.
- The most common tool used to help grow the E&ES industry is to promote networking and the formation of cluster initiatives.
- The focus on promoting the growth of green industry sectors is at an early stage of development, and it will take time to see where the industry takes hold and what types of incentives are effective in accelerating its growth.

GROWING CENTRAL UPSTATE NEW YORK'S E&ES SECTOR

This analysis has shown that there is a large emerging market for E&ES products and services and Central Upstate New York is well positioned to become a center for green businesses. The region has assets on which to build; but, many of these industry sectors are at an early stage of development and will need to be nurtured. It is proposed that Central Upstate New York do the following:

- Build on its strengths in IEQ, continuing to develop its R&D base and supporting the growth of its innovative IEQ firms.
- Leverage its expertise in sensors, monitoring, and other technologies developed to address IEQ to address other sectors, such as water quality and water resources.
- Continue to pursue opportunities in renewable energy with a focus on biomass and fuel cells while at the same time encouraging the use of wind and solar power.
- Market the region's assets to attract companies and entrepreneurs but also support the creation and growth of emerging companies.

Table 21 identifies a number of approaches that could be undertaken to grow Central Upstate New York's E&ES industry sector and suggests actions that have been taken elsewhere that might apply in this region. Further information on these actions can be found in Appendix D.

Table 21: Objectives and Possible Actions to Grow E&ES Industry Sector and Examples From Other Regions

Objective	Possible Actions	Examples of Initiatives in Other Regions
Stimulate the market for green products and practices	Adopt green procurement standards	In 2006, Columbus City Council changed City's procurement code to include a preference for environmentally preferable bidders, vendors, and contractors
	Adopt renewable energy goals	Grand Rapids committed to buying 20% of power from renewable sources by 2008 Eugene, OR plans to purchase 25% wind power for all existing general fund buildings
	Commit to building green buildings	City of Columbus is requiring that all new public buildings be developed to LEED certification
	Offer tax incentives to individuals and businesses that employ green technologies	City of Columbus is targeting its tax incentives to green businesses Portland OR offers municipal incentives for installation of solar power Austin offers rebates for installation of solar energy
	Educate the public on the value of using renewable energy and green building products and practices	Rochester's Greenprint proposes a public relations and education campaign, including public service announcements to increase citizen awareness about green products and practices
	Create a program to certify green businesses	San Francisco's Green Business Program promotes, recognizes, and supports firms that operate in an environmentally conscientious way
Raise profile of E&ES industry cluster in Central Upstate New York	Organize a media campaign featuring articles, op eds, and columns on the region's green companies	Northern Colorado Clean Energy Cluster, a network of 350 members with \$1.5 million budget, paid staff, and Web presence, is seeking to brand the region as a center for clean tech
	Continue to attract flagship green events to region, such as 2009 International Conference & Exhibition, "Healthy Buildings." Take advantage of opportunity to showcase companies and activities in region	Pittsburgh's Green Building Alliance is working to position region's building product manufacturers to take advantage of growth in green building products and practices
	Expand number of E&ES firms profiled on Essential Connections Web site	

Table 21: Objectives and Possible Actions to Grow E&ES Industry Sector and Examples From Other Regions (Continued)

Objective	Possible Actions	Examples of Initiatives in Other Regions
Provide business development resources to emerging green businesses	Create locations to house both start-up and established E&ES companies to encourage greater networking and partnering	A Green Building Fund has been created within CL Fund, a community development loan fund servicing greater Pittsburgh. GBF will provide loans ranging from \$200,000 to \$400,000 to help developers obtain LEED certification, and Pittsburgh Urban Redevelopment Authority makes low-interest loans for green construction
	Explore option of using Carrier's marketing channels to sell products of emerging IEQ companies	CleanStart in Sacramento provides coaching and mentoring for clean tech companies
	Provide commercialization assistance to start-up and emerging companies	New York City's Environmental Economic Development Assistance unit helps companies identify NYC programs that can support green tech companies
	Expand Emerging Business Competition to include award for Emerging Green Business	
Continue to build region's E&ES research base and link it to industry	Seek additional sources of operating funds and R&D funding that can be directed to industry needs for CoE	Colorado State University has grown its clean energy cluster to include 80 faculty who have attracted \$9.2 million in clean tech R&D funding
	Continue and possibly expand Grants for Growth program	

Stimulate the market for green products and practices

Both the information on leading and emerging firms and the review of regions that are successfully growing their green business sectors show that E&ES firms tend to grow in areas where there is local demand for their products. When the City of Chicago committed to purchasing a certain percentage of energy from renewable sources, several solar energy companies established locations in Chicago to be able to meet the increase in demand for solar collectors. Both public and private institutions can take actions to stimulate the market for green products and practices by adopting green procurement standards and renewable energy goals, committing to building green buildings, offering tax incentives to encourage the use of green products and services, and educating the public on the benefits of using green products and services. Columbus, OH is an example of a community that has made a commitment to strengthening its economy by growing its green business sector.

- The City is using tax incentives to encourage green businesses. In 2006, tax incentives awarded to three businesses that focus on recycling resulted in 100 jobs and \$20 million in investment.
- The City Council changed the City's procurement code to include a preference for environmentally preferable bidders, vendors, and contractors.

- The City instituted recycling in all of its buildings.
- The City committed to building green buildings for City use. The City is building a fire state, a police station, and a health center using LEED certification.
- The City is reviewing its business and zoning codes to identify and address any impediments to green building.

Raise profile of E&ES industry cluster in Central Upstate New York

Central Upstate New York has already begun to brand itself as a center of green technologies and renewable energy; but, more can be done to raise the profile of the region's E&ES industry sector. The region should continue to attract events that showcase the region and its companies and publicize its innovative E&ES companies and their successes. Sacramento and Pittsburgh are taking steps to brand their regions as home to clean energy technology and green building products, respectively.

- Early in 2004, a group of experienced start-up entrepreneurs, angel investors, and venture capitalists came together to focus on helping create clean energy businesses in the Sacramento region. The result was the creation of CleanStart, an organization that is committed to growing Sacramento's clean tech firms by investing in training and entrepreneurs and supporting companies in clean energy technology. During its first year, CleanStart held a clean energy business plan competition and a day-long Showcase that featured 10 start-up clean tech companies. CleanStart has set a goal of creating 10 new clean tech businesses by 2008 and 100 by 2010.
- Pittsburgh's Green Building Alliance is committed to making Pittsburgh the "green capital of the world." In addition to promoting green building use in the region, GBA is promoting the region's building products industry and assisting it in introducing green products and services. GBA has identified and published the names of 1,800 building product companies and is developing a network to link product companies to architects, engineers, and construction firms.

Provide business development resources to emerging green businesses

Central Upstate New York has a base of small, innovative E&ES companies. Many of these firms have already received assistance through programs sponsored by the CoE, MDA, and other economic development organizations. Additional actions that were suggested to further assist these companies include the following:

- Creating a location specifically targeted to E&ES firms that would provide space for both existing and start-up companies to encourage greater interaction and networking
- Exploring the option of using Carrier's marketing channels to sell products of emerging IEQ companies
- Providing additional commercialization assistance to start-up and emerging companies

- Expanding Emerging Business Competition to include award for Emerging Green Business.

Continue to build the region's E&ES research base and link it to industry

The region's E&ES research base is a key asset. While the region has a number of researchers doing cutting-edge R&D, the region still lacks scale in many E&ES areas. It will be necessary to continue to build the R&D base to support the growth of the E&ES sector in the future. Specifically, additional resources will be required to support the operations and staffing of the CoE if it is to truly become a driver of regional economic development. Efforts must continue to better align the university R&D agenda with industry needs. MDA's Grants for Growth program, which provides matching funds for university-industry collaborative projects, is an effective tool to achieve this.

CONCLUSION

Central Upstate New York clearly has an opportunity to promote the growth of its E&ES industry sector by expanding and marketing the region's green and sustainable assets. To do so, the region's public and private organizations need to commit to practicing sustainability and encouraging the adoption of green products and practices by the community at large.

The market for E&ES is growing both nationally and globally. Central Upstate New York is a leader in IEQ and is thus poised to grow this sector locally. The Syracuse CoE can be an important contributor but only if increased and sustained funding is obtained to support the Center's operations. Funds have been provided for equipment through the STAR program and for a state-of-the art building through the Centers of Excellence program; but, relatively limited funds are available to hire technicians and graduate students to operate equipment or to support industry-university research collaborations.

Central Upstate New York also has opportunities in the renewable energy sector. A number of pilot projects are underway that, if commercially successful, will pave the way for the region to become a leader in the production of energy from biomass sources, including forests and agricultural crops. The Central Upstate New York region is a leader in fuel cell development with world-class expertise in both academia and industry. The CFCI already is both attracting firms and spinning out companies based on CFCI technologies. Central Upstate New York should investigate ways to work collaboratively with Albany and Rochester, which have considerable assets in fuel cells, to support the development of this sector.

Growing the green buildings/sustainable design, solar energy, and wind energy sectors will require stimulating demand within the region and encouraging existing companies to introduce new products and services in response to this demand. Lastly, Central Upstate New York should look for ways in which to build upon the technologies developed to address IEQ, in the areas of sensors and controls, for example, and identify opportunities to apply those technologies to energy systems and water quality monitoring.

The green business sector is at an early stage of development, and most efforts to encourage it in a particular region are also in early development, making it difficult to determine best practices. Central Upstate New York can realize the opportunity to grow this sector if the region's public and private sector leaders and citizenry commit to sustainability and undertake a long-term collaborative initiative to build New York's "Creative Core" around green technologies and renewable energy.

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APPENDIX A

NEW YORK'S CREATIVE CORE MAPPING OF KEY ASSETS



New York's Creative Core

Real. Smart. Green.

Centers for Advanced Technology

- 1 Center for Advanced Technology in Biomedical and Bioengineering - University at Buffalo
- 2 Center for Advanced Ceramic Technology - Alfred University
- 3 Center for Advanced Technology for Electronic Imaging Systems - University of Rochester
- 4 CASE (Computer Applications and Software Engineering) Center - Syracuse University
- 5 Cornell University, Ithaca - Center for Life Science Enterprise - Sun Grant Center of Excellence - Cornell Fuel Cell Institute (CFCI) - Center for Materials Research
- 6 Integrated Electronics Engineering Center - Binghamton University
- 7 Center for Advanced Materials Processing - Clarkson University, Potsdam
- 8 Future Energy Systems - Rensselaer Polytechnic Institute, Troy
- 9 Center for Automation Technologies and Systems - Rensselaer Polytechnic Institute, Troy
- 10 Center for Advanced Technology in Nanomaterials and Nanoelectronics - University at Albany

Other Central NY Centers

- 11 SUNY Center for Sustainable & Renewable Energy SUNY ESF
- 12 Fuel Cell Institute Cornell University

Projects

- 1 Horizon Wind & PPM
- 2 PG&E
- 3 Enel North America
- 4 City of Auburn
- 5 Lemoyne College
- 6 Siemens Corporation
- 7 Northeast Biofuels
- 8 Airtricity Developments, LLC
- 9 NY Windpower, LLC
- 10 AES New York Wind, LLC
- 11 PPM Roaring Brook, LLC / PPM
- 12 Cape Vincent Wind Power, LLC
- 13 Empire Synfuel, LLC
- 14 Tompkins County
- 15 Seneca Meadows Inc.
- 16 Cornell University
- 17 Catalyst Renewables/ESF/New Energy Capital
- 18 Catalyst Renewables/ESF

Centers of Excellence

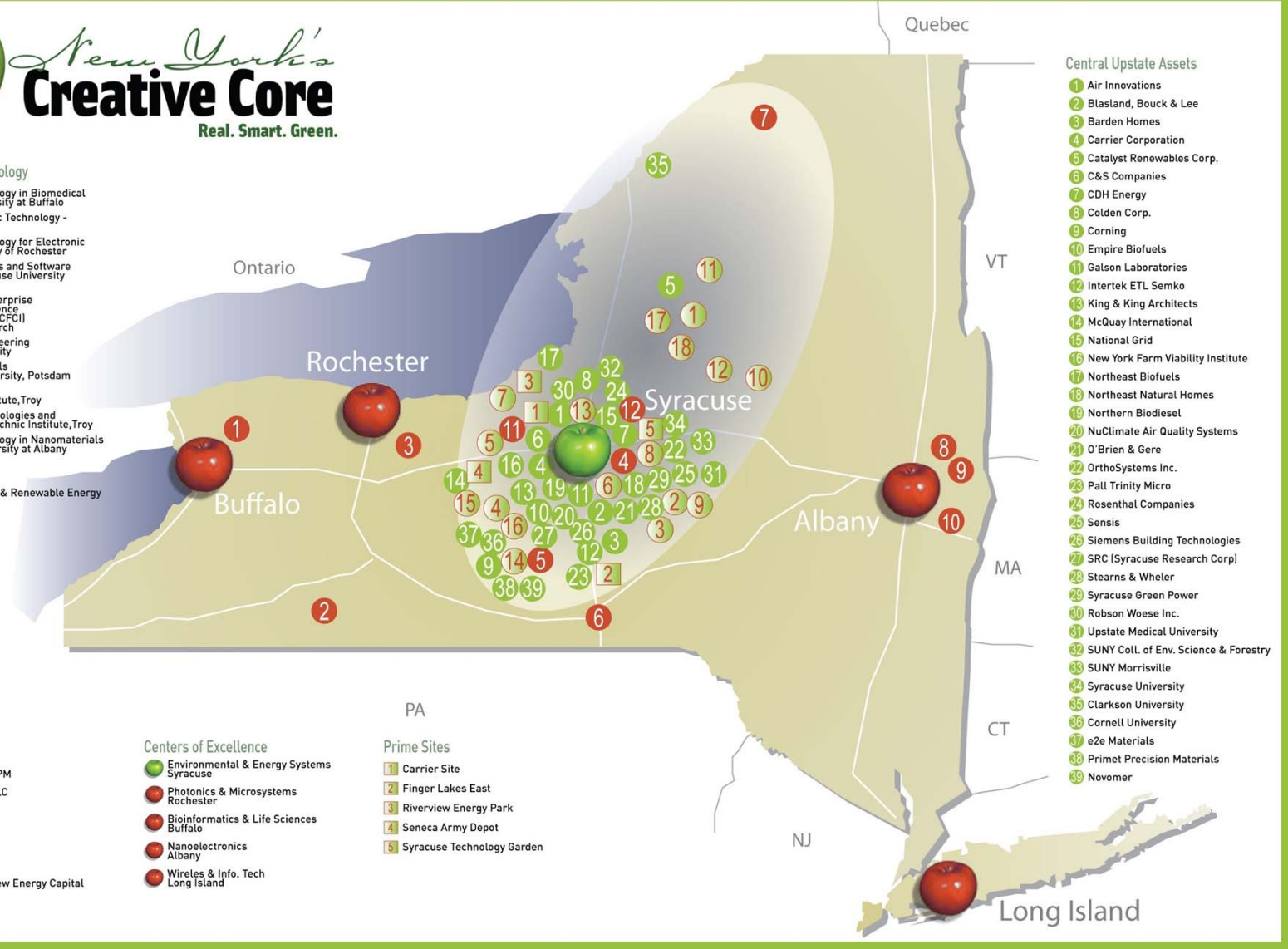
- 1 Environmental & Energy Systems Syracuse
- 2 Photonics & Microsystems Rochester
- 3 Bioinformatics & Life Sciences Buffalo
- 4 Nanoelectronics Albany
- 5 Wireless & Info. Tech Long Island

Prime Sites

- 1 Carrier Site
- 2 Finger Lakes East
- 3 Riverview Energy Park
- 4 Seneca Army Depot
- 5 Syracuse Technology Garden

Central Upstate Assets

- 1 Air Innovations
- 2 Blasland, Bouck & Lee
- 3 Barden Homes
- 4 Carrier Corporation
- 5 Catalyst Renewables Corp.
- 6 C&S Companies
- 7 CDH Energy
- 8 Colden Corp.
- 9 Corning
- 10 Empire Biofuels
- 11 Galson Laboratories
- 12 Intertek ETL Semko
- 13 King & King Architects
- 14 McQuay International
- 15 National Grid
- 16 New York Farm Viability Institute
- 17 Northeast Biofuels
- 18 Northeast Natural Homes
- 19 Northern Biodiesel
- 20 NuClimate Air Quality Systems
- 21 O'Brien & Gere
- 22 OrthoSystems Inc.
- 23 Pall Trinity Micro
- 24 Rosenthal Companies
- 25 Sensis
- 26 Siemens Building Technologies
- 27 SRC (Syracuse Research Corp)
- 28 Stearns & Wheler
- 29 Syracuse Green Power
- 30 Robson Woese Inc.
- 31 Upstate Medical University
- 32 SUNY Coll. of Env. Science & Forestry
- 33 SUNY Morrisville
- 34 Syracuse University
- 35 Clarkson University
- 36 Cornell University
- 37 e2e Materials
- 38 Primet Precision Materials
- 39 Novomer



APPENDIX B

ENVIRONMENTAL AND ENERGY SYSTEMS

TECHNOLOGY MARKET DRIVERS AND TRENDS ANALYSIS

TECHNOLOGY MARKET DRIVERS AND TRENDS ANALYSIS

The broad market for energy and environmental systems, “green,” or other environmentally-oriented sectors is driven by a unique set of factors and trends. While similar in some respects, market drivers facing each major subsector of this market are generally as diverse as the technologies and applications themselves. What drives the market for indoor environmental quality technologies and products will tend to be vastly different from those factors driving the market for renewable and alternative energy. For this reason, it is appropriate to separate out these major groups in a market study in order to more clearly delineate critical drivers and trends. However, recognition should be made that there are often intrinsic links between these major groups as firms develop technologies and solutions to market demands (e.g., solar-based air heating systems; energy-efficient user-controlled lighting systems; sound-absorbing wall treatments made of renewable materials; etc.)

The following report examines the market trends and drivers for four major industries and their subsectors within the broader energy and environmental systems sector. Each major industry is examined first in an introductory section detailing technologies, applications, and broader societal context. This is followed by a discussion of key overall market and economic development drivers.

Significant factors driving the energy and environmental systems sector were developed through an examination of existing literature and market research studies as well as websites of companies, organizations, and governments. In this research, particular attention was focused on pinpointing specific needs and requirements that are unique to the energy and environmental systems or related “green” sector companies. What became immediately clear was the recognition that these industries comprising the energy and environmental systems sectors under examination are at the same time both unique and similar to existing, more mature industries.

Energy and environmental systems industries are unique, in part, as they are only recently being thought about collectively as a potential for local market and economic development. Hence, available market research and economic development programs are extremely limited with respect to the specific needs of “green” companies and drivers and the location requirements of the broader “green” industries. These firms and industries are also unique in that the owners/entrepreneurs behind many emerging companies, while seeking appropriate financial returns for their activities, are often initially motivated by more personal “green” thinking and ambitions. This characteristic may drive a decision to locate or conduct business in regions with a relatively green mindset or established green infrastructure and support. While this may sound somewhat trivial from an economic perspective, it nonetheless causes locational decisions to be made according to personal preference or non-traditional business factors other than (or in addition to) more traditional economic development factors (such as availability of space and infrastructure, low costs or low taxes).

Beyond working to appeal to these personal preference or community factors (both programmatically and through marketing, branding, and image development), existing economic development efforts may often suffice with these firms (though ensuring applicability and robustness is still an issue). However, as with more traditional industries, local demand often spurs related economic development. For example, following the City of Chicago's establishment of a 25% renewable energy usage goal multiple solar panel manufacturers established operations in the area.

Following each major industry section are the subsector analyses which include similar technology overviews and focus on unique market trends (including market data and forecasts), technology trends and challenges, and key market opportunities going forward. Each subsector discussion concludes with tables identifying current market leading firms as well as those firms that are relatively small and/or emerging in the market.

The major industries and subsectors in this analysis include:

Indoor Environmental Quality

- Air Filtration, Ventilation, Conditioning, and Other Treatment Technologies
- Air Sensors and Air Analysis/Monitoring Instrumentation

Renewable Energy

- Biomass
- Wind
- Solar
- Micro-fuel cells

Water Quality and Water Resources

- Water Filtration, Purification, Desalination, and Other Treatment Technologies
- Water Sensors and Analysis/Monitoring Instrumentation
- Water Engineering and Watershed/Resource Management Consulting

Green Buildings and Sustainable Design

- Green Structural and Exterior Finish Materials
- Green Interior Systems, Surface, and Finish Materials

INDOOR ENVIRONMENTAL QUALITY

INTRODUCTION

Indoor environmental quality (IEQ) has a significant impact on occupant health and comfort, and is increasingly understood to play an important role in worker productivity. The definition of IEQ, according to the Federal Facilities Council, is not tightly defined in a universally accepted and measurable manner. However, the FFC has described the building-related factors that affect IEQ as:

“the amounts and components of air pollution (indoors and outdoors); sources and rates of ventilation (i.e., outdoor air supply); temperature and humidity ranges; levels and sources of lighting; noise and vibration; building and furnishing materials; and operations and maintenance practices.”

For the purposes of this analysis, this section focuses on the drivers and markets related to what is traditionally referred to as Indoor Air Quality (IAQ), but also examines issues of noise and lighting to some degree. These non-air aspects are also strongly related to building materials and hence drivers and markets in the subsequent section on Green Building and Sustainable Design will also be important to the overall view of IEQ.

The National Institute for Occupational Safety and Health (NIOSH), which has conducted over 1,500 Health Hazard Evaluations of indoor environments since 1971, has found that inadequate ventilation is the leading cause of poor IAQ in over 50% of the cases. Contaminants from indoor and outdoor sources affect IAQ even in cases where the quality of ventilation is reasonably adequate. Indoor spaces contain a number of pollutants or contaminants such as pesticide residues, tobacco smoke, cleaning material residues, and fumes from copy machines. Commonly used building and furnishing materials can also release contaminants due to wear and tear as well as gradual decomposition. Microbial contaminants, radon, and toxic mold are the other sources of contamination that compromise IAQ.

There is greater public concern over the impact of air quality employee productivity and wellness. The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has recently established minimum standards for indoor air quality in commercial and industrial settings. The World Health Organization in a recent study of indoor air quality concluded that airborne contaminants kill more people than automobile accidents.

Additionally, poor IAQ has a significant economic impact. A study conducted by the U.S. DOE and Lawrence Berkeley Laboratory in 1997 concluded that the total financial impact on the U.S. economy of poor IAQ could be as high as \$158 billion. The report estimated that the cost of allergy and asthma treatment ranged from \$7 billion to \$23 billion a year, and placed productivity losses at over \$12 billion a year.

Noise has traditionally been recognized as a health hazard in industrial and open workspaces, with federal and state laws on occupational safety substantially ad-

dressing this problem. However, noise in office environments has become a matter of significant concern only since the mid-1990s (although the problem has been a subject research since the early 1970s). Motivated by these concerns, the American Society of Interior Designers (ASID) and four of the leading building manufacturers of building materials, created a partnership to study the problem of office noise and develop strategies for improving acoustic comfort levels in offices. The study team found that noise had become a significant concern among office workers and was now the single largest negative factor impacting office productivity. In a survey of office workers, conducted as part of the study, it was found that 71% of workplace distractions were traced to noise, compared to 20% for air quality and 9% for lighting. Ambient noise levels were found to be a significant factor in perceptions and attitudes related to productivity in the workplace with 81% of the respondents expressing the opinion that they could be more productive if the workplace were quieter.

The quality of lighting, though perhaps posing a lesser impact, is also a determinant of office productivity and represents an untapped area for improving business performance. This is particularly important considering the increasing share of services in corporate revenues as a result of which, office improvements have become key facilitators of revenue generation.

In an experimental study conducted with human subjects in an office setting, the Light Right Consortium found that employee persistence and vigilance declined during the course of the day when personal lighting controls were not provided. However, when personal controls were provided there was no change during the course of the day. The most preferred lighting design, which was rated as comfortable by 91% of the participants, provided a combination of direct and indirect lighting, wallwashing, and occupant dimming controls.

The Consortium also found that lighting technology affects employee health and productivity:

- Published literature indicates there is a lower incidence of headaches when electronic ballasts are used instead of magnetic ballasts
- Office workers who reported being satisfied with the lighting in their personal work rated the space as more attractive, and reported being happier and satisfied with their workspace
- Workers reported that the presence of personal lighting controls increased motivation and allowed them to work longer and be more accurate on difficult tasks.

MARKET DRIVERS

SECURITY AGAINST AIRBORNE ATTACKS

The terrorist attacks of September 11, 2001, and the anthrax attacks that followed have also changed the nature of business for IAQ manufacturers. According to the Department of Homeland Security, the American Corporate Counsel Association, in

a white paper published in November 2002, recommended that corporations leasing commercial property take steps to minimize the threat posed by probable future terrorist attacks using biological contaminants. The association warned its members that a failure to take proactive action to defend a building, may have significant legal consequences.

These concerns over the consequences of chemical and biological terrorism is driving the market for the development of new air filtration and other air quality technologies and products that not only can handle routine every day air quality requirements but can also meet these extreme circumstances.

RECOGNITION OF BLACK MOLD THREATS

Increased media attention has made the presence of mold in interiors a matter of concern, much in the way concerns over radon and asbestos occurred in past decades. These concerns have affected strategy formulation and policy making in fundamental ways, changing the way the IAQ sector does business.

The presence of molds on building surfaces is not a new phenomenon. As a rule molds thrive on moist surfaces. As buildings and homes have come to rely almost exclusively on sealed ventilation, molds have become a more visible problem. Although the potential health hazards from molds has not been comprehensively studied, there is clear evidence of their potential as a source of allergens.

Since 2001 news reports about mold have driven public concerns over the problem. There has been a sharp rise in mold-related litigation. Claim payouts increased from about \$200 million in 2000 to about \$3 billion in 2005. The mold remediation services market has become the fastest growing segment within the IAQ services sector and is expected to maintain a double digit growth rate over 20% through 2012. This has led to fundamental changes in the IAQ services sector. New technologies and materials to control and suppress mold formation are being developed. IAQ industry associations have developed new certification standards for mold remediation services.

FINANCIAL & REAL ESTATE CONCERNS REGARDING SICK BUILDING SYNDROME

The EPA estimates that the U.S. working population spends 90% of its time indoors. The NIOSH has in its evaluations over the years found that 20-30% of non-industrial work spaces have poor IAQ. The Sick Building Syndrome (SBS) is a term used to describe a variety of symptoms exhibited by users of non-industrial workspaces. Symptoms include afflictions of the respiratory system such as nose irritation, and sneezing, and other effects such as headache, nausea, fatigue, and dizziness. The symptoms have been traced to multiple causative agents. Building related illnesses with more serious consequences include legionnaire's disease, asthma, and pneumonitis.

Studies by the EPA and professional trade associations such as the National Contractors Association, reveal that a significant number of office buildings have IAQ related problems. The EPA estimates that the concentration of certain air pollutants in indoor spaces can be two to five times higher than in outdoor environments.

According to the Occupational Health and Safety Administration (OSHA) poor IAQ can increase the risk of developing medical conditions requiring extensive medical treatment. OSHA estimates that the increased risk of developing conditions requiring medical attention per 1,000 employees is 57 in the case of headaches and 85 in the case of severe respiratory symptoms. Although the link between productivity and IAQ is not well established, there is little disagreement over the likelihood of increased health costs due to poor IAQ.

Surveys conducted by the consulting firm the Chelsea Group, reveal a high level of concern over IAQ in the workplace and a home. Over 70% of the sample of 1,000 respondents ranked workplace IAQ as “very important”, and 20% ranked it as somewhat important. In contrast only about 6% ranked it as “not important”.

COST EFFICIENT TECHNOLOGIES FOR URBAN ASSET ENHANCEMENTS

The increasing recognition of the importance that IEQ plays in worker productivity and satisfaction is becoming a financial inducement (for both building owners and tenants) to ensure that existing building assets are able to meet ever higher IEQ thresholds. The availability of cost-efficient technologies, both off-the-shelf and in some instances customized, to improve the quality of existing buildings’ working environments will be necessary to maintain the viability of older urban buildings. Tenants, left with no choice will seek newer (often suburban) construction to meet these IEQ thresholds.

INCREASING INTEREST IN IMPROVING ENERGY EFFICIENCY OF IEQ SYSTEMS

High energy costs in the 1970s led many HVAC system designers to sacrifice air quality in favor of energy efficiency, as dense filters used at the time were found to impede air flow and increase energy consumption. Today’s HVAC filtration systems must meet multiple objectives—protect internal machinery (compressors, blowers, and motors) and deliver high air quality—without causing a significant increase in energy consumption. Additionally, improvements in lighting systems (e.g., personal control, low-level ambient lighting, etc.) are often shown to compensate for additional up-front costs through energy efficiency-based cost savings.

LEGISLATION AND REGULATORY STANDARDS CAN SHAPE THE MARKET

In the U.S. although no single federal agency has mandated IAQ standards, the EPA, OSHA, and a few other industry associations, notably ASHRAE, have issued new guidelines. The Indoor Environments Division of the EPA implements a voluntary (non-regulatory) program that addresses IAQ with standards regarding pollutants, radon mitigation, asthma triggers, and other air toxics.

State legislation with respect to toxic mold further drives the IAQ market from a regulatory standpoint. Over 20 states have adopted legislation in response to increased awareness among citizens of toxic mold. These new laws vary but generally require mold inspections, develop standards for exposure, remediation requirements, licensing requirements for professionals, and more.

However, a **lack** of standards in some areas also impacts the IAQ/IEQ market as there are a number of manufacturers of stand alone devices whose claims are unverifiable. The Federal Trade Commission has disallowed several claims regarding air quality made by several manufacturers. ASHRAE is developing a new set of standards to help consumers evaluate the claimed benefits of various air filtration devices currently available in the market. Increased public interest and more information is expected to drive demand in the residential sector.

ECONOMIC DEVELOPMENT DRIVERS

FEDERAL, STATE, AND LOCAL FUNDING FOR HOMELAND SECURITY

Given the events of 9/11 and the related concerns over bioterrorism there has been an increased interest in the role indoor air quality equipment can play in the safety of building occupants. Significant resources have been targeted at R&D efforts to improve the efficacy of IAQ sensors, monitoring, and systems controls. Access to or involvement with these government implementation and research funds encourages firms to locate in regions with significant efforts.

ACCESS TO BROAD, MULTI-DISCIPLINARY RESEARCH

The technologies and sophisticated components associated with the entire spectrum of indoor air quality equipment requires access to a base of complimentary research and facilities in a broad range of disciplines. These disciplines include areas such as fluid dynamics, electronic engineering, information technology, and materials sciences/nanotechnology.

LEVERAGING EXISTING R&D CAPACITIES

Given the dominance of large firm players in the IEQ marketplace it is difficult for smaller and/or start-up firms to make all the infrastructure investments necessary to develop new, niche technologies. The ability for these firms to leverage substantial academic or industrial R&D facilities and expertise can potentially be an attractive locational feature for a region.

LOCATIONAL REQUIREMENTS OF MATURE INDUSTRIES

Of the four industry segments examined indoor environmental quality consists of a larger set of more mature companies. These more mature firms often prioritize community characteristics that attract and benefit workers, strong and supportive business climate, high quality K-20 education, and overall family-friendly lifestyle over more technology or segment specific requirements.

SPECIFIC INDOOR ENVIRONMENTAL QUALITY TECHNOLOGIES

- Air Filtration, Ventilation, Conditioning, and Other Treatment Technologies
- Air Sensors and Air Analysis/Monitoring Instrumentation

Air Filtration, Conditioning, Ventilation, and Treatment Technologies

Overview

In recent years, the U.S. indoor air quality sector has grown into a diverse market, driven by increased public awareness regarding the effects of harmful contaminants, the national and global threats surrounding the events of 9/11, and general interest in and preferences toward improved energy efficiency. The U.S. market includes IAQ-related equipment, IAQ consulting and testing services, and IAQ environmental services engaged in mold and asbestos remediation, removal, or abatement and other services such as radon mitigation. Though the recent growth rate of the IAQ-related equipment segment has shown signs of a slowdown compared to the other segments (growing only 4.5% from 2005-2006 compared to the double-digit growth in consulting and environmental services), the overall IAQ sector is growing at a steady pace and expected to grow by 7.5% annually from 2006-2011.

Numerous pollutants and contaminants can negatively affect indoor air quality (IAQ). The broad classes include

- microorganisms
- fine particles such as dust and smoke that are breathable
- volatile organic compounds (VOCs) released by building materials, furnishing materials, office equipment, and cleaning materials
- gaseous pollutants such as ozone from photocopy machines
- allergens such as toxic mold, dust spores, and pollens

Inadequate ventilation, high temperature and humidity levels, and the excessive use of certain building materials can lead to high concentrations of pollutants.

The three broad strategies involved in improving indoor air quality (reducing pollutant concentrations) include,

- source control
- improving ventilation
- filtration and treatment (air cleaning)

Source control methods include enclosing polluting material such as asbestos, fiber and coated surfaces, or making fine tuned adjustments to furnaces, heating and cooling equipment. Ventilation improvement methods include energy-efficient heat recovery ventilators, and high capacity air exhaust systems. These strategies are limited in scope and provide only a primary level of air quality, but are usually sufficient for residential and office spaces. Air filtration and treatment systems are used to maintain the much higher levels of air quality required clean rooms that house laboratory spaces, and electronics manufacturing facilities. Other applications include air pollution control in manufacturing spaces where operations such as welding, material processing, and painting take place.

With respect to air cleaning/filtration, there are numerous technologies that can be employed. These general process categories include

- Mechanical filters (capture particles via physical mechanisms); three types include Flat or Panel filters, Pleated filters, and HEPA (High-Efficiency Particulate Air) filters
- Electronic air cleaners (traps particles using an electronic field); types include Ionizers and Electrostatic Precipitators
- Hybrid filters (incorporate multiple of the above technologies)
- Gas phase filters (remove gases and associated odors); includes ozone generators

The two most common types of filters are mechanical filters and electrostatic filters. Mechanical filters consist of a dense matrix of fine fibers that may or may not be coated with adhesive substances. Particulate contaminants are either strained as in a sieve, or interrupted in their trajectory and trapped on adhesive fiber surfaces. In electrostatic filters particulate contaminants are first passed through an electric field that charges them positively. Farther downstream a negatively charged plate collects these positively charged particles, holding them through electrostatic attraction.

The above classification is not a rigid scheme. Air treatment systems are customized according to the demands of the process, and often use a combination of filtration systems.

The indoor air quality industry operates in three broad market segments.

The **Comfort Air** segment consists of commercial and institutional users of heating, ventilation, and air conditioning (HVAC) systems. HVAC filters provide a basic level of air quality and are designed to remove common allergens such as pollen, microorganisms, dust, and debris from fabrics, and furnishings.

The **Clean Process** market segment consists of users in the microelectronics, pharmaceutical, and food and beverage industries. For users in this segment, high air quality is a process and product design requirement. A clean room that meets ISO 4 (or the U.S. Class 10) standards must not contain more than 10,000 particles in the 0.1-0.2 micrometer range.

The **Safety and Protection** market segment consists of users in the manufacturing sector, who use filtration systems to capture dust and other process waste in work spaces such as paint shops, welding shops, and machining centers. Other users include operators of cement plants, sawmills, stone cutting and polishing lines.

This market study is limited to the Comfort Air and Clean Process segments. The Safety and Protection segment is not classified as a market for IAQ systems.

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- BCC Research estimates the overall IAQ market for 2005 was \$6.7 billion. This figure includes key subcategories such as the market for related equipment (except IAQ instrumentation included in the next section), consulting/testing services, and environmental services (including remediation/removal/abatement). BCC expects this market to grow at an average annual rate of 7.5%, to reach \$10.4 billion by 2011.
- According to BCC, the IAQ **equipment industry** (excluding instrumentation, sensors) represented a \$3.6 billion market in 2005 and has experienced steady, strong growth in recent years. Growth in the equipment sector is expected to continue at a 5% AAGR during the 2006 to 2011 period, and reach \$4.8 billion by 2011.
- Leading the market for IAQ equipment are air cleaners, valued at \$1.6 billion in 2005 and expected to grow to \$2.3 billion by 2011 (6.5% AAGR). Among the air cleaning segments, the market for portable cleaners accounted for \$970 million in 2005 and is expected to grow by 8.8% each year to 2011. In-duct cleaners represent a smaller segment (\$630 million in 2005) and are expected to see slower growth (2.5% AAGR).
- The dominant air cleaning filter technologies are mechanical (\$700 million in 2005) and electronic (\$290 million in 2005). Each is expected to retain its leading position with BCC forecasting AAGRs of 8% to 2011.
- The 6.5% average annual growth expected in the air cleaner market is driven by growth in the overall U.S. market for HVAC, as well as national increases in the prevalence of airborne allergies, especially asthma.
- Another major sub-market within IAQ equipment is for HVAC replacement filters. In 2005, the U.S. replacement filter sector was valued at \$750 million by BCC Research. This filter market is expected to grow at an AAGR of 4.5% to reach \$977 million by 2011. The rise in in-duct cleaning devices that require replacement filters in addition to a substantial upgrade of replacement filters among residential and commercial building owners are driving this steady industry growth.
- Ventilation systems and equipment are the third major component of the IAQ equipment market. It is important to note that only a portion of the total market for HVAC systems is correctly associated with IAQ equipment. In fact, industry experts attribute about 5% of the total \$24 billion U.S. HVAC market to ventilation technologies aimed at improving IAQ problems. This puts the U.S. market for ventilation systems at \$1.2 billion in 2005.
- BCC expects this market for IAQ-related ventilation systems to grow at a 3.5% AAGR and reach \$1.5 billion by 2011.

- Characterized by numerous independent consultants and small consulting firms, BCC estimates the market for **IAQ consulting** was approximately \$1.5 billion in 2005. Average annual growth among these consultants is projected to be 10% through 2011.
- The projected growth rate for IAQ consulting, though strong, is down from projections during the early 2000s. Experts point to improvements in construction with respect to IAQ as the industry is better educated in appropriate materials and methods used. This general trend includes using products that do not off-gas, installing vapor retardant inside new walls to prevent mold, and incorporating ventilation systems that bring in outdoor air.
- The **IAQ environmental services** sector performs remediation, removal, or abatement functions in buildings affected by contaminants (mold, asbestos, radon, sewage). This market includes not only the value of services (\$1.4 billion in 2005) but also the value of related equipment (\$200 million).
- The total IAQ environmental services market was \$1.6 billion in 2005. It is expected to see AAGRs of 9.5% to 2011 when the market should reach \$2.9 billion.
- The market breakdown within IAQ environmental services reveals mold as the largest current sector by value—\$800 million in 2005.
- The market for DCV-based systems is likely to show less growth at a little over 4% and reach \$348 million by 2011. The market for displacement ventilation systems is likely to remain a small one and grow only at about 1.6% annually to reach \$33 million by 2011. DCV is likely to see strong growth in the office buildings segment as it provides a solution to managing the ventilation problems associated with varying occupancy levels.

Technology Trends and Challenges

- Conventional HVAC systems are designed to operate at a constant rate of air intake. However as occupancy levels vary through a typical working day, constant ventilation rates may result in energy inefficiencies as the rate of intake and circulation may exceed the ventilation demand. Demand Controlled Ventilation (DCV) technology is an approach that allows intake rates to vary with occupancy levels based on measurements of occupancy levels. During periods of low occupancy (early or late in the working day) or vacancy (at night), re-circulation ventilation rates are reduced, using a suite of sensors to measure temperature and ventilation levels throughout the building, and processing this data to modulate outdoor air intake, damper position, and fan speed. DCV systems also monitor external temperature conditions to shorten the cooling cycle during the cooler parts of the day.
- Enthalpy recovery ventilation (ERV) is an approach that attempts to find an optimal solution to the need to maintain high IAQ at high levels of energy efficiency. One set of fans are used to remove stale air from areas with high levels of pollutants and moisture, while another set of fans maintains a low-

velocity flow of fresh air. This approach ensures that excess moisture is removed from intake air before it is cooled.

- The Heat Recovery Ventilation (HRV) system is built around a core containing a heat exchanger that permits the incoming and outgoing streams of air to transfer heat between each other. When the system is being used to heat the interior, the exhaust air is used to heat the incoming cold air stream. When the system is used to cool the interior, the incoming warm air is used to heat up the exhaust air stream. While the heat exchanger transfers heat between the two air streams it does not allow them to mix, thus maintaining air purity. HRV systems can capture as much as 85% of the energy from the outgoing stale air.
- Studies conducted by the Florida Solar Energy Center have shown that energy recovery ventilation systems attain high levels of humidity control and energy efficiency. The U.S. DOE estimates that energy recovery ventilation systems have the potential to save as much as 0.4 quads of energy nationally.
- Displacement ventilation (DV) is an innovative method, popular in the Scandinavian countries and some parts of Europe, though not widely used in the U.S. These systems depend upon the natural buoyancy of warm air to set up a circulation current in the space being ventilated. Cool supply air is introduced through vents at the floor level displacing warm air to the ceiling, maintaining a fresh cool air zone at the occupied level. The contaminants rise to the ceiling with the warm air where they are drawn out and vented through an exhaust grill. DV systems are effective in spaces that require high levels of ventilation such as in classrooms and conference rooms and have been found to be quieter than conventional systems. To a certain extent the energy spent on fresh air intake is considerably reduced as a DV system does not allow incoming and outgoing air streams to mix. The warm air that contains impurities does not return to the occupied levels of the ventilated space being lighter than the incoming air.
- A number of new pollutants and contaminants such as fine particles, gaseous contaminants, toxic molds, and microorganisms are now outside their traditional environments. This is leading to a demand for multi-functional filtration systems. Hospitals where disease-resistant bacteria are a serious concern require multi-stage filtration systems that use a combination of processes including ultraviolet screens to sterilize the air.
- Molecular contamination has become a serious problem in the manufacture of semiconductors as the resolution of lithography systems continues to become smaller. In addition to maintaining very low particulate concentrations, clean room filtration systems are now required to screen out specific molecules such as ammonia. Molecular contaminants are now required to be maintained at 5 parts per billion compared to the earlier 3 parts per million, as contamination leads to product failure and costly repairs of capital equipment.

- As nanoscale materials have become popular in consumer goods, their health effects are still not fully understood. As these materials are of the same scale as hemoglobin, viruses, and smaller than common pollutants such as pollen, they are a potential hazard in closed spaces. For instance gallium arsenide from ICs in discarded cell phones is a potential source of such contaminants. Air filtration systems of the future would have to handle this new class of pollutants.

Key Market Opportunities

- ***Global expansion of high tech manufacturing and research*** – Traditionally concentrated in the developed economies, these sectors are now expanding in China, India, and other developing economies. This opens up a new market with long term potential for the Clean Process segment, a high value market for air filtration systems. User industries expanding globally include semiconductors, chemicals, materials and pharmaceutical research, and pharmaceutical manufacturing. Air filtration system manufacturers have to design a new class of systems that can work in the extremely polluted environments of developing economies, and still help deliver products that meet the regulatory standards prevalent in the developed economies.
- ***Overcoming economic cycles in the Clean Process segment*** – Demand from this segment is dependent on business investment cycles. As new standards of IAQ in commercial spaces continue to emerge, air filtration system manufacturers have the opportunity of delivering more advanced systems to the Comfort Air segment, where replacement demand accounts for a bulk of the revenues.
- ***Meeting the demand for lower “Life Cycle” costs*** – The cost of a filter accounts for only 15-20% of its life cycle costs while energy accounts for most of the remainder. With more complex filtration systems being used in the Comfort Air segment air filtration system manufacturers can establish new markets in this segment by promoting the sale of more energy efficient filters.
- ***Expansion of the residential air filtration market*** – This market is served by a number of small companies whose product claims have not been established conclusively. However, the incidence of respiratory and allergy related diseases among the general public continues to rise, and recent studies estimate that over 50 million people in the U.S. suffer from a variety of diseases including asthma, rhinitis, dermatitis, and food allergies. Other agents that affect IAQ in homes include radon and toxic mold. The residential air quality market offers opportunities for remediation services, and re-designed HVAC filtration systems. Currently large companies do not have a significant presence in this market.
- ***The air filtration industry is not consolidated*** – There are a number of small manufacturers of low-end HVAC filters in the U.S.

- **Growth in market for ERV systems** – ERV systems are likely to see strong growth in constant occupancy buildings such as schools and homes. Displacement ventilation is likely to remain a niche technology as currently there are few U.S. based companies developing the technology. However, DV may become a serious contender for cooling large enclosed spaces with high ceilings such as enclosed shopping malls.
- **Office building remediation market will experience double digit growth rates** – Environmental Business International, Inc., (EBI) estimates that the remediation services market is set to expand dramatically. Apart from toxic mold, over 100 chemicals including formaldehyde, solvents, and pesticides have been found to have an adverse effect on IAQ. EBI reports that toxic mold has been identified as a premier business risk by the real estate and insurance industries. The scope of remediation services is projected to expand beyond the overhaul of the HVAC filtration system, and rebuilding of interior surfaces. IAQ consultants will be required to offer services that draw upon expertise in areas such as fungal biology and the modeling of atmospheric dispersion of particulates. EBI estimates that the remediation services market is likely to account for a substantial slice of the total IAQ market.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
3M	Air Filters	MN	U.S.
American Air filter	Air Filters	KY	U.S.
Aprilair	Air filters; ventilation; other IAQ products	WI	U.S.
Camfil Farr	Air Filters	-	Sweden
Carrier	Process Air, Comfort Air	CT	U.S.
Clarcor Inc	Air Filters	TN	U.S.
Danfoss A/S	Process Air, Comfort Air	-	Denmark
Danfoss, North America	Process Air, Comfort Air	MD	U.S.
Donaldson	Air Filters	MN	U.S.
Fedders	Process Air, Comfort Air	NJ	U.S.
Filtration Group	Air filters	IL	U.S.
Friedrich Air Conditioning	Air filters; Comfort Air	TX	U.S.
Halton Group	Air filters; ventilation	-	Finland
Honeywell	Air cleaners; sensors & other instrumentation	NJ	U.S.
Hunter Air Purifier	Air purifiers; filters	AZ	U.S.
Johnson Controls Inc.	Process Air, Comfort Air	WI	U.S.
Lennox International	Process Air, Comfort Air	TX	U.S.
Lydal	Air Filters	CT	U.S.
Pall Corporation	Air Filters	NY	U.S.
Price Industries	Air distribution products; Comfort Air	GA	U.S.
Whirlpool	Air purifiers; air conditioners	MI	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Nu-Air Ventilation Systems	HRV systems	NS	Canada
RenewAire	ERV	WI	U.S.
StrionAir	Air filtration	CO	U.S.

Air Sensors and Air Analysis/Monitoring Instrumentation

Overview

Accurate monitoring and measurement of the quality of indoor air is essential to the efforts of industry professionals to ensure safety and/or address problems. As the IAQ-related industry and general public awareness grows, there is increasing demand for both common type and specialty type air monitoring instruments and devices. IAQ instrumentation continues to be in demand among professional consultants and environmental services providers, but also is increasingly utilized by maintenance technicians in large office, light industry, and commercial settings.

Demand controlled ventilation (DCV) is a recent development in HVAC systems technology that aims to dynamically modulate air conditions based on actual ventilation needs that vary based on occupant density in a given space. However, a complete and effective implementation of DCV depends substantially on the availability of stable and inexpensive sensor systems. Controlling the concentration of other pollutants such as volatile organic compounds (VOCs), particulate matter, gaseous pollutants, and biological contaminants are some of the other problems in IAQ that require a more versatile, reliable, and affordable suite of air quality sensors than currently available.

IAQ monitoring systems and instruments are used by professionals to measure the following **parameters**.

- temperature
- relative humidity
- carbon dioxide concentration
- volatile organic compounds (VOCs)
- other gases – NOX, CO, ozone
- chemicals in aerosol form
- particles, pollen, microorganisms

Specific **IAQ instrumentation** used to investigate indoor air quality includes:

- Thermohygrometers (temperature, humidity)
- Multi-parameter ventilation meters (temperature, humidity, velocity, volume)

- Air velocity meters
- Air capture hoods for volume; combustion analyzers for CO
- Photometers for airborne particulates
- Optical particle counters and condensation particle counters (airborne particulates and ultra-fine particles)
- Electro-chemical gas sensors (chemical gases)
- Photo- and flame-ionization detectors (VOCs)

IAQ sensors use the following **sensing principles**.

- catalytic reaction
- infrared spectroscopy
- electro-acoustics

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- BCC Research, in its broad assessment of the U.S. IAQ market, isolates IAQ instrumentation within a larger equipment market. While these instruments represent the smallest segment of the full IAQ equipment market, they are expected to see the highest growth rate among the equipment subsectors—an AAGR of 7.5% between 2006 and 2011. This growth rate is in line with the 10% AAGR expected in the market for IAQ consultants, who purchase roughly 75% of all IAQ instrumentation.
- In 2005, BCC valued the market for IAQ instruments at \$34 million and based on the projected growth rate, it should rise to approximately \$52.6 million by 2011.
- There are two major subgroups of the IAQ instrumentation market. The larger of the two is that for **commonly used instruments** for measuring temperature, humidity, CO and CO₂. This group accounts for \$21 million of the overall \$34 million instrumentation market for 2005 and includes IAQ monitors, multi-parameter ventilation meters, and thermohygrometers.
- Within the common instrumentation subgroup, IAQ monitors make up about 50% of the market, with multi-parameter ventilation meters accounting for about 30%, and thermohygrometers rounding out the remaining 20%. IAQ monitors are such a large share because in addition to the IAQ professional market, these instruments are also purchased by maintenance technicians in schools, light industry, and commercial settings as well.
- The second of the two major instrumentation subgroups is **specialty instrumentation** used to measure VOCs, gases, and particles. This \$13 million market in 2005 includes photometers, optical particle counters, condensation particle counters, electro-chemical gas sensors, and photo and

flame ionization detectors. The market for specialty instrumentation is smaller than for common instruments simply based on need and usage.

- The leading instruments in the U.S. specialty market in 2005 were photometers (\$3.9 million), followed by optical particle counters and condensation particle counters each valued at \$3.25 million. These leading specialty instruments are in this position because they have more applications during IAQ investigations in testing for airborne particles and ultra-fine particles.
- BCC expects the market for the common types of IAQ instrumentation to grow at twice the rate as for the specialty instrumentation subgroup—AAGR's of 9.2% versus 4.6%, respectively.
- IAQ industry information from 2003 highlights the breakdown of instrumentation purchasers. As mentioned, about three-quarters of IAQ monitoring and testing instruments are purchased by professional IAQ consultants. This breaks down into about 41% purchased by environmental service providers and 36% by general consultants. Maintenance technicians purchase the remaining share.
- In a broader context driving the potential market for IAQ instrumentation, PNNL reporting a study by BCS Partners 2002 places the annual market for building control systems, including controllers, network devices, instruments, and actuators, at over \$740 million.
- The market for sensors and other IAQ instrumentation is further driven by the Process Air segment and according to estimates published by McIlvaine Company in July 2005, the worldwide market for clean room consumables used by customers in the Process Air segment was worth \$5.3 billion, while the market for clean room hardware was worth \$4.2 billion. Sensors and sensor consumables account for a significant share of this revenue. The highest market growth is expected from monitoring systems for sterility and microbial control.

Technology Trends and Challenges

- A core trend in building paradigms presents a challenge to incorporating IAQ monitoring systems in design. At present the dominant paradigm in building construction—the plan/design/build model, and the design/build model—are characterized by reliance on standardized designs, and avoidance of innovation. The collaborative building paradigm, using a systems approach to integrate new functionality, is followed in not more than 4-8% of ongoing projects at any point in time. The dominant building paradigm prevents developers from integrating IAQ monitoring systems in the basic design.
- Despite increased awareness, investments in IAQ monitoring are often not a major investment priority. Currently, IAQ monitoring systems are not considered as high a priority as energy management systems by owners/managers of commercial and institutional buildings. Less than 50% of the total built up commercial and institutional space uses energy management and control systems. Similarly, in office environments energy expendi-

tures account for a little over 1% of total annual costs, and are not a significant cost compared to employee payroll and rent. In retail environments where energy costs are comparatively more significant, investment in advanced HVAC control systems are often deferred in favor of investments in interior décor (lighting or displays) that are seen to provide a more immediate payback in revenue.

- Temperature and relative humidity sensors are the most well established sensing applications for HVAC systems. Carbon monoxide and CO₂ sensors are less common. Current designs have a number of problems largely due to their unstable performance following initial calibration. Infrared based CO₂ sensors are used in some high end DCV systems, but their high cost constrains demand. Currently available carbon monoxide sensors are known to trigger false alarms.
- Devices based on currently available technologies for detecting other pollutants such as VOC, particles, and microorganisms, are bulky and expensive and are rarely used in the Comfort Air segment. As a result these devices are not suitable for continuous monitoring systems.
- Existing devices provide limited functionality as they all but lack processing and memory capabilities, and are designed to transmit data to a central location, rather than function in an autonomous network.
- Chemical, biological, and nuclear hazard detection sensors are prohibitively expensive for the Comfort Air segment.
- PNNL has identified the following directions for future research.
 - Self-calibration/testing/diagnosing/reporting sensors
 - Mobile sensors that can work in a network and sense the change in IAQ conditions with changes in occupancy
 - Inexpensive sensors with memory and processing abilities.

Key Market Opportunities

- Media attention and education efforts targeted at building occupants have raised awareness of issues with IAQ and driven market growth in recent years. As a result of this awareness in places of work and public buildings, well-educated individuals are now interested in having the air quality of their homes tested by professional consultants. This is, in turn, driving demand and creating market opportunities for home IAQ instrumentation.
- Increased awareness and IAQ-related litigation have prompted demand for common IAQ instrumentation among non-professional users such as maintenance staff at schools, in large offices, and in commercial settings. The market for IAQ monitors is large and growing, and the demand for user-friendly or simpler technology in this arena will be a primary issue as fewer professionals adopt these technologies for use in their respective business settings.

- Likewise, the market for specialty instrumentation measuring VOCs, gases, and particles may offer market opportunities among non-professional consumers. Currently, IAQ consultants purchase about three-quarters of all IAQ instruments. While the consultant market is expected to see strong growth, market opportunities among schools, offices, light industry, and potentially homeowners purchasing these instruments also represents a potential growth segment.
- IAQ monitoring with respect to chemical, biological, or nuclear detection is a key market opportunity for IAQ instrumentation manufacturers in the current climate of global security. That said, technology and cost hurdles must be overcome in order for this market to be viable.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Danaher	Control systems, sensors	DC	U.S.
Danfoss A/S	Controls	-	Denmark
Danfoss, North America	Controls	MD	U.S.
Ember	Wireless sensor networks	MA	U.S.
GE Sensing – Telaire	Sensors (infrared gas sensors, other)	MA	U.S.
Gray Wolf	Control systems, sensors	CT	U.S.
Honeywell	Control systems, sensors, consulting & engineering	NJ	U.S.
Johnson Controls, Inc.	Controls	WI	U.S.
Honeywell analytics	Air quality detectors	FL	U.S.
KD Engineering	Control systems, sensors	WA	U.S.
Lennox International	Controls	TX	U.S.
Quest Technologies	Control systems, sensors	WI	U.S.
Siemens Building Technology	Control systems, sensors, consulting & engineering	-	Germany
Siemens Building Technology, U.S.	Control systems, sensors, consulting & engineering	IL	U.S.
Testo AG	Control systems, sensors	-	Germany
Testo, US		NJ	US
Tranzeo Wireless Technologies Inc.,	Wireless sensor networks	BC	Canada
TSI Inc.	Control systems, sensors	MN	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Aircuity	Control systems, sensors	MA	U.S.
ICx Photonics (formerly Ion Optics)	IR gas sensors	MA	U.S.

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RENEWABLE ENERGY

INTRODUCTION

A range of external factors shapes and influences the future direction of the market for renewable energy and the technologies that produce it. Such factors may be technological, regulatory, or consumer preference-based in nature. Technological factors include large shifts in research funding and the development of innovative technologies by industry leaders who can affect the market. The extent of these technology breakthroughs is dependent in large part on R&D funding. Regulatory factors include various financial incentives and policies that can alter demand for traditional and alternative sources of energy. Finally, increasing desire for a sustainable economy, rising electric power needs, environmental concerns, and moral pressures are among the factors influencing the preferences of energy consumers.

MARKET DRIVERS

NATIONAL R&D BUDGETS AND FINANCING FOR ENERGY TECHNOLOGIES

Changes in R&D budgets in both public and private sectors drive the rate of the identification of solutions to current technology barriers. Increased R&D budgets yield accelerated research, firm entrance, and, ultimately, falling costs for alternative energy technologies. In addition, as oil and natural gas prices rise, excess capital normally directed to traditional energy companies is rerouted to company-level venture capital funds, many of which are investing in a variety of alternative energy technologies.

The Advanced Fuels Infrastructure Research and Development Act, H.R. 547, passed in the House on February 9, 2007 by a margin of 400-3 and directs the EPA, in consultation with the National Institute of Standards Technology, to establish a program of research and development of additives that will make biofuels more compatible with existing fuel infrastructure.

PUBLIC POLICIES, GOVERNMENT SUBSIDIES, AND INCENTIVE PROGRAMS

Political and financial instruments, such as R&D incentives, tax credits, or fees can spur R&D, production, consumption, and market competition. Of note, the Energy Policy Act of 2005 provides tax incentives to consumers who can keep their energy consumption at or below specific levels and mandated an ethanol production increase to 7.5 billion gallons/yr by 2012. In 2007, the White House announced an initiative to produce as much as 35 billion gallons/yr of alternative fuels by 2017.

The 2005 Investment Tax Credit (ITC) gave a boost to industry efforts toward commercialization of fuel cells by encouraging the purchase of fuel cells for both residential and business use. (The ITC is set to expire in 2008, although the industry and U.S. Fuel Cell Coalition are lobbying for a long-term extension of the credit.)

The Renewable Energy Production Tax Credit (PTC) is helping to lower the costs of wind power by encouraging new firm investments. However, in recent years the PTC has been approved for short-term periods only. This leads to “boom and bust” cycles within the wind power sector. If the credit is renewed under a long-term structure, businesses may be more comfortable investing and hold steady their short-run costs. Internationally, the elimination of coal subsidies in China contributes significantly to reduction in the use of fossil fuels.

GOALS/MANDATES, TARGETS, AND STANDARDS

A growing number of states and countries have enacted policies designed to increase the use of energy derived from renewable resources. Renewable portfolio standards (RPS) are a key driver of U.S. renewable energy utilization and production. At present, twenty-two states and the District of Columbia have enacted renewable portfolio standards, which cumulatively could result in the development of more than 46,000 MW of new renewable energy by 2020. In August 2007, the U.S. House of Representatives voted to require investor-owned electric utilities nationwide to generate at least 15 percent of their electricity from renewable energy sources. The countries of the European Union have adopted a goal of deriving 20–30% of their total energy demand from renewable resources by 2020. Worldwide, numerous countries have in place industrial and vehicular emissions standards that set specific limits to the amount of pollutants that can be released into the atmosphere.

INCREASED NATIONWIDE SUPPORT FOR A SECURE AND SUSTAINABLE ECONOMY

The security and reliability of traditional sources of energy such as oil are questionable given current geopolitical crises and related concerns around the globe. Rising and fluctuating fossil fuel costs and the threat of foreign fuel supply interruptions are the primary contributors to a growing nationwide demand for development of domestic fuel sources. Current U.S. oil and gas production is expected to peak within the next 2 to 3 decades. Therefore, development of domestic energy reserves and supply diversification are viewed as critical national security measures.

GROWING GLOBAL AND DOMESTIC ENERGY DEMAND

The world is experiencing a rising demand for energy and electric power, a trend that is resulting in increased global competition for energy resources. The energy requirements of China and India have increased sharply as literal fuel for their rapidly growing economies. U.S. growth in high-tech equipment and personal electronics is also contributing to increased energy use; domestic energy consumption per capita is expected to rise 17% through 2025. These changes in the electric power intensity of the economy are creating numerous opportunities in development of energy efficiency or power reliability technologies, electric grid revitalization, and the alternative fuels transportation network.

CONCERNS OVER GLOBAL WARMING/CLIMATE CHANGE

Mounting scientific evidence of global climate warming due to greenhouse gas emissions has produced a convergence of political and public opinion that reduction of fossil-fuel generated greenhouse gases is imperative. In addition, many businesses are responding to moral pressure by moving to the “correct” side of the climate change and renewable energy issue, where they may receive credits and goodwill and are less likely to face criticism over “climate liabilities.”

CONSUMER TASTES AND PREFERENCES GOING “GREEN”

Many energy consumers are increasingly demanding alternative sources of energy, and if given a choice between traditional and alternative energy supplies at a similar cost, many consumers are opting for the cleaner alternatives.

ECONOMIC DEVELOPMENT DRIVERS

ACCESS TO INPUTS AND SUPPORTING INFRASTRUCTURE

As with any siting decision, availability of key inputs and a distribution network are critical. Renewable energy production plants require proximity to abundant natural resources—wind, sunlight, biomass feedstock, or water (as a renewable source of hydrogen). Access to transmission lines for the distribution of electricity to the main grid or to consumers is also needed. Depending on the possibility of interstate transmission, the presence or absence of uniform grid interconnection standards may be worth considering.

Renewable energy generation facilities are often situated in sparsely populated locations where residents cannot complain about noise, smell, or sight pollution. However, distinct advantages—such as access to machinery and skilled labor—exist for siting plants in metropolitan areas that have strengths in manufacturing, construction, or operations. Access to traditional university-centered research could also be advantageous, particularly if strong programs in environmental engineering, materials science engineering, plant genetics, and/or biochemistry are in place and research clusters can be developed around broad renewable energy themes.

Certain types of capital may be designated specifically for investment in renewable energy projects. “Green funds”—funds that invest in environmentally progressive companies—or “green energy grants”—competitive grants that support renewable energy R&D or deployment at the consumer or corporate level—are potential sources of capital for new or growing renewable energy companies.

FORWARD-THINKING POLICY-MAKING AT LOCAL, STATE AND FEDERAL LEVELS

States are using increasingly aggressive and ambitious Renewable Portfolio Standards (RPS) to spur economic development and to create a reliable and diversified supply of electricity, as well as to reduce greenhouse gas emissions and conventional pollutants. Twenty-two states and the District of Columbia have imple-

mented an RPS. The proliferation of RPS initiatives at the state level provides real-world models of whether a federal RPS may be a feasible option to increase the nation's use of renewable energy sources as part of a larger energy and climate change policy. Whether or not a state has or is considering enacting an RPS should weigh into the decision of where to locate a renewable energy production facility.

WILLINGNESS OF EXISTING UTILITIES TO PARTNER WITH RENEWABLE ENERGY COMPANIES

While states with RPS' in place require utilities serving their state to obtain a specific percentage of retail electricity from renewable resources, new or growing renewable energy companies can only benefit from these standards if the existing utilities are willing to partner with them rather than obtain renewable energy generated outside of the state off of the grid or build their own solar, wind, biofuel, or hydropower facilities.

PURSUIT OF BOTH ALTERNATIVE ENERGY INVESTORS & BUSINESSES

A meaningful, earnest pursuit of both new alternative energy firms and venture capital firms (and other early-stage investors) is attractive to a company as it chooses its location for operations. At the same time, if a state or local government takes a strong, pro-environmental policy stance, businesses will look favorably to the region as a potential site. The regulatory and public policy climate goes a long way in attracting VC investments in new energy companies where policy incentives provide a critical boost to the early stages of business development. This coordinated business, investment, and policy push emphasizes the serious nature of a region's intentions to foster growth and develop a real alternative energy cluster.

SPECIFIC RENEWABLE ENERGY TECHNOLOGIES

- Biomass
- Wind
- Solar
- Micro-fuel cells

Biomass Energy

Overview

Biomass—plant matter and other biodegradable materials—is a sustainable resource that can be utilized directly or indirectly as a source of heat, electricity, transportation fuels, or organic products.

Conversion of biomass into “biofuels” such as ethanol, biodiesel, biobutanol and biogas is a major focal point of today's economy due to the potential to relieve dependence on foreign oil and to reduce greenhouse gas emissions. The two most common types of biofuels are ethanol and biodiesel. Typically, ethanol is made from fermentation of starches and sugars in corn and other plants such as sugar

cane, but cellulosic plant matter such as corn cobs, husks and agricultural waste offer greater energy potential and less controversy regarding the use of feedstock to meet energy needs. Hardwoods are an especially abundant source of cellulose and represent the largest biomass energy resource today. Therefore, major re-search initiatives are now being directed towards collection, treatment, digestion and fermentation of cellulosic materials to produce ethanol. Biodiesel is produced through a different method altogether (transesterification) using crops, waste, or microbes with high oil content.

Biobutanol is an alcohol as is ethanol, but has greater energy value and other characteristics that make it a better performing component of automotive fuel. BP and DuPont are pioneering the production of biobutanol from starchy feedstocks as well as from cellulosic materials.

Methane, or biogas, can be captured from landfills or other sites where biomass naturally decays (e.g., manure-rich dairy farms) and used for energy production. It can also be produced by certain bacteria that decompose organic matter. Once methane is captured and collected at a central location, it is filtered, cleaned, and burned, producing electricity while simultaneously reducing the amount of methane released into the atmosphere.

Biopower refers to the use of biomass energy sources to generate electricity. Biopower technologies include direct-firing, co-firing, gasification, pyrolysis and anaerobic digestion. Paper mills are the largest current producers of biomass power, generating electricity via direct-fired burning of pulp waste to generate steam that drives a turbine. Co-firing refers to mixing biomass with fossil fuels in conventional power plants. Gasification systems use high temperatures and anaerobic conditions to convert biomass into a synthetic gas or “syngas,” which can subsequently be converted to other fuels or used to power a turbine. Pyrolysis is the high-temperature, high-pressure, anaerobic conversion of biomass to gases and liquid that can be burned like fuel oil or refined into chemicals and fuels.

Biomass can also be used to produce chemicals and materials currently generated from fossil sources, further increasing the efficiency and economic value of bio-based technologies. The variety of products that can be generated is diverse, ranging from adhesives and paint to nutraceuticals and animal feed.

Market Trends, Challenges, and Opportunities

The ethanol and biodiesel markets are growing rapidly—ethanol at roughly 15% and biodiesel at 85% in recent years—and continued rapid growth of these markets both worldwide and in the U.S. is anticipated. While much of the focus in achieving national or state goals in biofuel production is on corn-based ethanol and biodiesel, interest in cellulosic-based ethanol, algae-based biodiesel, biobutanol, and biopropane is escalating.

Global and U.S. Market Trends

- **Worldwide biomass installed capacity** was 44GW in 2005. The top 5 countries for existing capacity were the U.S., Brazil, Philippines, and Germany/Sweden/Finland (tie). (REN21)
- **70% of all biomass in the world is used in the residential sector** compared to 14% in industry; 11% is transformed into electricity, heat, biofuel or biogas (ABS Energy Research)
- **Worldwide ethanol production** in 2005 was 8.7 billion gallons, yet this was less than 3% of total gasoline consumption. Production has increased ~15% a year since 2000, led largely by the U.S. (BP) The top 5 ethanol-producing countries were Brazil/U.S. (tie), China, and Spain/India (tie). (REN21; SRI Consulting Business Intelligence) In 2006, the U.S. and Brazil accounted for 89% of global ethanol production (BP).
- **Worldwide biodiesel production** in 2005 was 1.0 billion gallons. The top 5 biodiesel-producing countries were Germany, France, Italy, U.S., and Czech Republic. Growth in biodiesel production has generally outpaced that of ethanol with an 85% increase in annual production in recent years. Growth is particularly strong in Europe, which represents 90% of biodiesel production and consumption: in 2006, biodiesel production in the EU was over 1.6 billion gallons, compared to 0.3 billion gallons in the U.S. (REN21; BCC Research)
- Current **U.S. biomass installed capacity** is 10GW and is expected to reach 100GW by 2025. Growth in domestic biodiesel capacity is becoming more aggressive, with numerous plants under construction and plans for biodiesel blends to displace 5% of the diesel fuel market by 2015 (National Biodiesel Board).
- **U.S. ethanol production** in 2005 including imports (primarily from Brazil) was 4.2 billion gallons, worth an estimated \$10 billion (BCC Research). Ethanol production is growing at ~7.3% annually (BCC Research). Currently, U.S. ethanol production stands at 5 billion gallons/yr, consuming over 20% of the nation's corn (USDA).
- In 2007, 115 **ethanol biorefineries** are in production and 79 under construction in the U.S., almost all located in the upper Midwest (Renewable Fuels Association). The **ethanol biorefinery construction market** is currently estimated at \$10.5 billion.
- **U.S. biodiesel production** was 75 million gallons in 2005 and is projected to reach 816 million gallons by 2011, worth an estimated \$2.9 billion (BCC Research).
- In 2007, 148 **biodiesel plants** are in production and 96 under construction. Biodiesel producers will invest over \$800 million by 2015 to build new biodiesel plants and expand existing facilities. (www.biodiesel.org)

Technology Trends and Challenges

- Major **areas of investment** in biomass technologies by university and industry R&D programs include cellulosic ethanol, bio-based hydrogen production, and process improvements (feedstock pretreatment, fractionation/gasification, fermentation, chemical/enzymatic conversion, separation, and process integration).
- In the U.S., the wholesale cost of producing a gallon of ethanol from corn is currently \$1.10/gallon; from cellulose, \$1.10–\$3.09/gallon. By comparison, the wholesale cost of a gallon of petrofuel is \$0.90. It is hoped that development of **technologies for digesting cellulose and hemicellulose** for production of ethanol will make bioethanol cheaper, more widely accepted and used. Cost-competitive cellulosic ethanol is necessary to meet stated goals of achieving 20% biofuels use by 2017 (“Twenty-in-Ten” Initiative) and DOE Roadmap goal of replacing 1/3 of U.S. fuel needs by 2030.
- Genetic modification of microbes or identification of extremophiles that can **convert biomass** into substrates for fermentation to bioethanol
- Identification and characterization of **feedstocks with high energy potential**, such as hardwoods and algae, or genetic modification of existing feedstocks, such as eucalyptus
- **Closed-loop biofuel production plants**—capturing methane gas from cattle feedlots to power the production of ethanol from corn, and using distillers grain, one of the byproducts, for cattle feed
- A new process termed **consolidated bioprocessing (CBP)** is under development and involves the direct fermentation of biomass using cellulolytic microorganisms without the addition of enzymes. Although CBP is still under development and may take a few years to attain commercial viability, it may turn out to be the most commercially competitive processing technology.
- **Separations** – new membrane technologies and novel procedures are needed for the isolation/recovery of fermentation products and high value chemicals from feedstocks

Key Market Opportunities

- The **worldwide market for biofuels** was \$20.5 billion in 2006 and is expected to reach \$80.9 billion by 2016. (Clean Edge) Growth in the biofuels sector will come from new commercial and industrial biomass power plants, distributed production in pulp/paper mills, wholesale power generation, solid-waste conversion to energy, and farm, landfill and wastewater treatment projects.
- The **worldwide market for cellulosic biofuels** is projected to reach \$10 billion by 2012. (Shell)
- The **U.S. ethanol industry** is the one of the fastest growing energy industries in the world. Ethanol demand is driven by replacement of gasoline ad-

ditive MTBE with ethanol; government-mandated production targets; air quality issues; tax credits and other financial incentives; and reducing dependence on foreign oil (BCC Research).

- **U.S. demand for transportation biofuels** for cars and trucks will double to 6% of all road fuels by 2010. Road fuels currently represent a \$28.4 billion market (Cambridge Energy)
- The majority of **new U.S. biomass power projects** will be at distributed facilities near demand centers.
- Major **market barriers** include consumer acceptance or awareness; cost of competing technologies (fossil-based fuels and products); biomass availability, transportation, and labor; access to biorefineries; lack of a well-developed fueling station distribution network
- **Additional products and key market opportunities** derived from biomass-based technologies include:
 - Butanol, which has greater energy potential than ethanol and has properties similar to gasoline so that it can be shipped in existing gasoline pipelines
 - E-85
 - Flex fuel vehicles
 - Green diesel (a diesel additive made from plant carbohydrates)
 - Dimethyl ether (DME, an ecological alternative fuel for diesel engines)
 - Hydrogen for fuel cells
 - Jet biofuel,
 - Gasification of biomass to produce syngas, which is then used in gas turbines to produce electricity
 - Pyrolysis liquids
 - Syngas liquids
 - Anaerobic digestion of municipal and agricultural wastes to produce methane, which can be burned or used to generate electricity
 - “Biorefinery” products: bioproducts conventionally made from petroleum such as lubricants, surfactants, adhesives, plasticizers, composite materials, paints and coatings, plastics; or high-value bioproducts such as sorbitol, xylitol, nutraceuticals and bioactive compounds
 - Co-products generated during biomass processing, such as protein feed, gluten meal, germ, fermentation-derived chemical intermediates like lactate and citrate, starches and sweeteners, carbon dioxide

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Abengoa Bioenergy	Ethanol; cellulosic ethanol	MO	U.S.
Archer Daniels Midland Co	Ethanol and biodiesel	IL	U.S.
Aventine Renewable Energy	Bioethanol	IL	U.S.
Biopetrol Industries	Biodiesel	-	Switzerland
BIOS-BIOENERGIESYSTEME GMBH	Biogas	-	Austria
Blue Sun Biodiesel	Biodiesel	CO	U.S.
BlueFire Ethanol, Inc.	Cellulosic ethanol	CA	U.S.
BP	Biofuels research	-	U.K.
Cargill	Bioethanol; bioproducts (polylactide)	MN	U.S.
Ceres	Cellulosic ethanol and bioproducts	CA	U.S.
Chevron	Cellulose and biofuels research (partnerships with Georgia Tech, Weyerhaeuser)	CA	U.S.
Choren Industries	Biomass gasification	-	Germany
Cosan	Sugarcane-based bioethanol	-	Brazil
DuPont	Biobutanol (partnership with BP)	DE	U.S.
Dyadic International Inc.	Enzymes for bioethanol production	FL	U.S.
E3 BioFuels	Corn-based bioethanol	KS	U.S.
Iogen Biorefinery Partners	Cellulosic ethanol	ON	Canada
Midwest Grain Processors	Bioethanol	MN	U.S.
Monsanto	Engineered corn for bioethanol	MO	U.S.
Neste Oil	Biodiesel	-	Finland
Novozymes	Bioethanol	-	Denmark
Organic Fuels	Biodiesel	TX	U.S.
Pacific Biodiesel	Grease trap biodiesel	HI	U.S.
Pacific Ethanol	Corn ethanol; cellulosic ethanol	CA	U.S.
Petrobras	Bioethanol	-	Brazil
POET	Cellulosic ethanol	SD	U.S.
Range Fuels	Cellulosic ethanol	CO	U.S.
Renewable Energy Group	Biodiesel	IA	U.S.
Safe Renewables Corporation	Biodiesel	TX	U.S.
Suncor Energy Products	Biodiesel	AB	Canada
Syngenta	Enzymes for converting cellulosic biomass	-	Switzerland
U.S. BioEnergy	Corn-based bioethanol	MN	U.S.
VeraSun Energy	Corn-based bioethanol	SD	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Algatechnologies	Microbe-based biofuels	-	Israel
Amyris Biotech	Engineering microbes to make hydrocarbons	CA	U.S.
Aurora BioFuels	Microbe-based biofuels	CA	U.S.
C3 BioEnergy	Biopropane from corn or sugarcane	MA	U.S.
Global Green Solutions	Microbe-based biofuels	BC	Canada
GreenFuel Technologies	Microbe-based biofuels	MA	U.S.
Imperium Renewables	Microbe-based biofuels	WA	U.S.
LS9	Engineering microbes to make hydrocarbons	CA	U.S.
Masada	Producing ethanol from municipal waste	AL	U.S.
Prometheus Energy	Biogas (converting landfill methane to liquefied natural gas)	WA	U.S.
Solazyme	Microbe-based biofuels and bioproducts	CA	U.S.
Solix Biofuels	Microbe-based biofuels	CO	U.S.
SunEthanol	Engineering microbes to make hydrocarbons	MA	U.S.
Verenium	Corn-based ethanol, cellulosic ethanol	MA	U.S.

Wind Energy

Overview

As one of mankind's oldest sources of power generation, harnessing wind energy to produce electricity can be seen as a natural and logical fit today when 6 billion people have ever-increasing demands for electricity. Whether on a sailboat for transportation or powering windmills for production, humans have utilized wind for centuries. Today, wind generates electricity by converting the mechanical energy of rotating turbine blades into an electrical current.

Wind energy is produced in both large- and small-scale operations. Large-scale wind farms produce for the electrical grid and require energy storage devices in order to compensate for the variability in output associated with wind (i.e. wind does not occur at a constant rate). On a smaller scale, individual wind turbines are capable of providing electricity for off-the-grid locales and might similarly utilize power storage systems, often batteries.

- Wind power can be seen as an effective driver of economic development. Wind farms boost the local tax base, contributing to local education and infrastructure. Wind production has a direct benefit for local farmers and other landowners by providing steady income and allowing for other land uses up to the foot of the turbines. Jobs are created along the technology and production supply chain for wind turbines and related goods.
- The cost of generating wind power has come down dramatically in recent decades. In the 1980s, a kilowatt hour of electricity produced by wind cost as much as 30 cents. Today, the cost has fallen by 80% to as little as five cents per KWH (general range is 4-7 cents per KWH factoring in tax credits and other government incentives).

- Danish manufacturer, Vestas, has developed units with blades three times the traditional length while also producing related machinery that costs much less to maintain. These developments allow efficiency gains with respect to both greater power generation and economic cost.
- New technologies and economies of scale are also leading to lower operating costs. Wind turbines built today can stand as tall as a 40-story building and use blades hundreds of feet in length. Larger wind farms create economic savings by reducing construction and other per unit costs.

Market Trends, Challenges, and Opportunities

The following bullet points summarize current market and technology trends and challenges for wind energy. Technology challenges ranging from determining optimal turbine design and site selection to installation and effective energy storage all present innovation and economic opportunities in this fast-growing global market.

Global and U.S. Market Trends

- Globally, the market for and production of wind power has experienced rapid growth. Technological advances coupled with government investment incentives are leading to rapid installation of wind turbines. The U.S. and Europe are currently the major investors in wind energy, together accounting for nearly 90% of investments, each with a roughly equal share.
- Worldwide, installed capacity of wind power from 2004 to 2005 increased nearly 24%. Global wind generation capacity approached 60 GW for 2005, and the large percentage increase since 2004 represents the fastest growth rate among all sources of energy. For the first time since 1992, the U.S. was the leader in additions to wind power in 2005.
- Global added capacity helped total sales of wind power reach nearly \$18 billion in 2006. Some projections have this sales total reaching over \$60 billion by 2016.
- U.S. consumption of wind power grew five-fold from 1990 through 2005 to 149,490 billion BTUs. This level of current national consumption translates to about 0.4% of U.S. energy consumption—a share that is growing rapidly.
- In 2006, the U.S. continued its strong investment push in wind energy, installing over 2,400 MW of new wind power capacity amounting to an investment of about \$4 billion. Total installed U.S. capacity in wind power is over 11,600 MW, or enough to serve about 3 million households (one megawatt of wind power can provide electricity for 250-300 homes).
- Texas overtook California in 2006 as the top U.S. state with respect to installed wind energy—2,736 MW versus 2,361 MW in capacity. Iowa, Minnesota and Washington round out the top five.
- The American Wind Energy Association forecasts that by 2020, wind power will rise to meet 6% of U.S. electricity needs.

- European wind power plants are generating an even greater share of national power in some countries. BP plc finds that at the end of 2005, Denmark was producing 16% its electricity from wind; Spain generated 8%; and Germany generated 5%. European wind power is projected to meet approximately 12% of all continental electricity needs by 2020.
- Government policies directed at wind energy promote investment by reducing tax and other costs. In the U.S., there is both a production tax credit (PTC) for wind power equipment (1.9 cent-per-kilowatt-hour generated) and an accelerated tax depreciation schedule for turbines.

Technology Trends and Challenges

- Offshore wind installations (in a lake or sea) present an opportunity for regions in close proximity to water. Turbines located offshore may generate more power as they harness the greater wind speed recorded over water and they are less obtrusive due to their remote location. While these benefits are significant, offshore wind farms are more costly to install.
- New, larger wind turbines measuring up to 460 feet across are being designed for offshore operations. Turbines of this size are capable of generating up to 7 megawatts of electricity. One current obstacle in the installation of these offshore giants is finding the best way to anchor in deep water. Experts are working to apply offshore oil platform and other technologies in order to anchor wind platforms to the ocean floor. One company has adopted a tripod-type base design for added stability in open water.
- Energy storage systems related to wind power represent both a challenge and a potential economic opportunity. In order to maximize an intermittent resource like wind, storage is crucial to holding surplus energy. Existing storage technologies such as batteries, flywheel energy storage, and pumped storage hydroelectricity should be evaluated and utilized based on efficiency and cost.
- Small wind turbines (SWT) provide residential consumers an opportunity to produce electricity that is less expensive than solar power. The average capacity of SWT reached 1 KW by 2004 when the AWEA estimated a total installed capacity of 30 MW in the U.S. Market opportunities for SWT are growing as demand increases and manufacturers hope to expand the market to \$56 million by 2010.
- New designs for “micro” or small-scale urban wind turbines are underway. These turbines are installed on top of buildings in order to generate power in an urban or suburban setting. Many of these building-integrated devices are in testing and trial stages but others are fully operational and have generated considerable interest from business owners demanding diversified renewable sources to meet their energy needs.
- The market for wind power may be limited to some extent in a drive to supplant traditional power generation due to its intermittent nature. Attempting to achieve significant scale for wind power may prove difficult for a region or

its firms due to this potential ceiling. That said, many regions have abundant wind and can effectively replace other sources of electricity and perhaps store or “export” electricity generated by local wind plants.

Key Market Opportunities

The trends and challenges discussed here point to numerous viable market opportunities for private companies to pursue, namely:

- Offshore wind turbine design including specialized anchoring methods and offshore-specific technologies to reduce costs and boost efficiency.
- Wind energy consulting services including optimal site selection; regional economic development potential and assessments; environmental impacts on birds and noise reduction; advising on government policy and optimizing tax credits.
- Small wind turbine design for residential and other small scale applications and the ability to improve payback time through grid connections for electric surplus. As a subset, these include new opportunities in micro, building-integrated wind turbines installed on buildings in urban environments.
- Energy storage systems R&D to determine best fits for storing intermittent and surplus wind energy.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Acciona	Wind farms	-	Spain
DeWind	Large wind turbines	-	Germany
Ecotecnia	Large wind turbines	-	Spain
Eozen	Large wind turbines	-	Spain
FPL Energy	Wind power generation; wind farm ownership and operations	FL	USA
Fuhrlander	Large- and mid-sized wind turbines; wind farms; consulting	-	Germany
Gamesa Corporacion Tecnologica	Large wind turbines; wind farms	-	Spain
GE Energy	Large wind turbines incl. offshore	GA	USA
Goldwind Science & Technology	Large wind turbines	-	China
Harakosan	Large wind turbines incl. offshore	-	Netherlands
Mitsubishi Power Systems	Large wind turbines	-	Japan
Multibrid	Large offshore wind turbines	-	Germany
Nordex	Large wind turbines	-	Germany
REpower Systems	Large offshore wind turbines	-	Germany
Siemens	Large wind turbines incl. offshore	-	Germany
Suzlon Energy	Large wind turbines; full wind solutions (incl. wind farms)	-	India
Vestas	Large wind turbines incl. offshore; full wind solutions	-	Denmark

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Aerotecture International	Micro wind turbines for urban rooftops	IL	U.S.
AeroVironment	Micro wind turbines for urban rooftops	CA	U.S.
Austin Energy	Wind power generation	TX	U.S.
Bergey Windpower	Small wind turbines	OK	U.S.
Clipper Windpower	Large wind turbines	CA	U.S.
Energy Maintenance Service	Products and services for the wind industry	SD	U.S.
Enertech	Large- and mid-size wind turbines	KS	U.S.
Horizon Wind Energy	Wind power generation; wind farm ownership and operations	TX	U.S.
Southwest Windpower	Small single wind turbines for residential market	AZ	U.S.
Windflow Technology	Large wind turbines; wind farm project management	-	New Zealand
Windside Wind Turbines	Small wind turbines for harsh conditions	-	Finland

Solar Energy

Overview

Solar power is derived by converting energy from sunlight into heat or electricity. Solar energy technologies can be found in a range of applications from the micro level (e.g., mobile power generators) to the macro level (e.g., skyscrapers). Solar power can be divided into two principal categories: photovoltaic and solar thermal systems.

Photovoltaic (PV) cells convert sunlight directly into electricity. PV cells are semiconductor devices that almost always consist of silicon crystals doped with impurities, a combination that in the presence of sunlight generates free electrons and thus an electric current. "Single-crystal," "multi- or poly-crystal," and "thin-film" (amorphous silicon) are the three main types of PV cells. Crystalline cells account for the vast majority of the PV cell market. Thin-film solar cells do not absorb light as well as crystalline cells, but are far thinner, smaller and weigh less. A system of lenses or mirrors can be used to focus sunlight onto a small area of PV cells, increasing the amount of sunlight absorbed. Anti-reflective coatings on PV cells also increase absorption.

Solar thermal systems produce heat for or hot water for buildings or industrial processes. They can also generate electricity by operating heat engines, or by producing steam to spin electric turbines in solar thermal electric power plants. Solar thermal systems may be concentrating or non-concentrating. Concentrating solar power systems use various configurations of lenses or mirrors to convert sunlight into heat and then into electricity. The amount of power generated by a concentrating solar power plant depends on the amount of direct sunlight. These systems possess high solar-to-electric conversion efficiencies, and some are equipped with thermal storage capacity for use during low-sun periods. Non-concentrating systems do not use lenses or mirrors to focus sunlight and thus are less efficient thermodynamically.

Electricity produced by solar energy systems is either stored in batteries or is fed into the electricity grid using grid-connected PV systems called inverters.

Market Trends, Challenges, and Opportunities

Electricity generation from solar energy has increased rapidly, growing annually by an average of approximately 20% for the past decade. The solar photovoltaic industry is one of the world's fastest growing industries with a growth rate of ~40% in recent years (RenewableEnergyAccess.com) However, the majority of installed solar PV capacity is concentrated in very few countries: 85% of total installed capacity is in Germany, Japan and the United States. In Germany and Japan, generous government subsidies have stimulated demand spurring most of this development, while in the U.S. a few states—namely California—have passed major solar initiatives resulting in a broad range of installed projects. Because of its chip industry, California is the ideal setting for the development of new materials and technologies for solar cells.

Global and U.S. Market Trends

- In 2005, **worldwide solar energy consumption** was measured at 64 trillion Btu's, with more than 90% consumed by residential/private use. (DOE via Plunkett's). Cumulative solar energy production accounts for > 0.01% of total global energy demand (Solarbuzz 2007). Growth in demand for solar energy has been roughly 25% annually over the past 15 years (Solarbuzz 2007).
- The **global solar energy market** is currently valued at \$11B (Business 2.0 Magazine) and is projected to reach \$69.3 billion by 2015 (Clean Edge, Inc.). Since 2002, revenues in the solar market have grown at 47% on an annual compounded basis (Clean Edge, Inc., 2006).
- **Worldwide photovoltaics installations** in 2006, a \$10.6 billion market at the time, were estimated at 1,744 MW after a growth of 19% from 2005 (Marketbuzz, 2007). Grid-connected solar PV installed capacity rose from 2.0 GW in 2004 to 3.1 GW in 2005 (REN21); over 600 MW of this increase came from Germany (REN21). Electricity generated from photovoltaics is projected to grow to 589 TW by 2025 (Photovoltaics 2005-2010, March 2007, Global Information, Inc.).
- Projections on the **market size for PVs** range from \$16.4 billion by 2012 (PRNewswire), \$69.3 billion by 2016 (Clean Edge), or \$70 billion in 2010 (*Nature* **443**, 19-22 (7 September 2006)). Despite the differences in estimates, a 20–25% annual rise is widely expected.
- **Worldwide solar hot water capacity** in 2005 was 88GWth, up from 77GWth in 2004 (REN21).
- **Solar power accounted for about 0.2% of all energy consumed in the U.S. in 2005** (Plunketts)

- **U.S. solar energy installed capacity** was estimated at 520 MW in 2006 (ACORE). The solar energy capacity in the U.S. is projected to reach 164 GW annually by 2025 (ACORE). Annual growth of solar installed capacity in the U.S. is projected at 35% through 2015, after which it is projected at 26% until 2020 (U.S. Photovoltaic Industry Roadmap).
- The **U.S. share of the global photovoltaics market** in 2006 was 23% (Marketbuzz, 2007).
- **U.S. photovoltaics installed capacity** in 2006 was approximately 95 MW and averaging 17MW of new capacity each year (Interstate Renewable Energy Council). The fraction of grid-tied to non-grid tied PV systems continues to increase. Demand for photovoltaic solar power is expected to grow 40% annually by 2011 (RBC Financial Group); electric generation from solar PV modules could reach 1025 MW by 2015 (Freedonia) or 22GW by 2020 (Sandia). The market is projected to rise from \$7.7 billion in 2007 to \$11.5 billion in 2011 (RBC Financial Group).
- **Power generation accounts for about 85% of the total demand for PV modules** (Freedonia)
- **U.S. solar thermal installations** increased from \$34.3 million in 2004 to \$45.8 million in 2005 (U.S. EIA).
- **Leaders in capacity, growth:**
 - The top five countries in solar PV grid-connected installed capacity in 2005 were Germany, Japan, U.S., Spain, and Netherlands (REN21). The top five countries in solar hot water installed capacity in 2005 were China, Turkey, Japan, Germany, and Israel (REN21). Japan has been the global leader in PV production for the last several years (PV News; SRIC-BI). Germany was the leader in PV installations in 2005 with approximately 830 MW (Solarbuzz). China, India and other developing markets account for 17% of production and 10% of all PV installations in 2005 (SRI Consulting Business Intelligence).
 - In 2006, roughly half of the world's solar electricity was produced in Germany. Of the 20 largest photovoltaic plants, 15 are in Germany. This is explained in large part by a 2000 law requiring utilities to buy renewable energy at marked-up rates from the country's solar start-ups. (Washington Foreign Post Service, May 5, 2007)
 - Global sales for the PV industry are increasing roughly 30% annually with most growth occurring in Germany and Japan.
 - "Thanks to aggressive government subsidies, Germany and Japan are currently the global leaders in solar production, with Japan's Sharp Electronics the world's biggest manufacturer of solar cells." (Business 2.0 Magazine)

- The Western region of the U.S. dominates the total U.S. photovoltaics installations market with 71%; the South, 15%; the Northeast, 10.5%; and the Midwest 3.5% (Freedonia Group via Power Electronics).
- Florida, California, Arizona, New York, and Illinois accounted for 70% of solar thermal shipments in 2005 (U.S. EIA)
- In 2005, global investments in solar PV were \$9.9B, including \$1.6B in venture capital (REN 21 and Cleantech Venture Network). Global investments in solar thermal were \$4.2B.
- In 2005, U.S. investments in photovoltaics were \$1.8 billion (Photovoltaics 2005-2010, March 2007, Global Information, Inc.). Three of the largest technology IPOs of 2005 were for solar companies (Business 2.0 Magazine).

Technology Trends and Challenges

Major technology research goals in solar energy lie in three areas:

- **Making solar cells cheaper and more efficient.** Approaches include lowering costs related to the manufacturing of silicon crystals, increasing the conversion efficiency of silicon-based solar cells, and using systems of mirrors and lenses to focus sunlight directly onto cells. Also, new manufacturing techniques such as “printing” solar cells on plastic sheets instead of on silicon chips are helping to drive down costs.
- **Developing new solar cell architectural designs.** Approaches include restructuring—particularly nano-structuring—the surface to reduce reflection loss, using a pyramid-shaped structure so that incoming light hits the surface multiple times, and using tandem or stacked cells that absorb a wide spectrum of radiation.
- Almost 90% of photovoltaic cells contain silicon, yet there is a limited supply of it worldwide. Therefore, an important research goal is to develop **new materials** for absorbing light and carrying charge. Materials under investigation include gallium arsenide (GaAs), cadmium telluride (CdTe) and copper indium selenide (CuInSe₂).

Key Market Opportunities

- Alternative (non-silicon-based) thin-film photovoltaic technologies
- The market for on-grid applications (in which solar power is used to supplement electricity obtained from the utility network) is the fastest-growing segment of the solar power systems market.
- Consumer PV markets include installations for use in residential grid-tie systems, water pumping, RV & marine applications, and remote home systems.
- Industrial PV markets include the employment of PV technology in communications, oil and gas industries, traffic safety, railroad applications, lighting

systems, rural development, installations in commercial grid-tie systems, and defense-related applications for the government.

- Solar nanotech (tiny solar cells can be printed onto flexible, very thin light-retaining materials, bypassing the cost of silicon production). NanoMarket's projections indicate that printed PV could be a \$1B market by 2011.
- Hybrid power systems incorporating PVs such as generators, batteries, etc.
- Rooftop solar – once solar panels are smaller and lighter, they can be incorporated directly into roofing material

Economic Trends and Government Policies

- The Solar America Initiative (SAI) is determined to make photovoltaic energy cost-competitive by 2015. Thus far, the plan has committed to funding 13 solar projects at a total of approximately \$168 Million. The teams, called Technology Partnership Pathways (TPPs), are composed of 50 companies, 14 universities, 3 non-profits, and two DOE national labs. Involved industries will also contribute their own funds to the efforts as part of the agreement.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Alanod	Reflecting and absorption surfaces for solar thermal applications		Germany
Amonix	High-concentration PV systems	CA	U.S.
BP Solar	PV systems	MD	U.S.
Central Electronics	Solar PV systems	-	India
CentroSolar Group AG	PV systems	-	Germany
Conergy AG	Solar thermal systems, solar water pumps, PV systems	-	Germany
ET Solar	Polycrystalline PV cells and modules	-	China
Evergreen Solar	Multicrystalline silicon solar panels	MA	U.S.
First Solar	Cadmium telluride-based thin films	AZ	U.S.
GE Energy	PV modules	GA	U.S.
Green Energy Technology y	Solar wafers; thin-film solar cells	-	Taiwan
Heliodyne	Solar thermal products	CA	U.S.
Kyocera Solar	PV modules	AZ	U.S.
Mitsubishi	Polycrystalline PV modules	-	Japan
Motech	Crystalline PV cells	-	Taiwan
Nanjing CEEG PV Technology	Mono- and multi-crystalline PV cells	-	China
Photowatt	PV plates, cells and modules	-	France
PowerFilm	Flexible thin-film solar panels	IA	U.S.
Q Cells	Mono and Multicrystalline PV cells	-	Germany
Sanyo	Monocrystalline and thin-film PV cells	-	Japan
SCHOTT Solar	PV modules; solar thermal receivers	CA	U.S.
Sharp	Polycrystalline PV modules	-	Japan
Solargenix Energy	Solar thermal energy systems	NC	U.S.

Solarworld AG	Multicrystalline silicon wafers, PV cells and modules	-	Germany
Spire	Solar energy equipment	MA	U.S.
Stirling Energy Systems	Concentrating solar power	AZ	U.S.
Sun Energy Systems	Solar water heating systems	-	India
SunEdison	Solar energy system installations and operations	MD	U.S.
SunPower	Solar multicrystalline PV cells and panels	CA	U.S.
Suntech Power	PV modules	-	China
SunWize Solar	PV systems	NY	U.S.
United Solar Ovanic	Thin-film solar cells	MI	U.S.
Worldwater & Solar Technologies Corp.	Solar pumps; solar electrical systems	NJ	U.S.
Yingli Solar	PV cells and modules	-	China

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Advent Solar	Back contact solar cells/modules	NM	U.S.
Applied Materials	Wafer-based, flexible, and thin-film solar cells	CA	U.S.
BlueTec	Absorber bands for solar systems	-	Germany
Energy Innovations	High-concentration PV systems	CA	U.S.
Energy Photovoltaics	Thin-film solar cells	NJ	U.S.
Greenray	Integration systems for PV modules and inverters	MA	U.S.
Heliovolt	Thin-film CIGS (copper indium gallium selenide)	TX	U.S.
Konarka Technologies	Flexible PV material	MA	U.S.
Miasolé	Thin-film solar cells	CA	U.S.
Nanosolar	Printed thin-film solar cells	CA	U.S.
Nanosys	Flexible solar cells	CA	U.S.
Pacific SolarTech	Concentrator crystalline silicon-based PV modules	CA	U.S.
REC Group	Solar-grade silicon production; crystalline wafers, PV cells, modules	-	Norway
SkyFuel	CSP technologies	NY	U.S.
Solaicx	Single crystal silicon wafers	CA	U.S.
Solaria	Solar cells requiring less silicon	CA	U.S.
SolFocus	Concentrator germanium-based PV modules	CA	U.S.
Soliant	Solar concentrators	CA	U.S.
Spectrolab	New materials for solar cells	CA	U.S.

Fuel Cells (Micro)

Overview

Fuel cells are electrochemical devices that use hydrogen and oxygen to produce electricity with the only by-products of the reaction being water and heat. By emitting only these “clean” by-products, fuel cells offer a promising alternative in which to convert energy that does not pollute the environment. Fuel cells have tremendous potential to replace a variety of energy conversion devices including gas turbines at power plants, gas engines in automobiles, and batteries in portable electronic devices like computer laptops. While these cells represent a proven

technology and would ideally begin to replace traditional devices now, several obstacles remain that make them difficult to fully integrate into these energy-intensive applications.

Fuel cell technology, in basic terms, positions hydrogen and oxygen separated by a catalyst. Within the cell, a chemical reaction inside the catalyst generates electricity. As long as hydrogen is supplied as the input, the fuel cell will continue to generate power. Because the conversion of the fuel to energy occurs via an electrochemical process, not by combustion, the process is clean, quite, and highly efficient compared with traditional combustion of fossil fuels. In fact, fuel cells are two to three times more efficient than burning fossil fuels.

Different fuel cells incorporate different chemistry and are categorized by their operating temperature and the type of electrolyte used. The major types of fuel cells include: polymer exchange membrane fuel cell (PEMFC), solid oxide fuel cell (SOFC), alkaline fuel cell (AFC), molten-carbonate (MCFC), phosphoric acid (PAFC), and direct methanol (DMFC). The PEMFC is the most promising candidate for use in automotive transportation. This type of fuel cell operates at a relatively low temperature (140-176 degrees Fahrenheit), which means it does not take long to warm up. The SOFCs are best suited for powering large stationary generators for towns or large factories. Direct methanol fuel cells are proving to be optimal for micro fuel cell applications.

Micro fuel cells (MFC), which generally encompass systems developed for small portable electronic devices such as cellular phones, PDAs, digital cameras and camcorders, and notebook PC represent mass market commercial opportunities for the fuel cell industry. In addition, other portable and small fuel cells might be included in a related market focusing on applications like small off-road transportation including golf carts and forklifts, motor scooters and motorized bicycles, wheel chairs, etc. Portable power systems for emergency first responders, recreational, or defense-related field use also represent viable market opportunities for reliable portable power access in remote areas.

While there is no strict definition of a micro fuel cell, the term generally describes small fuel cells that produce fewer than 50 W of power. Fuel cells, unlike batteries, do not require recharging. A fuel cell can produce electricity continuously as long as it has a constant supply of fuel. MFCs have the potential to replace lithium ion batteries as an energy source, providing up to *ten times* the energy of existing battery technology.

The micro fuel cell market has vast commercial potential given the role these systems could play in powering the multi-billion dollar global industry that is portable electronic devices. If cost, weight, and other technology hurdles can be overcome, these conversion systems could meet the power needs for millions of devices. Numerous external factors can drive and shape the market for micro fuel cells. The following summarize these potential market drivers.

The overall global demand for and extraordinary use of portable electronic devices is a primary driver for better power sources. The power demanded by these devices and their users requires an upgrade from existing battery technology

that must continually recharge. Consumers demand longer power duration in order to run increasingly intelligent and highly functional devices with more memory, color screens, and serving multiple purposes (e.g. phones that are also cameras and PDAs). Devices tied to a network are often never turned off. In addition, to be truly mobile, these devices must no longer rely on a power cord. MFCs have the potential to replace lithium ion batteries as an energy source, providing up to *ten times* the energy of existing battery technology. The low emissions and greater efficiency to be gained with fuel cells are preferable to recharging batteries using existing electrical power supplies.

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends: All Fuel Cells

- According to Clean Edge research, the market for fuel cells and distributed hydrogen is projected to grow from \$1.4B (mostly in research contracts and test units) to nearly \$16B over the coming decade.
- The Worldwide Fuel Cell Industry Survey, a joint information gathering effort by leading national fuel cell industry associations in the U.S., Canada, Europe and Japan, has been conducted annually for the past four years. According to the 2006 survey (reporting 2005 data), global industry sales increased by 7% from 2004 to 2005 to \$353M.
- In the Fuel Cell Survey, the U.S. accounted for \$168M (48%) of global sales; Japan had \$48M (14%); Germany reported \$40M (12%). Korea and Canada rounded out the top five countries with respect to fuel cell sales.
 - The Worldwide Industry Survey reports R&D expenditures also experienced a substantial increase. In 2005, R&D expenditures rose by 11% to \$796M.
 - Global R&D expenditures break down as follows: the U.S. spent \$460M (58% of world expenditures); Canada spent \$156M (20%); Germany spent \$60M (8%); Japan spent \$59M (7%); and the UK spent \$13M (2%).
 - Survey responses revealed PEMFCs as the key technology focus of fuel cell companies. The focus of market activities were reported to be in small stationary markets, followed closely by the “portable” market which includes micro fuel cell systems.
 - The U.S. and Canada account for more than 50% of company locations for fuel cell manufacturing and R&D activities according to responses from the Worldwide Survey. Japan and Germany also have significant shares of fuel cell production and research sites.
- The U.S. Department of Energy is actively engaged in its Hydrogen, Fuel Cells & Infrastructure Technologies R&D initiative seeking to reduce costs associated with fuel cells, the size of cells, and improve the performance and durability of fuel cell systems. The DOE program focuses on fuel cell R&D in

three main areas: transportation systems, distributed/stationary systems, and fuel cell subsystems and components.

- Current large-scale R&D in PEM fuel cell technology is focused on automotive power solutions. At present, there are major obstacles in terms of cost (components of PEMFCs are very expensive); durability with respect to operating temperatures and proper hydration; and critical infrastructure issues with respect to generating, transporting, storing, and providing hydrogen as fuel.
- Fuel cell developers are currently working on residential applications (3-10 kW). Residential fuel cells can provide either backup power to an existing electrical system or full, primary power for the home. Fuel "reformer" technologies allow residential fuel cells to extract hydrogen from conventional sources.

Global and U.S. Market Trends: Micro Fuel Cells

- According to a market study recently released by Innovative Research and Products (iRAP), the market for micro fuel cells was expected to hit \$12 million in 2006 and forecast to reach \$112 million by 2011. The market predictions by iRAP work out to an average annual growth rate that exceeds 50%.
- The majority of the 2006 market for MFCs was accounted for in North America (61%) according to iRAP, followed by Europe (19%) and Japan (16%), respectively. Market expectations, however, put North America's future share at a somewhat lower position while the Japanese market share will increase over Europe's.
- The iRAP report cites the high-energy requirements of handheld electronics as a primary driver of demand for fuel cell power conversion technologies. Leading products expected to incorporate micro fuel cells include PDAs which are expected to see the largest growth; camcorders, chargers, and other consumer electronics; and mobile phones.
- Micro fuel cell R&D is targeting direct methanol fuel cell technology as this type of cell is expected to account for the largest share of the micro market. Hydrogen-based cells and others based on proprietary fuels follow methanol fuel cells in iRAP's demand projections.
- The report identifies over 60 global companies and institutions that are actively working on MFC systems. With respect to company activity in micro fuel cells, it is important to note that although there are numerous "emerging" companies at work on these technologies, most continue to be in the research, testing, and prototype development stages. The "leading" companies in this market, however, have generally made their products commercially available or are very close to market. Industry analysts see MFCs becoming more mainstream in the coming years, perhaps by 2010; and as a result, analysts expect a major shakeout in the industry that will reduce the number of key players.

- As in a number of renewable energy technology markets, the U.S. military is driving the market for portable fuel cell power. In 2003, the department of defense spent approximately \$130M on fuel cell development. Fuel cells are characterized by a number of features of interest in military applications, namely: low heat signatures and noise levels, less weight than traditional batteries, fuel efficiency, potential for superior vehicle acceleration, and key onboard electric power generation supporting numerous applications (communications, surveillance, etc.).
- One significant legal hurdle with respect to micro fuel cell safety is the current inability to bring methanol fuel cartridges aboard commercial aircraft. In 2005, the International Civil Aviation Organization's Dangerous Goods Panel voted to clear these cartridges beginning in 2007. In August 2006, however, TSA banned liquids and gels and in doing so banned the carry-on permission for these fuel cartridges. This remains a major hurdle for viable market opportunities in portable fuel cells. The fuel cell industry is actively lobbying for carry-on permission.

Technology Trends and Challenges

In general, fuel cells are a proven technology, converting energy for an array of applications. Achieving widespread usage and commercial scale, however, is proving to be a challenge on a number of fronts. The following summarize current obstacles that must be overcome with respect to micro fuel cells.

- Micro fuel cells have greater energy density than batteries and allow for a significant power upgrade for portable electronic devices. Developing fuel cells for these small electronics, however, has posed several challenges for engineers including:
 - High energy density requires that the "rest of the system" be miniaturized. This challenge is being addressed by incorporation of new and emerging MEMS technology.
 - Electronic products themselves must have a high-efficiency design in order to support the fuel cell system.
 - Safety is a major concern with a micro fuel cell system, specifically with regard to fuel storage and handling.
 - Generally, the major challenges facing researchers are achieving a viable cost-to-power ratio and a weight-to-power ratio (energy density).

Key Market Opportunities

- Portable Personal Electronics:
 - Personal Digital Assistants (PDA)
 - Digital Cameras and Camcorders
 - Chargers/Power Packs

- Other consumer electronics
- Mobile Phones
- Notebook PCs
- Portable Power Systems:
 - Defense-related field power systems including generators
 - Personal Recreational Power Systems for Camping and other uses
 - Emergency first responders, powering radios, portable satellite phones and other devices at an emergency scene
- Small Off-road Transportation:
 - Wheelchairs
 - Golf Carts and Motor Scooters
 - Forklifts and other industrial applications
- Other applications:
 - Power tools
 - Buoys/Beacons/GPS
 - Chemical/Biological point sensors
 - Medical devices (i.e. defibrillators)
 - Remote weather sensors
 - Oil and gas pipeline instrumentation
 - Rail track monitoring
 - Tower/antenna sites

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Angstrom Power	"Micro Hydrogen" fuel cells for portable applications; prototype stage	BC	Canada
Jadoo Power Systems	Portable fuel cells, commercially available	CA	U.S.
Millennium Cell	Micro fuel cells using hydrogen technology for portable applications	NJ	U.S.
MTI MicroFuel Cells	Developing micro DMFCs; power packs for portable electronics	NY	U.S.
Samsung	DMFC (micro) for portable electronics	-	S. Korea
UltraCell	DMFC (micro) for portable devices; utilizing "reformed" methanol system	CA	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Motorola	Developing miniature DMFC—internal and external research	IL	U.S.
Tekion	Micro fuel cells that use purified and modified formic acid for power packs	IL	Canada/ U.S.
Medis Technologies	Direct liquid fuel cells (DLFC) for personal portable electronic devices (power packs)	NY	U.S.
PolyFuel	Developing new hydrocarbon membranes for portable micro fuel cell applications	CA	U.S.
Toshiba	DMFC (micro) for portable electronics	CA	Japan/US
Adaptive Materials	Portable SOFC	MI	U.S.
Ball Aerospace & Technologies	Portable PEMFC systems; DMFC system	CO	U.S.
CMR Fuel Cells	Fuel cell stacks for portable DMFC systems	-	UK
Direct Methanol Fuel Cell Corp.	Methanol fuel cartridges; Licensing rights to DMFC intellectual property	CA	U.S.
Antig Technology	DMFC (micro) for portable electronics	-	Taiwan
eVionyx	Micro fuel cells utilizing metals as fuel	NY	U.S.
Manhattan Scientifics	Micro fuel cells (methanol-based) for portable applications	NY	U.S.
Mesoscopic Devices (Protonex Technology Corp.)	DMFC and SOFC technology for portable generators and electronics	CO	U.S.
Neah Power Systems	Micro fuel cells with a silicon-based design for portable applications; testing and prototype stages	WA	U.S.
Protonex Technology	Micro fuel cells for portable military applications; prototype stage	MA	U.S.
QinetiQ	Micro fuel cells for portable applications	-	UK
SFC Smart Fuel Cell	Micro fuel cells for portable applications	-	Germany

KEY SOURCES

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www.sandia.gov

WATER QUALITY AND WATER RESOURCES

INTRODUCTION

Business activity that involves water as a resource or its supply and consumption as a service or product consists of the following four sectors:

5. Water utilities – entities that collect water from surface or ground sources, purify it, and distribute it to water consumers and their residential, commercial, industrial, and agricultural customers;
6. Wastewater treatment and water reuse/recycling facilities;
7. Water distribution and purification equipment and chemicals companies; and
8. Water systems engineering and consulting companies.

The global water services and equipment industry segment is estimated to be a \$40 billion business growing annually at 6%. Water treatment has been a mature business in the U.S. and other developed countries, but is now experiencing a revival due to new regulations, prompting large water users to turn to water treatment companies for complete solutions and contracted services. The global market has seen the emergence of consolidated water service companies, such as France's Veolia Environment, which operates in all four sectors of the water industry.

The overall U.S. water industry (including sales/distribution of water) achieved total revenues of approximately \$86 billion in 2000, and business volume has continued to grow.

MARKET DRIVERS

INCREASING GLOBAL DEMAND FOR FRESHWATER

The World Health Organization estimates that over 50% of the world's population lacks access to clean water and sanitation. Water-borne diseases account for nearly 80% of all infections affecting people in the developing world. Freshwater is also essential for agriculture, transportation, electricity generation, wildlife, and recreation.

The ultimate sources of freshwater are snow and rain, and the natural climatic cycle ensures that much of the freshwater consumed is recycled through the evaporation-precipitation cycle. As long as the rate of withdrawal is balanced by the rate of replenishment, freshwater resources remain in balance. However, the doubling of the world's population since 1960 from 3 billion to 6 billion has strained these resources. In 2000, global water withdrawals were roughly 1,000 cubic miles, representing 30% of the world's total accessible freshwater resources. In 2020, withdrawals are expected to represent 70% of the total accessible resources.

COMPETING DEMANDS FOR FRESHWATER

The daily withdrawal of freshwater in the U.S. is on the order of 346 billion gallons.

- The farm sector, including the irrigation, aquaculture, and livestock operations, accounts for 40% of the total water withdrawn. At 34%, irrigation continues to be the largest one-way or open loop user of freshwater.
- Thermoelectric power stations account for 39% of the total freshwater withdrawn. But a considerable amount of the water used by this sector is returned to its source. Freshwater accounts for only 70% of the total water used by the thermal power industry, and saltwater sources provide the remainder.
- Public water supply works account for 11% of freshwater consumption while independent domestic users of surface water and ground water account for 1%. Mining and industrial users of water, at 1% and 5% respectively, are relatively minor users of water. However, their impact on the quality of water is not insignificant.

SOURCE DEPLETION AND ACCESSIBILITY TO WATER CONCERNS

The depletion of groundwater resources is a serious problem. The Central Plains' Ogallala aquifer, which covers an area of 174,000 square miles across eight states and sustains 30% of U.S. agricultural output, has been under strain due to severe overuse for the last few decades with withdrawals exceeding the rate of natural recharge. To complicate matters, disagreements over the sharing of water resources have cropped up in a number of states.

MANAGEMENT OF WATER RESOURCES

The Twenty-first Century Water Commission Bill that is currently in Congress seeks to establish a national commission to devise a long term strategy for the management of water resources. The Water Science and Technology Board of the National Research Council's report *Envisioning the Agenda for Water Resources Research in the Twenty-first Century* (NRC 2001) identifies 43 research priority areas spanning the biological, physical, and social sciences, and calls for setting up a national level water research entity.

INITIAL INTEREST IN SUSTAINABLE WATER TREATMENT, REUSE, AND RECOVERY TECHNOLOGIES

Integrated approaches to wastewater treatment will likely become a significant growth area. An inventory of water resources conducted in accordance with the Clean Water Act in 2000 revealed that 39% of river and stream miles, 45% of lake surface area, and 78% of the Great Lakes shoreline miles do not meet ambient water quality standards.

In developing countries, as much as 85% of all wastewater is discharged untreated into surface water bodies. Many of the modern methods of water treatment, such as reverse osmosis, desalination, and performance chemicals-based purification,

are either too energy-intensive or too dependent on an efficient wastewater treatment infrastructure to be administered effectively. Thus, a contemporary global water resources agenda would include the following elements:

- Address issues related to water quantity and quality in the developed world, and facilitate a transfer of process and policy development know-how to developing countries;
- Develop new technologies for improving water quality that are energy efficient or powered by alternative sources of energy such as solar and wind power; and
- Develop more environmentally friendly industrial processes with a reduced “water footprint”, such as zero discharge processes and water recycling.

While wastewater treatment plants in the U.S. process over 40 billion gallons of used water, only 1 billion of treated discharge is reclaimed to meet non-potable needs. Over 50% of the sludge generated from wastewater treatment is now used beneficially on agriculture sites. There is considerable scope to use the rest, which includes 17% that is incinerated and 19% that is dumped into landfills.

AGING DRINKING WATER AND WASTE WATER INFRASTRUCTURE

The American Society of Civil Engineers, quoting reports by the EPA, estimates that rebuilding the national drinking water and wastewater infrastructure will require an annual investment of \$11 billion and \$19 billion respectively over the next 20 years.

SECURITY OF PUBLIC WATER SYSTEMS

Following the terrorist attacks of 2001, the security of the nation’s water resources became a major concern. The EPA and the National Homeland Security Research Center have developed an action plan for research focused on studying the following elements:

- Water security threats with the greatest likelihood and their potential consequences;
- Response and recovery capacity, risk reduction, and consequence mitigation; and
- Prioritization of new technologies based on cost, usefulness, and maintenance requirements.

SIGNIFICANT CORPORATE EXPANSION AND M&A ACTIVITY

The water treatment business has attracted the attention of large corporations with significant global reach and market penetration whose reach now includes segments previously considered to be “public utilities.” Examples include:

- General Electric, which has been expanding its water treatment portfolio and acquired several companies since it formed its water business group in 2001;

- Large private sector companies such as Veolia and Suez, both of France, which entered the U.S. water utilities market and provide water management services to several medium sized utilities on a contractual basis;
- Siemens, which bought USFilter, originally an independent company and the largest player in the U.S. water treatment market, from Veolia in 2004; and
- Dow Chemicals, which announced the formation of Dow Water Solutions, a water treatment business group.

ECONOMIC DEVELOPMENT DRIVERS

LOCAL DEMAND FOR WATER TESTING AND RELATED SERVICES

Some regions may demand water testing, treatment, and related services for local bodies of water. Communities engaged in water restoration projects such as Chesapeake Bay and Onondaga Lake are examples of regions that are likely to consume technologies related to water purification, sensing, and monitoring, as well as consulting services targeting the sustainable management of water-related resources.

LOCAL DEMAND FOR SUPERSTERILE WATER OR WATER TREATMENT TECHNOLOGIES

Certain industries such as biopharma, computer chips, and surgical devices require exceptionally clean water as part of their manufacturing or testing processes. Siting new or growing firms operating in the water quality market space within reach of industries that demand treated water or water treatment technologies on a large-scale, continual basis could be advantageous from both an economic and logistical perspective.

PROXIMITY TO STRONG PROGRAMS IN ELECTRICAL ENGINEERING, ENVIRONMENTAL ENGINEERING, MATERIALS SCIENCE

Proximity of new or growing firms to academic centers of excellence or strong programs in traditional, university-centered research in particular fields—namely environmental research, hydrology or limnology, computational modeling, electrical engineering, and materials science engineering—could yield partnerships or other beneficial outcomes such as knowledge transfer or IP licensing. In addition, development of a critical mass of both public- and private-sector organizations in any technology area is likely to attract support from policy and economic development officials as well as significant capital investment. Key federal funding agencies for water treatment and related environmental projects include the EPA, National Oceanic & Atmospheric Administration (NOAA), the Department of Homeland Security, and the NIH (e.g., National Institute for Allergy & Infectious Diseases; Centers for Disease Control). Many states also offer their own municipal water and sewer funding programs.

While appropriate manufacturing infrastructure, distribution networks, and skilled labor are each critical economic development drivers, one non-obvious driver is access to locations where water testing or sensing technologies can be evaluated on a large, if not community-wide, scale. Deployment of innovative water purification technologies or remote sensing or monitoring instruments into public water supplies is a contentious issue that requires permission from municipal water district authorities.

SPECIFIC WATER QUALITY AND WATER RESOURCES TECHNOLOGIES

- Water Filtration, Purification, Desalination, and Other Treatment Technologies
- Water Sensors and Analysis/Monitoring Instrumentation (both internal systems and environmental and watershed applications)
- Water Engineering and Watershed/Resource Management Consulting

Water Filtration, Purification, Desalination, and Other Treatment Technologies

Overview

The water-treatment infrastructure in developing areas of the world relies on basic processes such as coagulation and flocculation, sedimentation, sand and gravel filtration, and chlorine disinfection. In the oil-rich Middle East, desalination is commonly used because cheap power can be used to run large-scale commercial water supply projects. However, in developed countries, water treatment methods encompass two tiers. Primary treatment removes macroscopic-level, suspended, solid impurities and requires physical separation methods including coarse filters, sedimentation tanks, centrifuges, and screens. Secondary treatment purifies the water using chemical methods and non-chemical membrane filtration-based processes, both of which generally rely on advanced technologies.

Secondary treatment processes based on chemical methods can be classified into eight major groups by function:

- Corrosion inhibitors – protect metal piping and equipment in prolonged contact with water
- Oxidizers and biocides – used to destroy biological organisms
- Coagulants and flocculants – aggregation of suspended solids into sludge that can be physically separated from the process stream

- Neutralizers and softeners – balancing the acidity/alkalinity of input water
- Filter media, adsorbents, activated carbon, and ion exchange resins – removal of calcium, magnesium, and iron, or substances that affect taste and odor
- Defoamers – suppression of foam caused by particulates, humus, and coatings, to improve flow efficiency
- Chelating agents – removal of heavy metal ions to prevent scale formation in boilers and pipelines
- Fluoridation chemicals – added in residential water supplies to prevent tooth decay

Non-chemical membrane separation processes include:

- Microfiltration – separation of complex organic molecules
- Ultrafiltration – separation of complex organic molecules using high pressure
- Nanofiltration – separation of low molecular weight organic solutes and small inorganic ions
- Reverse osmosis – use of extremely fine membranes for water purification and desalination of seawater

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- The U.S. market for water treatment chemicals is worth \$4 billion. Markets in Europe and Japan are each roughly \$800 million. Annual market growth in developed economies is in the range of 4-5%, but the market is growing faster in China and Latin America.
- The industrial segment (consisting of the manufacturing, process, mining, and metals sectors) is the largest market segment for the water treatment industry and uses the complete range of water treatment technologies. It accounts for 55% of the market for water treatment chemicals. Of the remaining segments, water utilities and wastewater is the largest. The thermoelectric segment accounts for less than 5% of the water treatment chemicals market. The agricultural segment does not constitute a significant share.
- Within the manufacturing realm, the chemicals, petroleum, and paper and pulp industries account for the largest share of the water treatment market. The food and beverages industry is increasingly turning to non-chemical or membrane-based treatment systems such as reverse osmosis and ultraviolet purification.
- Specialty chemicals are more widely used in the U.S. than in Europe where commodity chemicals still command a large share of the treatment chemicals

business. The U.S. also leads in the use of chemicals for wastewater and sludge processing.

- The U.S. market for water treatment membranes is estimated at \$4 billion and growing at 7-8% a year, accounting for about 50% of the global market. The global market for reverse osmosis equipment is estimated to be over \$1 billion a year and growing at over 10% annually. The U.S. and the Middle East markets each account for about 30% of global equipment revenues.
- The cost of desalinated water has declined steeply over the last 40 years from \$10/cubic meter to \$0.47/cubic meter today. The trend is expected to continue. As a result, the consumer market for membrane systems—formerly limited due to high costs—may experience renewed growth.

Technology Trends and Challenges

- Water treatment chemicals are a significant point-source of effluents. The industry estimates that the hydrocarbons used as carriers for water treatment chemicals are responsible for over 100 million pounds of effluent discharge annually. Reducing and eliminating this source of effluents represents a steep challenge for the chemical industry. The industry is working on applying Green Chemistry principles to develop more environmentally friendly treatment chemicals.
- Over the last 20 years, water treatment chemical manufacturers have begun to work on reducing toxicity and improving biodegradability and are no longer restricting their efforts to improve performance. Industrial process water management traditionally concerned with water softening and deionization has now expanded in scope to include the control of corrosion, microbial fouling, and residual water management.
- Disinfection of water has become an area of concern in water treatment research. Chlorine-based compounds have been used to disinfect water for many decades, helped greatly in the effort to deliver safe and potable water, and reduced significantly the incidence of waterborne diseases. However, because it is highly reactive, chlorine generates numerous harmful byproducts through reactions with dissolved organic matter. Several green alternatives to chlorine-based disinfection systems are under investigation and this remains one of the most important areas of research.
- The filtration of arsenic in water supplies is a worldwide challenge. In countries such as Bangladesh, arsenic contamination has become an extreme public health hazard, where the arsenic content of aquifer water exceeds 100 micrograms of arsenic a liter, well in excess of the internationally accepted standard of 10 micrograms a liter. In the U.S., many water utilities are finding it difficult to meet the new EPA arsenic content standard, which was recently lowered from 50 micrograms/liter to 10 micrograms/liter.
- Disposal of the highly saline process waste from reverse osmosis systems is a complex problem. The impact of large-scale shifts in water supply from surface freshwater bodies to desalinated water is not fully understood.

Key Market Opportunities

- The decreased availability of freshwater in states such as California and Florida has led municipalities to explore the potential of brackish water, degraded water sources containing high concentrations of dissolved organic carbon compounds, and even seawater. As a result, a number of new high-efficiency filtration technologies are under evaluation.
- The largest markets for these systems in the U.S. lie in Florida, California, and lately Texas. International markets include Spain, the Middle East, and China. However, according to Dow Chemicals, industrial water treatment contributes to a very large share of the revenues of the membrane filtration business, and over 60% of the membranes in use treat water used for boilers and industrial processes, indicating a large untapped market in the public water utilities sector.
- About a third of the membrane-based water treatment facilities in the U.S. are based in Florida, where they are used to treat a variety of source waters including brackish water, groundwater, turbid surface water, and seawater. In some regions of Florida membrane-based systems are used to filter iron and sulfur from source water-drawn wells, as well as organic matter such as humus from surface water. California's Orange County has built a wastewater treatment plant that purifies water that is in turn used to recharge the region's sea-level aquifer. The treatment uses a filtration, reverse osmosis, and UV light to treat wastewater.
- Global desalination capacity is likely to grow 60% through 2010 from the current level of 40 million cubic meters per day. This will translate into capital investments of \$25 billion by the end of 2010. Membrane-based systems will continue to gain market share over the conventional thermal distillation-based systems. The Middle East desalination market will continue to account for over 40% of the global market, although new markets in the U.S., China, and India are likely to grow faster than the Middle East market.
- Household chemicals and drugs are a new class of pollutants that have the potential to seriously affect water quality. The U.S. Geological Survey, in a long term study of surface and groundwater bodies, identified several classes of household chemicals including common pharmaceuticals, hormones, fragrances, plasticizers, flame retardants, and detergents. The USGS reports that the 160 household chemical discharges it monitors form only a small fraction of the all chemicals that are routinely discarded by households in the U.S. Currently there are no effluent standards set by the EPA for these chemicals. Developing a comprehensive purification and treatment technology for water utilities may become a significant market opportunity for the water treatment industry.

Leading and Emerging Companies

Company	Technology/Application	State	Country
Albermarle	Chemicals	VA	U.S.
Ashland Water Technologies	Chemicals	KY	U.S.
Ciba Specialty Chemicals, Global Operations	Chemicals, Equipment	-	Switzerland
Ciba Specialty Chemicals, US Operations	Chemicals, Equipment	VA	US
Dow Chemicals	Chemicals	MI	U.S.
GE Water	Chemicals, Membranes, Instrumentation	PA	U.S.
Millipore	Membranes, Equipment	MA	U.S.
Nalco Chemicals	Chemicals	IL	U.S.
Nitto Denko	Membranes	-	Japan
Rohm and Haas	Chemicals	PA	U.S.
Siemens – US Filter Division	Chemicals, Membranes, Instrumentation	PA	U.S.
Suez	Treatment	-	France
Veolia Water	Equipment, Purification Systems	-	France

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
Aqua Sciences	Water Source Development	FL	U.S.
Argonide Corp.	Filtration Systems	FL	U.S.
Blue Water Technologies, Inc.	Primary Treatment Methods, Filters	ID	U.S.
eMembrane	Membranes/Filters	RI	U.S.
EnviroTower	Water Conditioning		Canada
HaloSource	Purification, Disinfectants	WA	U.S.
MIOX Corp.	Purification	NM	U.S.
NanoH2O	Membranes/Filters	CA	U.S.
Novazone	Ozone Purification, Disinfectants	CA	U.S.
Pionetics	Purification	CA	U.S.
Synergina, Inc.	Decontamination Technologies	NY	U.S.
WaterHealth International	Purification/Disinfection Systems	CA	U.S.
YSI, Inc.	Purification/monitoring	OH	U.S.

Water Sensors and Analysis/Monitoring Instrumentation

Overview

Water quality analysis represents the largest market for manufacturers of environmental instrumentation in the U.S. Wastewater discharges from chemical and manufacturing plants, although treated, must be monitored to ensure that upstream process deviations do not result in the release of contaminants into the environment. Any deterioration, or even benign variations, in the quality of water supplies can have serious consequences for public health. As a result, water quality is monitored at many stages of the water extraction, supply, and discharge cycle. Following the heightened threat of terrorist attacks since 2001, the safety and security of public water supplies in the U.S. has become a matter of concern for the public as well as the government. This has led some public water supply utilities in the U.S. to evaluate and install new continuous water quality monitoring systems.

Water quality is monitored at many stages of the water extraction, use, and discharge cycle including the following.

- **Source water** – including surface, groundwater, and seepage from landfills, industrial sites, and lagoons
- **Potable water** – in-line measurement or intermittent sampling of chlorine residues, total organic carbon, and disinfectant residues
- **Process water** – varies according to the needs of the user and the process; analysis of pH, corrosive substances, and biological matter
- **Wastewater** – comprehensive analysis including chemical characteristics and composition, microorganism content, dissolved solids, and metals, as well as any process residues such as catalysts, and chemical intermediates
- **Biomonitoring** – monitoring the health and presence of native species in water sinks that receive treated discharges

Some of the indicators used to measure water quality include:

- Biological oxygen demand (BOD);
- Chemical oxygen demand (COD);
- Total organic carbon (TOC);
- pH and oxidation reduction potential; and
- Concentration of target substances such as arsenic, and mercury, chlorine compounds, disinfectant residues; presence of microorganisms such as *E. coli*.

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- The global water quality and wastewater instrumentation market accounts for 44% of the total environmental instrumentation market and was estimated at greater than \$1.5 billion in 2000.
- Problems with water quality have led to lost business and heightened the problem of safe water supplies. In 2004, Chiron Corporation, a vaccine manufacturer, lost over \$300 million of business after it suspended production of flu vaccine due to microbial contamination at its manufacturing plant. Product recalls due to contaminated water have led to frequent recalls in the bottled beverages market.
- Concerns over water quality continue to drive steep growth in the sales of bottled water in the U.S. and globally. In the U.S., annual market growth has hovered around 10% between 2001 and 2006. Annual per capita consumption of bottled water has grown by about a gallon every year since 2001 and has doubled to exceed 28 gallons in 2006. The global bottled water market has seen a cumulative annual growth rate of nearly 9% from 2000 to 2005. This growth has been price inelastic despite bottled water being costlier than tap water by a few orders of magnitude. The use of water quality devices has also risen. According to the Water Quality Association, in 2001 41% of homes in the U.S. used some form of point-of-use or home water treatment device.
- A 2002 EPA report concluded that the country's public water supply infrastructure is in need of substantial upgrading. A long term upgrading program over the next 20 years is estimated to require an annual outlay of \$4-6 billion. Deterioration in the water supply infrastructure leads to problems such as main breaks, back-siphonage, seepage in municipal water storage tanks, and seepage within distribution pipes.
- Although the number of reported mass outbreaks of waterborne diseases has declined since 1982, the magnitude and severity of outbreaks continues to be matter of concern. The Centers for Disease Control and the EPA have recently concluded a study to assess the magnitude of endemic waterborne diseases among consumers of municipal water supplies.
- The age profile of the U.S. population and disease patterns have changed significantly over the last 10 years. Census data from 1990 to 2000 revealed a 26% increase in the number of people over 74 years of age and a 38% increase in the numbers of those over 85. The number of survivors of AIDS grew five-fold between 1985 and 2003. The number of cancer survivors tripled between 1971 and 2001 to 3.5% of the population. The number of organ transplant patients doubled from the year 1988 exceeding 22,500 in 2004. As a result, there is a growing population of people with weak or compromised immune systems who are susceptible to even mild levels of contaminants that might have little or no effect on the general population.

Technology Trends and Challenges

- Multi-parameter instrumentation that is currently available in the market can measure water quality characteristics such as BOD, COD, TOC, and pH on an on-off basis. But baseline data for calibrating alarm triggers does not exist. Collecting these data may require longitudinal studies that take into account seasonal fluctuations and the impact of large scale weather events. Without these baseline data, sensor networks cannot be integrated into a closed loop water quality control system.
- The development of online microbial detection technology is an evolving process, and most methods are not suitable for differentiating between microbes. Concentrating microbial samples for analysis is a steep challenge for designers of microbial field testing kits. Current online testing methods are not effective at detecting microbes that occur in public water supplies.
- Microchip and microfluidics technology is being used to miniaturize traditional instrumentation systems such as gas chromatography, infrared spectroscopy, and ion mobility spectroscopy. But devices based on these technologies are expensive, ranging from \$75,000-90,000. The EPA reports incidences of false-positive and false-negatives with some field kits. Some technologies such as ion mobility spectroscopy have not been adapted for analyzing drinking water.
- While classes of contaminants can be identified, contaminant-specific signatures have not been developed.
- The currently available methods for detection of radiological contaminants are effective only for the analysis of wastewater and not drinking water.
- Contaminant flow and dispersion modeling research lags instrumentation research.
- Technologies for the deployment of area-wide water quality sensor networks and algorithms for closed-loop control are still nascent fields of research.

Key Market Opportunities

- The European Union Water Framework Directive issued in October 2000 announced measures to prevent the deterioration of surface and groundwater bodies, initiating a long-term initiative to develop a comprehensive water quality monitoring program. New detection and monitoring systems represent an important and sizeable market opportunity.
- Since 2002, the EPA has provided over \$150 million in grants to communities with public water systems serving more than 100,000 to complete security assessments. Municipal drinking water systems, particularly under-managed small-water systems, represent the greatest need for consulting services, deployment, and management of effective, reliable water treatment and monitoring programs.

- An emerging field of research is the ability to knit together multiples of sensors into a network. New developments in the field of electronic remote sensor networks need to be integrated with technologies and instrumentation that sense and monitor water condition. Ideally, integration will also involve technologies (e.g., microarrays) that can detect specific chemicals, toxins, or pathogens rather than just the presence or absence of contaminants. Ensuring that such networks—which are likely to be wireless—are safe from a security standpoint is also crucial and will require the incorporation or possibly design of the appropriate technology specifications.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Analytical Technology, Inc.	Monitors	PA	U.S.
Emerson Process Management	Test Kits, Monitors	CA	U.S.
Foxboro, Inc.	Test Kits	MA	U.S.
Hach Co.	Test Kits, Distribution Monitoring Systems	CO	U.S.
HF Scientific	Test Kits	FL	U.S.
Teledyne Isco	Monitors	NE	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
ETwater	Sensors/Monitors for Irrigation	CA	U.S.
Fluid Conservation Systems	Sensors	OH	U.S.
HydroPoint	Sensors/Monitors for Irrigation	CA	U.S.
Intelligent Automation Corp.	Monitors	CA	U.S.
JMAR Technologies, Inc.	Monitors	CA	U.S.
Pocket Water, Inc.	Water Quality Monitoring	ID	U.S.
Puresense, Inc.	Monitors	CA	U.S.
Sensicore	Sensors	MI	U.S.
Sensor Research & Development	Sensors	ME	U.S.
Thermo Electron Corp.	Monitors	MA	U.S.

Water Engineering and Watershed/Resource Management Consulting

Overview

The water resources consulting and engineering (WRCE) business is a subset of the larger environmental consulting and engineering (ECE) business. The ECE business sector can be segmented into two groups:

- Media or material involved, such as hazardous waste, solid waste, natural resources, air quality, or water; and
- Service offered, such as pollution prevention, audits and assessments, project management, lab testing services, or process design.

Firms operating in the WRCE space have capabilities that overlap across multiple media as well as services. The scope of WRCE includes:

- Design of water distribution and wastewater processing systems;
- Watershed maintenance – a service that overlaps with environmental remediation;
- Water resources security assessments; and
- Water resource and hydrology/geological assessments.

The EPA provides the impetus for the management of watersheds in the U.S. Federal and state laws have significantly reduced pollution caused by point source discharges. However, regulation has been less successful in controlling pollution from non-point source discharges caused by the industrial and recreational impact on the environment. An inventory of water resources conducted in accordance with the Clean Water Act in 2000 revealed that 39% of rivers and stream miles, 45% lake surface area, and 78% of the Great Lakes shoreline miles do not meet ambient water quality standards. Pollutant runoffs from highways, golf courses, farms, and lawns are major non-point sources of water pollution listed by the EPA. The watershed approach is a framework developed by the EPA to coordinate public and private resources to preserve water resources in hydrologically defined geographical areas. Some of the larger EPA-operated watershed funding programs include:

- Nonpoint source pollution funding programs including Clean Water Sec.319 grants and Nonpoint Source Mitigants
- Targeted watershed grants
- Wetlands funding including Wetlands Program Development Grants, Five Star Restoration Grants, and the State Revolving Fund program
- National Estuary Program

WRCE firms work with local administrations in implementing EPA funded programs. With increased availability of federal and state grants, watershed maintenance presents a significant market opportunity for WRCE firms.

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- Global WRCE business has grown consistently at over 9% since 2001, in contrast to other ECE segments
- In 2002 the wastewater sub-segment accounted for over 55% of WRCE revenues, while the water sub-segment accounted for the balance. In 2006 among the largest 200 WRCE firms, wastewater business accounted for over 51% of revenues.
- In the U.S. public water utilities constitute the largest market, and commission projects for asset upgradation of wastewater systems, and water distribution. Aging infrastructure drives new projects in most cases.
- Municipalities across the U.S. are concerned over the long term threat to water quality and quantity posed by drought. Problems caused by population growth and capacity issues are already a matter of concern for municipalities in the southern states and on the coasts.
- Periodic assessments conducted by the European Environment Agency have revealed a number of gaps in the water management infrastructure within the EU.
- As of the beginning of 2002, 169 of the 526 cities with a population of 150,000 or greater did not have a wastewater treatment facility that met EU standards. These cities include some of Europe's largest population centers such as Milan, Cork, Barcelona, and Brighton.
- Eight EU countries that have been identified as water stressed—Germany, England and Wales, Italy, Malta, Belgium, Spain, Bulgaria, and Cyprus—house 46% of Europe's population. In all these countries, the Water Exploitation Index—the ratio of annual water abstraction to long-term freshwater resources—is around 20% in Italy, a country where consumptive water use for irrigation predominates.
- Nitrate and phosphate concentrations—a measure of nutrient runoffs from agriculture—in the Baltic and North Seas have decreased, but remained unchanged or increased in the Celtic seas and the coastal areas of Italy.
- The EU has committed itself to sustained levels of international funding of water projects in the region of €1.4 billion a year.

Technology Trends and Challenges

- Eutrophication or excessive aquatic fertilization is one of the high priority problems identified by the EPA. In order to address the problem more forcefully the EPA directed states to adopt new quantitative criteria in place of the narrative based directives such as permissible Total Maximum Daily Load. As a result states are now required to measure and control nutrient levels and turbidity within narrow concentration bands. The EPA has demarcated four-

teen Ecoregions that cut across state boundaries with varying permissible concentrations of nutrients in water bodies. This has led to a new approach in water quality management termed as ***adaptive implementation***. This involves a phased program that combines water treatment and monitoring, starting with low-cost immediate actions.

- Lincoln, Nebraska, and Boise, Idaho, are two of many cities where this approach has been used to control the levels of ammonia and phosphorus, respectively.
- The EPA monitors nearly 2,000 watersheds nationwide and supports a number of local programs aimed at watershed remediation. Citizens groups received around \$15 million in 2003 to implement watershed protection activities. For instance in the Meduxnekeag River Watershed in Maine, the Houlton Band of Maliseet Indians developed a cost-share program with local potato farmers to reduce agricultural runoffs.
- Upgrading water supply infrastructure is now addressed at the level of the watershed rather than being confined to distribution and wastewater infrastructure. One of the largest watershed-based urban water supply upgradation projects to be implemented in recent times is by the San Diego Water Department. In a damage assessment following the October 2003 fires in San Diego County, the city's water department reported that the fires that burnt over 380,000 acres had damaged over 90% of the city's watershed. Working with a WRCE firm, the city's water department is rebuilding some of its water reservoirs taking into account runoff patterns, and seasonal variations in precipitation.
- Long term watershed preservations will require WRCE firms to provide inputs on urban development guidelines including issues such as zoning.
- The EPA released its first water quality trading policy document in 2003. The agency has identified potential savings of 40-60% over conventional methods for the control of phosphorous discharges, following a study of three Mid-western watersheds. Connecticut has set up a trading program to reduce nitrogen loadings in the Long Island Sound.

Key Market Opportunities

- The average value of water projects commissioned by U.S. municipalities has increased substantially since the mid-1990s from \$5 million to over \$26 million today.
- WRCE is the fastest growing segment in the ECE space. WRCE revenues of the 200 largest ECE firms ranked by a 2006 issue of *Engineering News Record* magazine grew by nearly 29% over the previous year.
- The 20 largest WRCE firms in 2006 had a total of \$5 billion in revenues, accounting for 35% of the combined WRCE revenues of the top 200 ECE firms.
- The Clean Water State Revolving Fund (CWSRF) continues to be among the most important public sources of financial support for watershed

improvement projects. The program has over the last 20 years disbursed over \$57 billion in assistance and in 2006 annual funding levels were in excess of \$5 billion.

- The emphasis of the CWSRF on watershed protection can be gauged from the fact that it funded over 1,180 nonpoint source pollution management projects. Although nonpoint source projects accounted for only 4% of funding in 2006 at about \$370 million, this represents an increase of almost 100% over the previous year. Wastewater projects continue to account for bulk of project funding, but the goals of projects are increasingly oriented toward long term water quality and energy efficiency.
- In EPA Region 2, an area that covers New York, New Jersey, and Puerto Rico, the Atlantic Counties Utilities Authority, NJ, won a performance award from the fund. The authority implemented a project to produce photovoltaic energy at its wastewater treatment facility.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
AECOM Technology, Inc.	Water Resources & Wastewater Consulting	CA	U.S.
Black & Veatch	Environmental Management, Construction, Engineering	KS	U.S.
CDM	Environmental Management, Construction, Engineering	MA	U.S.
CH2M Hill Companies	Environmental Management, Water & Wastewater Infrastructure Engineering	CO	U.S.
Earth Tech, Inc.	Water Resources & Management Consulting	CA	U.S.
ERM Group	Water & Wastewater Management	PA	U.S.
Infiltrator Systems, Inc.	Wastewater Solutions	CT	U.S.
Kiewit Corporation	Resources Construction	NE	U.S.
Layne Christensen Company	Water & Wastewater Treatment, Source and Infrastructure Engineering	KS	U.S.
MWH Global	Environmental Management, Water & Wastewater Treatment, Source and Infrastructure Engineering	CO	U.S.
Skanska	Construction & Project Development	-	Sweden
Stantec, Inc.	Environmental Management	-	Canada
Tetra Tech, Inc.	Water Resources & Environmental Management	CA	U.S.
The Walsh Group	Preconstruction & Construction Engineering	IL	U.S.
Veolia Environnement	Environmental Consulting	-	France

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
HydroPoint	Water Management Systems	CA	U.S.
Hydrotech Water Resource Consultants, LLC	Water Resource Management Consulting	MT	U.S.
Integrated Water Solutions	Water Resource Management Consulting	FL	U.S.
New England Environmental, Inc.	Freshwater, Stormwater & Watershed Management	MA	U.S.
Water Resources Consulting Services	Resources Engineering and Consulting	CA	U.S.

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GREEN BUILDINGS AND SUSTAINABLE DESIGN

INTRODUCTION

This section describes the broadly defined, and in many respects newly emerging green buildings technology segment. The “green” aspect involves:

- Manufactured from recycled, salvaged, waste, or readily renewable inputs
- Manufactured in a sustainable fashion which is resource efficient, conserves energy and water, and minimizes waste and pollutants
- Provides benefits to the built environment by conserving or reducing the use of energy or water and reducing or eliminating indoor pollutants
- Largely recyclable at the product’s end-of-useful life.

The reduction or eliminating of indoor pollutants combined with efforts in indoor environmental quality provides the basis for “healthy buildings.” Therefore, by their nature, green building technologies and products improve or at worst are neutral toward indoor air/environmental quality. Historically building materials including exterior/structural materials, carpets, paints, ceiling tiles, and furniture are often emitters of particles or volatile organic compounds (VOCs) into the indoor environment or potentially leach toxic elements into the outdoor environment. The green building segment is targeted at changing these outcomes for overall environmental improvement.

Unlike other industry/technology segments much of the structured development of this segment has occurred due to the advocacy, education, policy development, and standards development of a non-profit organization—the U.S. Green Building Council (USGBC). The USGBC is composed of leaders from every sector of the building industry and works to promote buildings and building practices that are environmentally responsible, profitable and healthy places to live and work. The USGBC’s LEED® (Leadership in Energy & Environmental Design) Green Building Rating System, is the nationally accepted standard for green buildings. Beyond LEED other standards programs such as the U.S. EPA’s ENERGYSTAR, the Greenguard Environmental Institute’s GreenGuard certification, or other indoor air requirements are also integral in developing green and healthy buildings.

MARKET DRIVERS

COMMERCIAL AND CONSUMER INTEREST IN “GREEN” BUILDING

Recent study by American Institute of Architects found that 34% of the architectural firms surveyed characterized some of their current efforts as “green” and these efforts accounted for 14% of their revenues. Additionally over 20% of these firms have recently completed a “green” new construction or remodeling project.

The National Association of Home Builders and McGraw-Hill Construction predict that green building will reach somewhere between \$19 billion and \$38 billion by 2010. This will amount to a 10% residential penetration by 2010, up from current estimates of 2%. While this penetration may seem low, true evidence of green building going mainstream is the recent announcement that the Discovery Channels are currently working on a new "reality TV" program called "Green That House" in which each half-hour episode will tell the story of a single house as it is remodeled to reduce its overall environmental impact. From learning how to better use available sunlight for heating to using energy-efficient lights and appliances, each show will be filled with helpful ideas for homeowners.

APPLICATIONS FOR GREEN TECHNOLOGIES

Research into green or high-performance building practices and technologies represents only 0.2% of federally funded R&D—averaging slightly more than \$190 million per year from 2002-2005. This amount represents only 0.02% of the estimated value of all building construction in the U.S.

A decade ago the construction cost premium for green buildings was as much as 20%, today it ranges between 1% and 9%, with a 2005 study estimating that the average premium was 2.42%.

ADOPTION AND IMPLEMENTATION OF LEED STANDARDS

To date, 11 federal agencies, 22 states, and 55 individual municipalities require buildings to meet either local green standards or those set by the U.S. Green Building Council. Of the commercial space falling under these requirements, according to the U.S. Green Building Council over 1 billion square feet of space is currently LEED registered or certified with 884 LEED certified projects. Because LEED standards have a growing influence on materials used by building product manufacturers, LEED is rapidly becoming the nation's de facto green building code.

ECONOMIC DEVELOPMENT DRIVERS

"GREEN" FRIENDLY LOCATION

The owners/leadership of most green/healthy building companies entered this market in part due to their own personal beliefs and interest in providing environmentally sustainable products. In order to foster the development of these firms regions need to have the "look and feel" of an environmentally conscious region. Examples include strong consumer and commercial recycling programs, an environmental aware business press, willingness to try new products, and a zoning and building permit infrastructure that allows for construction materials that are outside of traditional building norms.

ACCESS TO RESEARCH, TESTING, AND CERTIFICATION CAPABILITIES

As a truly emerging area, green/healthy building products are being developed and deployed at an increasingly fast pace. For smaller firms, having the ability to easily and readily tap into either regional academic or industrial research and testing capabilities for product development, confirming specifications, and measuring performance (including the outgassing of VOCs) would be an extremely attractive locational factor. However, given the wide ranging nature of green building products these capabilities would need to be broad in scope. Additionally, local capabilities to certify performance of green/healthy building products against national and international standards would also be an extremely positive locational factor.

STRONG LOCAL DEMAND FOR GREEN BUILDING MATERIALS, PRODUCTS, AND COMPONENTS

All else being equal, green building products companies will gravitate toward regions that exhibit the potential for strong local demand of “green” products. This potential can be exhibited through income characteristics (e.g., more affluent consumers), coordinated efforts toward renewing the housing stock, or significant planned developments (either private or public sector oriented) that will provide a strong demand component. Additionally, a strong driver for locational decisions for “footloose” green building products companies (e.g., those not strongly tied to a regional asset), is to be located where the demand for building products is most robust. Historically, this has followed population growth and migration trends with the South and West seeing the most profound residential building growth rates. Indeed, the Southwest is currently the fastest growing region in the country in terms of both population growth and increases in the new housing stock.

LOWER BUZZ, BUT STILL STRONG INVESTMENT INTEREST

According to Forbes, despite the relatively low sex appeal of the green buildings materials market (as compared with renewable energy investments, etc.), investors—both individual and institutional—will undoubtedly position themselves at a competitive advantage by aggressively seeking out companies that produce sustainable building products as they see significant consumer and commercial markets beginning to emerge.

EASY ACCESS TO PRODUCT INPUTS

Whether the product is manufactured locally or sourced internationally green building products companies require easy and seamless access to their supply chain. To the extent natural materials and other raw materials can be sourced locally is an extremely important driver in some segments (e.g., fly ash for “green concrete”).

STRONG GREEN ARCHITECTURAL AND DESIGN FIRMS

A key market driver for green/healthy building companies is the ability to develop close working relationships with local architectural and design firms with strong green/LEED orientations. These relationships can drive both market demand (as design firms specify products that they know well from local relationships) and en-

hanced product development (strong ties to consumer requirements and integral product feedback).

LEED-BASED TAX INCENTIVES

Development of LEED standards has allowed for more precise and applicable tax incentives to be developed—cities and states are using LEED certification to implement a wide variety of energy conservation and green building tax incentives as well as property tax abatements. Additionally, other cities are encouraging LEED development and certification by reducing permitting fees for green buildings.

GREEN BUILDINGS AND SUSTAINABLE DESIGN TECHNOLOGIES

- Green Structural and Exterior Materials
- Green Interior, Surface, and Finish Materials

Green Structural and Exterior Materials

Overview

Materials used to construct the structural and exterior components of any building, whether residential or commercial, play the major role in the overall efficiency and viable life of the building. Similarly, in the context of “greening” homes, offices, and other buildings, the extent to which structural materials combine to provide energy efficiency, improve air quality, conserve natural resources, and reduce waste streams is critical to achieving a more green, sustainable outcome. At the same time, these materials must be economically attainable and perform well over an extended life cycle.

Green building materials represent choices among several characteristics that give a product or material its green environmental profile. Salvaged materials can substitute for new and reduce both overall cost and solid waste associated with building construction. Recycled content materials divert waste from landfills by reusing waste products. Rapidly renewable materials and certified wood products minimize the consumption of natural resources. Using materials supplied locally further reduce the environmental impact of transportation.

Structural elements provide the weight-bearing aspects that support the building and allow a point of attachment for both exterior and interior surfacing materials. Generally, these elements include framing systems and wall systems. The following briefly shows the overall structure and alternative green materials/products available for these systems:

- Framing systems form the internal building structure (e.g. beams, studs, joists).
 - A green alternative to traditional lumber or metal is engineered lumber and wood products—a composite material incorporating wood that would otherwise be waste. Engineered wood products make efficient

use of available timber by utilizing smaller and less desirable dimensions and types of timber and yet are engineered to be stronger than similar sizes of solid wood. Types of engineered lumber include:

- Glued laminated lumber (“glulam”)
 - Structural composite lumber
 - Wood-plastic composite lumber
 - Wood I-joists
- Wall systems provide support and rigidity to a structure and may be either self-supporting or attached to the existing building frame. Some wall systems are designed for below-grade (foundation) walls, and others are designed for above-grade walls.
 - Green alternatives to traditional wall systems include:
 - Insulating concrete formwork
 - Straw bale construction systems
 - Permanent wood foundation systems
 - Wood/plant fiber-cement composite blocks
 - Structural insulating panels
 - Structural sheathing (incl. Oriented Strand Board)

Exterior building materials provide weatherproofing and enhance outward appearance. Three major components and their associated green materials include:

- Insulation
 - Green alternatives to traditional insulation materials include those that are manufactured from recycled or waste materials or renewable resources, as well as beneficial to the building’s interior or the environment (noise and/or pollution reduction). Other considerations include their degree of thermal insulation, effect on interior air quality, fire resistance, and acoustical properties. These types of insulation include:
 - Recycled cellulose (recycled newsprint, other)
 - Cementitious foam
 - Rock wool
 - Cotton insulation (garment wastes, no VOC)
- Roofing
 - Green alternatives for roofing materials include those that have a long service life and therefore result in fewer roofs over the building’s lifetime; reduce the amount of landfill waste; provide the appropriate

thermal insulation to heat loss/energy consumption; and/or incorporate recycled materials. These green alternatives include:

- Sprayed polyurethane foam
- Metal roofing (residential)
- Fiber-cement roofing systems
- Other recycled-content materials
- Though not covered in the BCC research green building materials study, the use of vegetation on a rooftop, often called a “green roof,” as an alternative to traditional roofing materials is gaining in popularity and market share.
- Siding
 - Green alternatives to traditional siding materials include steel and aluminum siding that can incorporate up to 80 percent recycled materials and can be recycled yet again at the end of their life cycle. In addition, metal siding offers other green benefits including solid insulation and water-tightness, resistance to pests and the material most resistant to fire. The major specific green alternative materials include:
 - Metal siding (recycled aluminum or steel)
 - Fiber cement (recycled cellulose/wood and cement)

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- According to BCC Research, **structural materials** account for \$16.5 billion, or almost 80% of the entire 2005 U.S. market for green building materials. The projected AAGR for structural materials is 4% for the 2006 through 2011 period, rising to \$20.7 billion by 2011.
- Among structural materials, wall systems account for the majority (55%) of the current market at \$9.0 billion in 2005. That said, rapid market growth in the market for framing systems (6.5% estimated AAGR) should reverse this position by 2011 when framing systems are expected to make up almost 53% of the market.
- Driving the growth in framing systems is the strong demand for engineered lumber products. Currently, I-joists, composite and plastic lumber, and glulam account for the majority of sales (89%). Among these, BCC expects composite and plastic lumber to experience the fastest AAGR to 2011 at 11% annually. Key drivers in this market include overall housing starts and the successful penetration of these products in the market.
- In the U.S. market for wall systems, structural sheathing was by far the largest component in 2005, making up 92% of the market. With \$8.1 billion in

U.S. sales, Oriented Strand Board (OSB) accounted for nearly all (97%) of the structural sheathing market.

- Though currently smaller than structural sheathing, the market for structural insulating panels is expected to grow at a 30% AAGR during the 2006 through 2011 period. Likewise, the market for insulating concrete forms is projected to grow at a rapid, 19% pace.
- **Exterior materials** comprise a nearly \$2.5 billion market, or about a 12% share of the overall U.S. green building materials market in 2005. Among the major product segments in the materials market, exterior materials are expected to grow at the fastest rate—an AAGR of 10% from 2006 through 2011. Given this forecast, the market for green exterior materials should reach \$4.4 billion by 2011 and command a 16% share of the overall green materials market.
- In 2005, green siding materials made up the largest share (46%) of the green exterior materials market, followed by roofing materials (33%) and insulation (21%). BCC projects that green roofing will have the highest annual growth rate in the coming years—12.5% during the 2006 through 2011 period.
- In 2005, the bulk of the U.S. market for green insulation materials went to cellulose insulation (73% of all green insulation). The market for this recycled cellulose is currently at \$375 million and projected to hit \$575 million by 2011. One major market driver for cellulose insulation is the price of recycled newsprint, the main component of this type of insulation. Compared with other green building materials, the cellulose insulation market is relatively mature.
- BCC expects the market for green roofing materials to reach \$1.6 billion by 2011, up from \$815 million in 2005.
- Metal roofing accounts for the majority of the current green roofing market (64%) and is expected to increase its share by 2011 to 75%. These metal roofing systems, such as metal shingles, are used in residential structures and currently comprise a \$525 million market and are expected to reach \$1.2 billion by 2011 (a 15% AAGR).
- The green roofing materials market data presented here do not include “green roofs” with live vegetation. According to the not-for-profit industry association Green Roofs for Healthy Cities, the green roof market in the U.S. has seen growth of more than 80 percent in roof square footage from 2004 to 2005.
- BCC research puts the U.S. market for green siding materials at \$1.1 billion in 2005 and projects it to grow to almost \$2.0 billion by 2011. The forecast assumes average annual growth of 9%.
- Fiber cement materials represent the largest current and fastest growing segment of the U.S. green siding market. These materials are expected to grow at an AAGR of nearly 12% in the coming years compared with only 2%

for metal siding. This will boost the fiber cement materials market to \$1.6 billion.

- In a related exterior materials market, the demand for alternative decking materials is robust. Freedonia expects “alternative” decking materials to lead the overall market for decking with respect to annual gains to 2011. Wood-plastic composites using recycled materials will drive gains in the alternative materials market as its environmental profile becomes more important to consumers and builders.

Technology Trends and Challenges

- Green alternatives to conventional building materials can have their own unique installation and maintenance support challenges. Installers or facilities staff may lack the training or guidance to properly install certain products or materials and this may result in misuse or failure.
- While engineered lumber and wood products make efficient use of wood and thus promote sustainable use of natural resources, they require adhesives that can be toxic. Resins can release formaldehyde in the finished product. In addition, engineered lumber is more expensive to produce than solid lumber in time, money, and energy. Though there are efficiencies to be gained in these areas, engineered lumber offers key offsetting economic advantages due to the rare nature of solid wood trees useful for cutting into large panels.
- The challenges associated with green, vegetated roofing are as numerous as the variables involved in a green roofing system. These include selecting the appropriate underlying waterproofing and protection layers, assuring proper drainage and water retention, and choosing the optimal growing media balancing thickness, local climate, and weight. These are in addition to generally higher up-front construction costs.
- To some extent, the technology challenges and cost-benefit relationship associated with green, vegetated roofing are still under study in the U.S. Portland State University (Oregon) has begun a study to determine optimal green roof design, taking into account building energy savings and storm-water runoff reduction. The study will result in energy-simulation software designed to provide guidance on the appropriate green roof for a particular building.
- Separate from the Portland study, performance thresholds are being developed by ASTM International (PA) for green roofs and their numerous individual components. In partnership with the National Roofing Contractors Association (IL), ASTM is also working on building guidelines for green roof construction. All U.S. studies and builders are drawing heavily from the vast green roofing experience of Europe.
- Cellulose insulation and the technologies associated with it are relatively basic and have a long history of use. Modern cellulose insulation, made from recycled newspaper with added fire retardant, began to be used in the 1950s and became widespread in the 1970s. Though issues with fire retardants

and relative performance in a fire have been debated for decades, cellulose insulation is widely used today with increased interest in green building.

Key Market Opportunities

- Assessments of market leaders in the green building arena reveal the opportunity presented to the major players in the overall building materials market to go green. Existing market leaders are diversifying their market presence and adding to their product offerings by providing green building alternatives.
- Wood-plastic composites that incorporate recycled materials for exterior decking present a fast-growing market opportunity. Composite decking provides high durability and low maintenance for owners and is in high demand among consumers and builders with preferences for building green.
- Recent federal legislation, tax incentives, individual state initiatives, and revised building codes promote or require the implementation of “cool” and “sustainable” roof systems. These government trends combined with the further acceptance and demand for environmentally-friendly roofs in the commercial market are creating a strong demand for High-Performance Roofing (HPR). This new class of HPR requires meeting traditional roofing requirements including installed cost, overall performance, and longevity, in addition to green criteria balancing the environment, energy efficiency, and life-cycle costs.
- Green roofs that incorporate vegetation and appropriate growing media improve environmental performance by absorbing rainfall, reducing roof temperatures, improving ambient air quality and the condition of urban habitats. Though costly, these innovative roof systems lower the long-term costs of energy and improve urban infrastructure. Experts believe there is a large, untapped market for green roofs throughout North America and trends in green roofing should be monitored for potential future market opportunities.
- For regions with abundant small trees and existing lumber facilities producing wood wastes, there are viable market opportunities in supplying wood for engineered lumber and other products as well as manufacturing these products locally. Likewise, existing firms engaged in newspaper or other recycling can become suppliers to firms producing cellulose insulation, for example. Going green can expand the market for firms in an existing supply chain.
- The rehabilitation of existing buildings using green building practices and technology presents market opportunities and significant, positive environmental impact. Rehabilitating older building shells minimizes overall material use, reduces solid waste volumes and diverts this waste from landfills.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
Alcoa	Metal roofing	PA	U.S.
ALSCO Metals	Residential aluminum building products	NC	U.S.
BASF Corp. (N. America)	Cool roof coatings & technology for metal roofs	NJ	U.S.
BaySystems	Spray polyurethane foam roofing; cool roofing; metal roofing	TX	U.S.
Berridge	Metal roofing & siding	TX	U.S.
Boise Cascade	Engineered lumber	ID	U.S.
Bonded Logic	Cotton insulation (no VOC)	AZ	U.S.
Dow Chemical Co.	Spray polyurethane foam roofing	MI	U.S.
Follansbee Steel	Metal roofing (stainless steel)	WV	U.S.
Gentek Building Products	Metal siding (aluminum, steel)	ON	Canada
Georgia-Pacific	Engineered lumber; OSB sheathing	GA	U.S.
Homasote	Green structural sheathing (fiberboard, recycled wastepaper)	NJ	U.S.
International Cellulose	Recycled cellulose insulation	TX	U.S.
LP Building Products	Engineered lumber; OSB sheathing; composite decking; cellulose insulation	TN	U.S.
McFarland Cascade	Composite decking	WA	U.S.
Met-Tile	Metal roofing (tile panel); cool roofing	CA	U.S.
Norandex/Reynolds	Metal (aluminum, steel), fiber cement, & engineered wood siding	OH	U.S.
Nu-Wool	Recycled cellulose insulation	MI	U.S.
Regal Industries	Recycled cellulose insulation	IN	U.S.
TAMKO Building Products	Metal roofing; composite decking	MO	U.S.
Trex	Composite decking, railing, fencing; uses recycled wood & plastic	VA	U.S.
United States Seamless	Metal siding (seamless steel)	ND	U.S.
Universal Forest Products	Engineered lumber; composite decking	MI	U.S.
Weyerhaeuser	Engineered lumber for structural framing & industrial applications	WA	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
AEP Span	Metal roofing; cool roofing	TX	U.S.
BioBased Systems	Soy-based polyurethane spray foam insulation	AR	U.S.
Carlisle SynTec	Roof garden systems for green roofs	PA	U.S.
Custom-Bilt Metals	Metal roofing; cool roofing	CA	U.S.
GreenKrete Building Systems	Wood/plant fiber-cement materials	IA	U.S.
Hamilton Manufacturing	Recycled cellulose insulation	ID	U.S.
Mountain Fiber Insulation	Recycled cellulose insulation	UT	U.S.
Re-New Wood	Recycled roofing shingles (vinyl & cellulose)	OK	U.S.
Rollex	Metal siding	IL	U.S.
Ryerson	Metal roofing; cool roofing (metal fabricators/distributors)	IL	U.S.

Green Interior, Surface, and Finish Materials

Overview

Most of the market impact of healthy, renewable, and green building applications has been through “green” structural and exterior materials, as demonstrated in the fact that these materials account for more than 90% of the total green building materials market. However, materials used for interiors, surfaces (e.g., wall and floor coverings, countertops) and paints and other finishes are often the most responsible for IAQ concerns (either direct from the materials themselves or through their harboring of IAQ degrading matter). These areas are increasingly being examined as important elements in creating healthy and green designs and spaces. Additionally, interior, surface, and finish materials are often a major factor in the “non-air” part of Indoor Environmental Quality—issues related to light, sound, other factors.

As with structural and exterior materials, most of these green applications and materials are currently niche markets with significantly larger and more mature overall markets, that are often very “ungreen” due to the use of chemicals, significant outgassing of VOCs, and the use of non-renewable resources. The discussion and information presented here relates only to the healthy/green niches within these markets.

For the purposes of this assessment the interior, surface, and finish materials subcategory is further divided into six areas: Floor Coverings, Wall Coverings, Coatings, Cabinetry & Countertops, Furniture, and Lighting & Electronics.

Floor coverings constitute one of the largest areas in which green and healthy building technologies have made important inroads into the mainstream marketplace. Carpets made of manmade fibers have been singled out as one of the most significant compromisers of indoor air quality, and hence significant work is being performed to reduce the outgassing from carpets (through chemical and material substitution) as well as a wide variety of natural-based products are seeing new and/or renewed interest.

Additionally, efforts are being made into the further “greening” of existing carpet and flooring manufacturing through the development of recycling techniques to make use of old, worn out carpets and padding as inputs into the manufacture of new carpet. Through these recycling efforts significant material resources, energy, and landfill space can be saved.

Important areas of green/healthy floor coverings include:

- Natural Fiber Floor Coverings (e.g., wool carpets, sisal/jute/sea grass carpets and mats)
- Renewable Wood (e.g., bamboo, cork)
- Linoleum
- Recycled Content Tiles

Wall coverings include those applications of additional materials to walls for aesthetic, acoustic, or other functional purposes.

- Renewable Wood Panels/Paneling
- Renewable Material Acoustic Panels
- Low VOC Wallpapers
- Modular Wall systems

Coatings and adhesives include a wide variety of “liquid” applications including paints, stains, varnishes, epoxies, and adhesives. Given the traditional “chemical” nature of these materials much effort has been put into developing new green chemistries both from a low/no VOC context and more bio-based formulations.

Cabinets and countertops are those products that are made from renewable, recycled, or sustainable materials and are low-VOC/low formaldehyde emitters. As most “off the shelf” cabinetry includes a substantial amount of particle board or medium density fiberboard (MDF) an important aspect of green cabinets is that they are made of low-VOC/formaldehyde binders. Increasingly, MDF manufacturers are exploring the use a wide variety of agricultural waste products (e.g., wheat straw) as the “fiber” in this product. The development of green countertops is a more difficult market challenge as current consumer preference is aimed strongly at Corian-type products or granite/other natural stone products—these are not considered green due to the petroleum inputs in the former, and the environmental impact of the latter. Green countertops are constructed out of a wide variety of materials ranging from recycled glass, cast concrete, linoleum laminates, and bamboo.

Furniture, though not always included in green/healthy building discussions, is seen as an important area for further future efforts as furniture accounts for the largest surface area in the interior environment. With this large surface area comes significant potential to impact indoor air quality (i.e., textiles/foams used in furniture and bedding; VOC/formaldehyde emissions from particle board used in furniture), significant waste stream issues (i.e., low quality, throw-away particle-board furniture), and recycled materials/renewable and reclaimed wood/low chemical content and emissions

Lighting and electronics provide a direct link between green building materials and the goals of reducing the energy demands and footprints of our nation’s buildings. Lighting and electronics also constitute one of the first “green” technologies that many consumers engage from ENERGY STAR appliances, programmable thermostats, and increasingly, the use of compact fluorescent lighting.

Lighting and electronics is also a key “green” area for commercial and industrial applications, as reducing the energy footprint of these structures often has a direct bottom-line result. These savings can be achieved through lighting and occupancy sensors that reduce the use of light/HVAC.

Market Trends, Challenges, and Opportunities

Global and U.S. Market Trends

- The U.S. market for green wall, floor, and ceiling coverings is estimated to be \$773.8 million in 2006 and is forecast to grow by an average annual growth rate of 3.3% reaching \$912.1 million in 2011. Natural fiber carpets and pads (mostly wool, but also including sisal, jute, and other natural fibers) account for nearly 66% of this market in 2006. But with forecast growth in the renewable woods (e.g., bamboo, cork) segment (6.3% AAGR) and linoleum segment (10% AAGR), natural fibers share will decrease to 61% of the market by 2011.
- The green coatings and adhesives market in the U.S. is forecast to grow by an average annual growth rate of 12.9% from 2006 to 2011. This will take the market from its \$665.2 million level in 2006 to \$1,217.8 million in 2011, with coatings (e.g., paints, stains, varnishes) accounting for over 90% of the market. Green (low-VOC) coatings and adhesives only accounted for an estimated 10% of all coatings and adhesives used for interior applications in 2006, however, due to both consumer and regulatory pressure market penetration is forecast to reach 15% by 2011.
- The U.S. market for green cabinets and countertops is estimated to be \$33.2 million in 2006, with projections to reach \$45.1 million in 2011. Of these numbers cabinetry accounts for two-thirds of the overall market value.
- Rising interest in “green” technologies for building lighting has spurred demand for compact fluorescent bulbs, with sales reaching nearly \$960 million in 2006. Newer LED applications in higher-end products (including automobiles and panel displays) allowed the market for LEDs to reach almost \$990 million in 2006, though usage in building applications account for only a small percentage of this current demand. Altogether, advanced lighting technologies accounted for nearly \$3 billion in sales in 2006.

Technology Trends and Challenges

- Small niche manufacturers as well as large corporation are increasing their use of Forest Stewardship Council (FSC)-certified wood for mid and high end cabinetry.
- Use of recycled materials, fibers, and in some instances agricultural waste products (e.g., straw, sugar cane stalks) for composite boards/medium-density fiberboard (MDF) used in some cabinetry and closet organizer products. Additionally, these composite boards are manufactured using low-formaldehyde or formaldehyde free binders.
- Expanded interest in green building has sparked a renewed interest in intelligent-building technologies. A recent focus group of varied real estate, education, hotel, and health care building owners/developers had 90% of the

participants planning to incorporate intelligent-building technologies into projects over the next two years.

- Overcoming cost hurdles of “green” materials and technologies to allow for more adoption and use.

Key Market Opportunities

- Commercial opportunities exist for “green” furniture, cabinetry, and fixtures in retail operations (e.g., Starbucks, Whole Foods grocery stores) that are looking to maximize their use of green components as part of their overall designs.
- Currently, most dedicated green cabinetry and furniture manufacturers are small, privately owned firms. Larger firms, however, are improving the green quality of their products, through the use of new materials and green chemicals and adhesives.
- As the interest and demand in LEED certification for new construction and remodeling efforts increase (for both commercial and residential spaces), incorporating green/recycled content within interior coverings, cabinetry, countertop, and other fixtures selections qualify for additional certification points.

Leading and Emerging Companies

Leading U.S. and International Companies

Company	Technology/Application	State	Country
GE Lighting	Lighting (Compact Fluorescents)	OH	U.S.
Interface Flooring	Carpet Tiles	GA	U.S.
Milliken	Wall Covering	SC	U.S.
Philips Lighting	Lighting (Compact Fluorescents)	NJ	U.S.
Shaw Contract Group (EcoWorx)	Carpet/Carpet Backing	GA	U.S.
Sherwin Williams	Paint	OH	U.S.
Summitville Tiles, Inc.	Recycled Content Tiles	OH	U.S.
Valspar	Paint	MN	U.S.
Wausau Tile	Countertops	WI	U.S.

Small/Emerging U.S. and International Companies

Company	Technology/Application	State	Country
AlterECO	Cabinetry	CA	U.S.
American Clay Enterprises, LLC	Coatings, Plaster	NM	U.S.
BamStar	Flooring	OH	U.S.
Coverings Etc.	Recycled Content Countertops, Flooring, Panels	FL	U.S.
CREE	Lighting (LED)	NC	U.S.
Environ Biocomposites	Cabinetry	MN	U.S.
Green Planet Paints	Paint	AZ	U.S.
Green Products	Adhesives; Coatings	IL	U.S.
Holophane	Lighting	OH	U.S.
Humabilt	Panels, Doors, Cabinetry	OR	U.S.
IceStone	Countertops	NY	U.S.
ITW TACC	Adhesives; Coatings/Sealants	MA	U.S.
Neil Kelly Cabinets	Cabinetry	OR	U.S.
Ortech/Durra Building Materials	Wall Panels	TX	U.S.
PaperStone (Paneltech Int'l/KlipTech)	Recycled Content Countertops/Wall Panels	WA	U.S.
PermaGrain Products	Flooring	VA	U.S.
Richlite	Recycled Content Countertops	WA	U.S.
Safecoat (AFM)	Paint	CA	U.S.
Sea Gull Lighting	Energy Efficient Lighting Fixtures	NJ	U.S.
Smith & Fong Plyboo	Flooring, Panels, Veneers	CA	U.S.
Studio eg Inc.	Furniture (office)	CA	U.S.
Syndesis Studio	Recycled Content Tiles	CA	U.S.
TCP, Inc.	Lighting	OH	U.S.
Tectum, Inc.	Wall Coverings, Panels	OH	U.S.
Teknion	Furniture	ON	Canada
Teragren	Flooring, Panels, Veneers	WA	U.S.
Terra Green Ceramics	Recycled Content Tiles	IN	U.S.
Vetrazzo	Countertops	CA	U.S.
Watt Stopper/Legrand	Electronics/Sensors	CA	U.S.
Yolo	Paint	OR	U.S.

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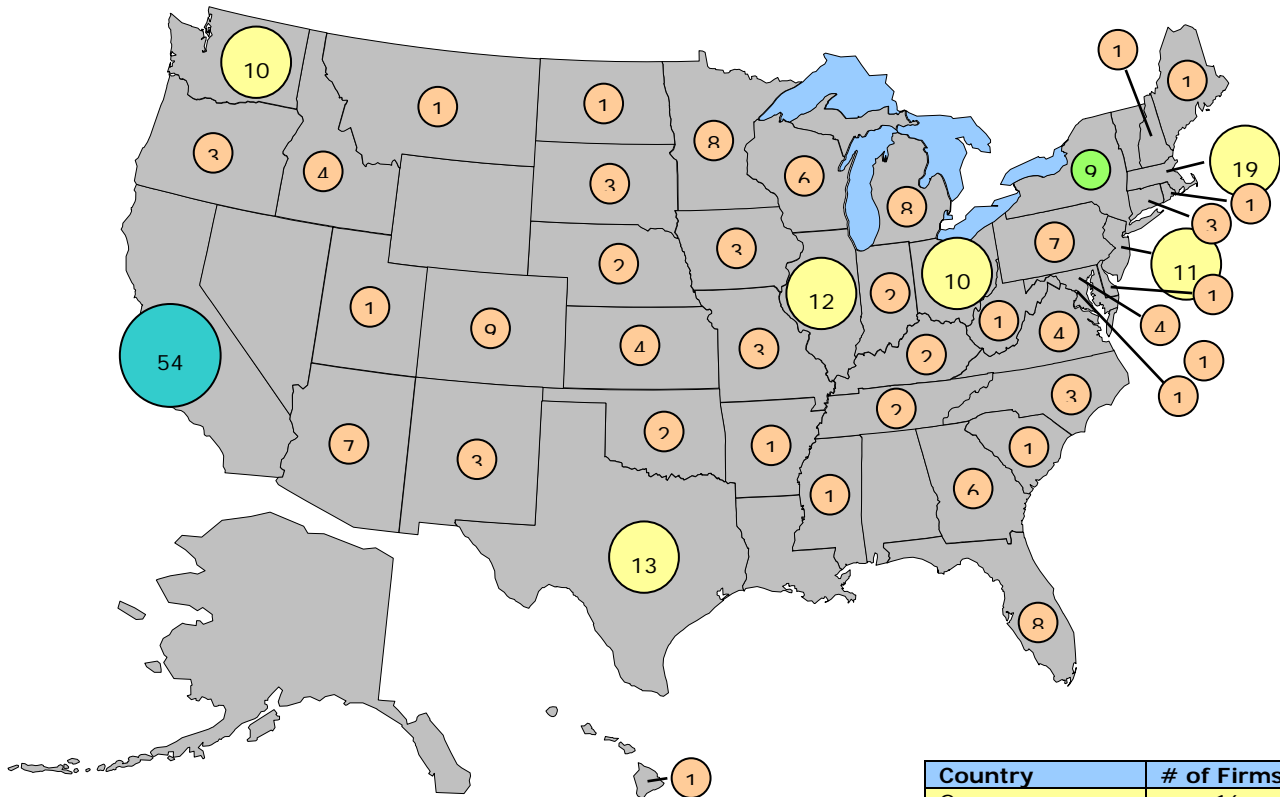
APPENDIX C

ENVIRONMENTAL AND ENERGY SYSTEMS

LIST OF LEADING AND EMERGING COMPANIES

Battelle identified leading and emerging companies for each of the subsectors of the E&S cluster. As can be seen from the map below, the largest concentration of such companies are in California, Massachusetts, Germany, Texas, Indiana, New Jersey, Ohio and Washington, all of which had 10 or more companies. New York state is home to nine of the companies identified as leading and/or emerging. A list of all of the companies follows.

Geographic Distribution of Energy & Environmental Systems Companies Identified in the Market Analysis



Numbers in circles indicate the number of firms identified in each state.

Country		# of Firms
Germany		16
Canada	AB	2
	BC	2
	NS	1
	ON	4
China		5
Japan		5
Denmark		4
France		4
Spain		4
Finland		3
India		3
Switzerland		3
Taiwan		3
UK		3
Brazil		2
Sweden		2
Austria		1
Israel		1
Netherlands		1
New Zealand		1
Norway		1
South Korea		1

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	3M	Air Filters	3M Filtrete air quality products are used in ventilation systems for homes, and inside cars	MN	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	American Air filter	Air Filters	American Air Filter makes filter screens used in ventilation systems for clean rooms, homes, and industrial air quality management systems	KY	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Aprilaire	Air filters; ventilation; other IAQ products	Aprilaire manufactures a range of home air quality products including air purifiers, humidifiers, dehumidifiers, thermostats, and zone control systems	WI	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Camfil Farr	Air Filters	Camfil Farr is a global leader in air filter technology and is a leading supplier of filters used in ventilation systems for both the clean process and comfort air segments	-	Sweden
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Carrier	Process Air, Comfort Air	Carrier is among the global leaders in HVAC systems for the comfort air and clean process air segments, and offers solutions for other related segments including transportation ventilation, and refrigeration	CT	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Clarcor Inc	Air Filters	Clarcor is a global provider of filtration products for industrial and mobile filtration	TN	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Danfoss A/S	Process Air, Comfort Air	Danfoss is a global leader in the development and manufacture of HVAC and refrigeration systems and has a range of solutions that span the comfort air and clean process air segments	-	Denmark
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Danfoss, North America	Process Air, Comfort Air	Danfoss is a global leader in the development and manufacture of HVAC and refrigeration systems and has a range of solutions that span the comfort air and clean process air segments	MD	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Donaldson	Air Filters	Donaldson is a leading global manufacturer of filtration systems used in homes, buildings, factories, and clean process space ventilation systems	MN	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Fedders	Process Air, Comfort Air	Fedders is a global provider of HVAC and air cleaner systems for homes, office buildings, clean process rooms, and industrial spaces	NJ	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Filtration Group	Air filters	Filtration Group designs and manufactures nonwoven based filtration media for HVAC systems used in clean rooms, buildings, homes, and industrial workspaces	IL	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Friedrich Air Conditioning	Air filters; Comfort Air	Friedrich Air Conditioning is a manufacturer of airconditioning, air cleaning systems, and humidifiers used in homes and buildings	TX	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Halton Group	Air filters; ventilation	Halton is a manufacturer of demand based ventilation systems that maintain indoor temperatures at high levels of energy efficiency	-	Finland
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Honeywell	Air cleaners; sensors & other instrumentation	Honeywell is a diversified manufacturer of control and automation systems that offers a complete range of HVAC automation systems and IAQ measurement and control systems instrumentation	NJ	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Hunter Air Purifier	Air purifiers; filters	Hunter is a manufacturer of residential air purifiers, filtration media, thermostats, and humidifiers	AZ	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Johnson Controls Inc.	Process Air, Comfort Air	Johnson Controls is a global leader in the design and manufacture of controls used in building HVAC systems. Its other product lines include the York range of commercial HVAC and refrigeration systems, and building safety and security systems	WI	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Lennox International	Process Air, Comfort Air	Lennox is a leading manufacturer of heating and airconditioning systems for homes and buildings	TX	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Lydall Filtration/Separation, Inc.	Air Filters	Lydall Filtration makes a wide range of filtration media for air purification and liquid filtration. Air filtration media using Lydall's microglass composite, and activated carbon matrices are used in building, clean process, and residential HVAC systems	NH	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Pall Corporation	Air Filters	Pall Corporation is a broadbased manufacturer of filtration, separation, and purification media and equipment used in high purity processes. Its air filtration media and equipment are used extensively by the bioscience industry to achieve and maintain high levels of air purity	NY	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and	Leading	Price Industries	Air distribution products;	Price offers among the widest range of heating and cooling equipment from an HVAC company	GA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
	Treatment Technologies			Comfort Air	today. Its product range includes diffusers, grilles, fan coils, terminal units, radiant systems, underfloor products, and displacement ventilation systems		
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Leading	Whirlpool	Air purifiers; air conditioners	Whirlpool is one of the world's largest manufacturers of white goods, refrigeration, and HVAC systems. Its HVAC and refrigeration systems are used in homes, buildings, and transportation cold storage spaces	MI	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Small/ Emerging	Nu-Air Ventilation Systems	HRV systems	Nu-Air Ventilation makes energy recovery ventilation systems for homes. In this high efficiency system incoming and exhaust air streams are passed through a heat exchange core where the outgoing air heats up the incoming air which is then circulated inside the home.	NS	Canada
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Small/ Emerging	RenewAire	ERV	RenewAire's energy recovery ventilation system exhausts pollutants and excess moisture and efficiently recovers heat from the exhaust stream during cold weather and pre-cools and pre-dehumidifies incoming air during hot, muggy weather, minimising moisture and pollutants inside the ventilated space. RenewAire systems have been installed in homes and buildings	WI	U.S.
Indoor Environmental Quality	Air Filtration, Conditioning, Ventilation, and Treatment Technologies	Small/ Emerging	StrionAir	Air filtration	StrionAir makes air filter media that combine the best elements of ionization, electrostatic and mechanical filtration resulting in a product that uses disposable media and that can be installed in any air handler or HVAC system. The StrionAir System enhances a mechanical filter resulting in increased levels of filtration efficiency with a very low pressure drop	CO	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Danaher	Control systems, sensors	Danaher is a global leader in water and air quality analysis and treatment, providing instrumentation and disinfection systems to utilities that supply clean water to residential and industrial users. Danaher's ultraviolet treatment systems are used in more than 35 countries and the company provides a broad array of environmental solutions, including underground tank monitoring and ad-	DC	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					vanced vapor recovery to protect water supplies and improve air quality		
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Danfoss A/S	Controls	Danfoss is a global leader in the development and manufacture of HVAC and refrigeration systems and has a range of solutions that span the comfort air and clean process air segments	-	Denmark
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Danfoss, North America	Controls	Danfoss is a global leader in the development and manufacture of HVAC and refrigeration systems and has a range of solutions that span the comfort air and clean process air segments	MD	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Ember	Wireless sensor networks	Ember is the developer of the Zigbee series of wireless sensor networks used to manage energy efficiency in buildings by real-time control of the HVAC and electrical system	MA	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	GE Sensing – Telaire	Sensors (infrared gas sensors, other)	GE Sensing develops technologies and solutions using techniques such as thermal validation, dew point measurement, ultrasonic and gas flow measurement, and liquid level detection for products and services in applications such as environmental and air quality monitoring	MA	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Gray Wolf	Control systems, sensors	GrayWolf Sensing Solutions provides advanced sensor and software technology, using mobile computers ('PDAs'), to constitute portable diagnostic environmental instrumentation used to monitor air quality in industrial spaces	CT	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Honeywell	Control systems, sensors, consulting & engineering	Honeywell is a diversified manufacturer of control and automation systems that offers a complete range of HVAC automation systems and IAQ measurement and control systems instrumentation	NJ	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Johnson Controls, Inc.	Controls	Johnson Controls is a global leader in the design and manufacture of controls used in building HVAC systems. Its other product lines include the York range of commercial HVAC and refrigeration systems, and building safety and security systems	WI	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	KD Engineering	Control systems, sensors	KD Engineering is an independent HVAC testing agency and manufacturer of indoor air instru-	WA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
	Instrumentation				mentation that uses wireless sensor networks to conduct real time tests of system performance		
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Lennox International	Controls	Lennox is a leading manufacturer of heating and airconditioning systems for homes and buildings	TX	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Honeywell Analytics	Sensors, Air Quality Detectors	Honeywell Analytics offers a wide range of toxic gas detection systems and its products range from disposable personal gas detectors to complete systems for large spaces	FL	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Quest Technologies	Gas Detectors	Quest Technologies offers hand held gas detectors that can be used to determine the quality of indoor air by the measure of humidity and the concentration of a number of gases including carbon dioxide, carbon monoxide, hydrogen sulfide, nitrogen oxides, ammonia, and oxygen	WI	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Siemens Building Technology	Control systems, sensors, consulting & engineering	Siemens Building Technologies is a global leader in products, systems, and solutions for the commercial comfort air sector and the clean process sector. It manufactures control systems, components, and provides consulting services to customers for improving the overall energy efficiency of buildings	-	Germany
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Siemens Building Technology, U.S.	Control systems, sensors, consulting & engineering	Siemens Building Technologies is a global leader in products, systems, and solutions for the commercial comfort air sector and the clean process sector. It manufactures control systems, components, and provides consulting services to customers for improving the overall energy efficiency of buildings	IL	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Testo AG	Control systems, sensors	Testo is a world leader in the design, development and manufacture of portable instrumentation for combustion efficiency analysis and air emission monitoring	-	Germany
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	Testo Inc	Control systems, sensors	Testo is a world leader in the design, development and manufacture of portable instrumentation for combustion efficiency analysis and air emission monitoring	NJ	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Leading	TSI Inc.	Control systems, sensors	TSI designs and manufactures precision instruments used to measure flow, particulate, and other key parameters in enclosed as well	MN	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					as open spaces including labs, offices, and outdoor environments		
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Small/ Emerging	Aircuity	Control systems, sensors	Aircuity is a manufacturer of integrated sensing and control solutions that enable optimization of building energy and operating expenses while simultaneously improving its indoor environmental quality. Aircuity's first product, the Optima, was developed in collaboration with a primary research contractor for the EPA's Indoor Environments Division. The Optima automated process captures key data about the air quality from a facility, and processes it to identify potential areas for improvement within the facility.	MA	U.S.
Indoor Environmental Quality	Air Sensors and Air Analysis/Monitoring Instrumentation	Small/ Emerging	ICx Photonics (formerly Ion Optics)	IR gas sensors	ICx Photonics manufactures a range of infrared products used in the measurement of air quality and is currently working on developing a single chip infrared based gas sensor	MA	U.S.
Renewable Energy	Biomass Energy	Leading	Abengoa Bioenergy	Ethanol; cellulosic ethanol	Abengoa Bioenergy's primary product is fuel-grade ethanol and is among the US's largest ethanol producers. The Company recently launched a research and development subsidiary that works in partnership with universities and other companies to develop improved processing technology for ethanol. Abengoa Bioenergy is a subsidiary of the Spanish engineering firm Abengoa.	MO	U.S.
Renewable Energy	Biomass Energy	Leading	Archer Daniels Midland Co	Ethanol and biodiesel	Archer Daniels Midland Company (ADM) is principally engaged in procuring, transporting, storing, processing and merchandising products made from soybeans, corn, wheat, and cocoa . Operations are classified into three business segments: Oilseeds Processing, Corn Processing, and Agricultural Services.	IL	U.S.
Renewable Energy	Biomass Energy	Leading	Aventine Renewable Energy	Bioethanol	Aventine Renewable Energy Holdings is a leading US producer and marketer of ethanol and its byproducts, including corn gluten feed and meal, corn germ, condensed corn distillers solubles, dried distillers grain with solubles, wet distillers grain with solubles, carbon dioxide and brewers' yeast. Aventine also markets and distributes biodiesel.	IL	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Renewable Energy	Biomass Energy	Leading	Biopetrol Industries	Biodiesel	Biopetrol Industries' principal activity is to supply biodiesel and pharmaceutical glycerin produced from plant oil raw materials, particularly rapeseed and soybean. The Company's key customers include mineral oil companies, oil trading companies and large fleet operators of cars and trucks.	-	Switzerland
Renewable Energy	Biomass Energy	Leading	BIOS-BIOENERGIESYSTEME GMBH	Biogas	BIOS BIOENERGIESYSTEME is active in R&D, planning, and project implementation of processes and plants designed to generate heat and power from biomass.	-	Austria
Renewable Energy	Biomass Energy	Leading	Blue Sun Biodiesel	Biodiesel	Blue Sun Biodiesel, LLC produces and markets premium agricultural and renewable fuels products. The Company offers an alternative diesel fuel that is a blend of 20% biodiesel with 80% conventional petroleum-based fuel along with a proprietary additive package specifically suited for the High Plains region of the U.S.	CO	U.S.
Renewable Energy	Biomass Energy	Leading	BlueFire Ethanol, Inc.	Cellulosic ethanol	BlueFire Ethanol Fuels, Inc.'s goal is to develop and operate cellulosic waste-based ethanol plants for the transportation fuels market. The Company holds exclusive licenses for a patented cellulosic conversion technology and is planning the first North American waste-to-ethanol production facility, to be located in CA, as well as CA's first cellulose-to-ethanol facility.	CA	U.S.
Renewable Energy	Biomass Energy	Leading	BP	Biofuels research	BP is the world's third largest integrated oil concern and is the largest oil and gas producer in the U.S. The Company's three business segments are Exploration and Production, Refining and Marketing, and Gas, Power and Renewables. Gas, Power and Renewables activities include marketing and trading of gas and power; marketing of liquefied natural gas (LNG); natural gas liquids (NGLs), and low-carbon power generation through BP's Alternative Energy business.	-	UK
Renewable Energy	Biomass Energy	Leading	Cargill	Bioethanol; bioproducts (polylactide)	Cargill, a privately held company, is highly diversified, international provider of food, agricultural and risk management products and services. Cargill is the leading grain producer	MN	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					and one of the top bioethanol and biodiesel producers in the U.S.		
Renewable Energy	Biomass Energy	Leading	Ceres	Cellulosic ethanol and bioproducts	Ceres is a privately-held plant biotechnology company utilizing genomics technologies to identify, characterize, and produce plant varieties and hybrids for ultimate use as energy crops. Ceres is developing and plans to bring to market energy crops such as switchgrass, miscanthus, energycane and poplar for biofuels.	CA	U.S.
Renewable Energy	Biomass Energy	Leading	Chevron	Cellulose and biofuels research (partnerships with Georgia Tech, Weyerhaeuser)	Chevron, its subsidiaries, and affiliates engage in fully integrated petroleum operations, chemicals operations, mining operations of coal and other minerals, power generation, and energy services. Chevron is the #2 oil company in the U.S. Chevron Energy Solutions (CES), a wholly owned subsidiary, is focused on energy efficiency and renewable power installations, hydrogen fuel cell research and plant design, and development of cogeneration and biomass facilities.	CA	U.S.
Renewable Energy	Biomass Energy	Leading	Choren Industries	Biomass gasification	Choren is one of the world's leading gasification technology companies for solid biomass and oil-based residue feedstock. Its 'Carbo-V' process turns wood and other biomass into 'SunDiesel.' The company is active in the global synthetic fuels, biofuels, and biomass markets.	-	Germany
Renewable Energy	Biomass Energy	Leading	Cosan	Sugarcane-based bio-ethanol	Cosan is the largest sugar industrial exporter in the world and a top exporter of various specifications of ethanol. With 17 manufacturing units and capacity to grind more than 17 million tons of sugarcane, Cosan is the global leader in sugarcane byproducts manufacturing.	-	Brazil
Renewable Energy	Biomass Energy	Leading	DuPont	Biobutanol (partnership with BP)	E. I. du Pont de Nemours and Company (DuPont) offers a diverse range of products to many different markets, including the transportation, safety and protection, construction, motor vehicle, agriculture, home furnishings, medical, electronics, communications, protective apparel, and the nutrition and health markets. The company recently announced a	DE	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					partnership with BP that commits to developing biobutanol for the transportation fuels market.		
Renewable Energy	Biomass Energy	Leading	Dyadic International Inc.	Enzymes for bioethanol production	Dyadic International, Inc. is a biotechnology company that conducts R&D and manufactures products for the bioenergy, industrial enzyme and pharmaceutical industries. The Company's BioEnergy Business is focused on technologies and solutions that enable the production of cellulosic ethanol from all agricultural biomass feedstocks, such as sugar cane bagasse, distiller dried grains, wheat bran and straw, various corn and soy fibers, wood fibers and pulp streams, energy crops and other lignocellulose.	FL	U.S.
Renewable Energy	Biomass Energy	Leading	E3 BioFuels	Corn-based bioethanol	E3 BioFuel's patented closed-loop technology brings together three components: cattle feedlot manure; an anaerobic digester that turns the manure into biogas; and an ethanol plant that runs on biogas rather than on fossil fuels. The E3 BioFuels Genesis plant at Mead, NE officially began production in the spring of 2007	KS	U.S.
Renewable Energy	Biomass Energy	Leading	Iogen Biorefinery Partners	Cellulosic ethanol	Iogen Energy Corp., a Canadian firm, is one of the global leaders in cellulosic ethanol production. Iogen Biorefinery Partners, LLC investors/partners include: Iogen Energy Corporation; Iogen Corporation; Goldman Sachs; and The Royal Dutch/Shell Group. In 2007, the U.S. Department of Energy selected Iogen Biorefinery Partners' cellulosic ethanol plant proposal as one of six funded nationally. Iogen will receive \$80M; the proposed plant will be built in Shelley, Idaho, will produce 18 million gallons of ethanol annually, and will use 700 tons per day of agricultural residues including wheat straw, barley straw, corn stover, switchgrass, and rice straw as feedstocks.	ON	Canada
Renewable Energy	Biomass Energy	Leading	Midwest Grain Processors	Bioethanol	Midwest Grain Processors (MGP Ethanol) is one of the fastest growing corn-to-ethanol producers in the U.S. The Company has plant locations in Iowa and Michigan with management in Minneapolis.	MN	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Renewable Energy	Biomass Energy	Leading	Monsanto	Engineered corn for bio-ethanol	Monsanto, a global provider of agricultural products for farmers, operates in two business segments: Seeds and Genomics, and Agricultural Productivity. The Company uses biotechnology to produce seed varieties with traits that assist farmers in controlling insects and weeds. The Company also manufactures herbicides for the agricultural and residential markets. Renewable energy efforts underway at Monsanto cover a wide range of activities, including improving the quality of corn and soybeans for the production of biofuel.	MO	U.S.
Renewable Energy	Biomass Energy	Leading	Neste Oil	Biodiesel	Neste Oil Corporation is a refining and marketing company focusing on advanced-technology, environmentally clean transportation fuels. The Company's primary products are gasolines, diesel fuels, aviation fuels, marine fuels, heating oils, heavy fuel oils, base oils, lubricants, traffic fuel components, solvents, LPGs and bitumen. Business units include oil refining, biodiesel, base oils, components, engineering services, and research & technology. A proprietary Neste Oil technology can use a flexible mix of vegetable oil and animal fat to produce premium-quality biodiesel.	-	Finland
Renewable Energy	Biomass Energy	Leading	Novozymes	Bioethanol	Novozymes conducts biotechnological research, produces, and sells enzymes and microbes. The enzymes business accounts for 95% of the Company's sales and is divided into four categories: detergent, technical, food and feed enzymes. Biomass-related enzyme products include fiber and starch modification enzymes.	-	Denmark
Renewable Energy	Biomass Energy	Leading	Organic Fuels	Biodiesel	Organic Fuels specializes in the manufacture and distribution of biodiesel. The Company has one plant, located in Galena Park, TX.	TX	U.S.
Renewable Energy	Biomass Energy	Leading	Pacific Biodiesel	Grease trap biodiesel	Pacific Biodiesel specializes in community-scale production of biodiesel. Its community-based biodiesel production model is built around the utilization of local feedstock (such as grease trap waste), local fuel production and local delivery of fuel that meets the standards of ASTM (American Society for Testing and Meas-	HI	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					urements). The Company's first production plant, built in Maui in 1996, was the first retail biodiesel pump in the country.		
Renewable Energy	Biomass Energy	Leading	Pacific Ethanol	Corn ethanol; cellulosic ethanol	Pacific Ethanol is a leader in producing and marketing ethanol. The Company has two operational plants and four currently under construction. Pacific Ethanol is also working to identify and develop other renewable fuel technologies, such as cellulose-based ethanol production and biodiesel.	CA	U.S.
Renewable Energy	Biomass Energy	Leading	Petrobras	Bioethanol	Petróleo Brasileiro S.A. (Petrobras) is a Brazilian oil company that owns oil refineries and oil tankers and produces more than 2 million barrels of oil equivalent per day. It is also a major distributor of oil products. Petrobras' biofuels strategy involves production of ethanol from sugarcane and adaptation of ethanol facilities to accommodate biodiesel production.	-	Brazil
Renewable Energy	Biomass Energy	Leading	POET	Cellulosic ethanol	POET is a leading producer of ethanol in the U.S. The Company has a network of 20 plants in five states producing over one billion gallons of ethanol annually.	SD	U.S.
Renewable Energy	Biomass Energy	Leading	Range Fuels	Cellulosic ethanol	Range Fuels uses a thermochemical process to convert cellulosic biomass into fuel-grade ethanol. Biomass sources includes all plant and plant-derived material, such as wood, switch grass, corn stover, and miscanthus grass. The Company's is planning its first plant to be located in Soperton, GA.	CO	U.S.
Renewable Energy	Biomass Energy	Leading	Renewable Energy Group	Biodiesel	Renewable Energy Group (REG) is a market leader in the production and sales of soy-based biodiesel. In 2007, REG broke ground on two 60 million gallon/year biodiesel plants, which it will own and operate.	IA	U.S.
Renewable Energy	Biomass Energy	Leading	Safe Renewables Corporation	Biodiesel	Safe Renewables Corporation supplies biodiesel to the transportation fuels sector. The Company operates one of the largest biodiesel refineries in North America at its primary facility, a 24 million gallon/year plant located in Conroe, Texas.	TX	U.S.
Renewable En-	Biomass Energy	Leading	Suncor Energy	Biodiesel	Canada-based Suncor Suncor produces oil and	AB	Canada

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy			Products		natural gas but is also investing heavily in wind power and ethanol. The Company's St. Clair ethanol plant in Ontario has the capacity to produce 200 million liters of ethanol annually from approximately 20 million bushels of corn, making it the largest such facility in Canada.		
Renewable Energy	Biomass Energy	Leading	Syngenta	Enzymes for converting cellulosic biomass	Syngenta is one of the world's largest agrochemical companies. The company produces crop protection products (insecticides, herbicides, fungicides), field crop seeds (soybeans), vegetable seeds (corn, beans, tomatoes), and flowers. Lately, Syngenta has been responding to interest in renewable energy by designing seeds engineered for improved biofuel production.	-	Switzerland
Renewable Energy	Biomass Energy	Leading	U.S. BioEnergy	Corn-based bioethanol	US Bioenergy is a leading producer of ethanol in the U.S. The Company operates four ethanol plants and has three under construction, each of which produce ethanol from distillers grain and corn. Altogether, these plants will have an expected ethanol production of 600 million gallons per year.	MN	U.S.
Renewable Energy	Biomass Energy	Leading	VeraSun Energy	Corn-based bioethanol	VeraSun is one of the nation's leading producers of ethanol, maintaining seven production facilities in Iowa, Indiana, Minnesota, and South Dakota. The Company also sells wet and dried distillers grain for cattle feed.	SD	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Algatechnologies	Microbe-based biofuels	Alga Technologies (Algatech) was founded in 1999 to develop and commercialize Astaxanthin and other microalgae-derived products for the nutraceuticals and cosmeceuticals industry. Since then, the Company has expanded its product offerings to include algae biomass for the biofuels industry.	-	Israel
Renewable Energy	Biomass Energy	Small/ Emerging	Amyris Biotech	Engineering microbes to make hydrocarbons	Amyris Biotechnologies leverages strengths in synthetic biology to develop solutions in infectious diseases and in renewable biofuels. The Company is developing a large-scale fermentation process to renewably produce next-generation biodiesel that has more beneficial properties than conventional biodiesel.	CA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Renewable Energy	Biomass Energy	Small/ Emerging	Aurora BioFuels	Microbe-based biofuels	Aurora BioFuels focuses on utilizing microalgae to generate bio-oil, which can be converted into biodiesel.	CA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	C3 BioEnergy	Biopropane from corn or sugarcane	C3 BioEnergy is an early-stage biofuels technology company that produces propane, propylene, and hydrogen from renewable biomass resources.	MA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Global Green Solutions	Microbe-based biofuels	Global Green Solutions, Inc. develops and implements "ecotechnology" solutions for renewable energy and the reduction of greenhouse gas emissions. Technologies focus on the conversion of algae to biofuel, wood waste to low-cost steam, and pipeline emissions reductions.	BC	Canada
Renewable Energy	Biomass Energy	Small/ Emerging	GreenFuel Technologies	Microbe-based biofuels	GreenFuel Technologies Corporation is a pioneer in bioreactor technology that uses algae to convert smokestack carbon dioxide into biofuels and other byproducts.	MA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Imperium Renewables	Microbe-based biofuels	Imperium Renewables Inc. (IRI) specializes in next-generation biodiesel refining and manufacturing technology. The Company develops proprietary technology and processes in both the production facility and oil feedstock areas of the biodiesel value chain. IRI also operates Seattle Biodiesel, the first company in the Pacific Northwest to open and operate a commercial-scale biodiesel refinery producing fuel that meets or exceeds ASTM (American Society for Testing and Measurements) specifications.	WA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	LS9	Engineering microbes to make hydrocarbons	LS9 Inc., "The Renewable Petroleum Company," combines core competencies in industrial biotechnology and synthetic biology to produce renewable biofuels and industrial biochemicals. The Company's Renewable Petroleum biofuels will be derived from diverse agricultural feedstocks.	CA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Masada	Producing ethanol from municipal waste	Masada Resource Group, LLC (Masada) specializes in municipal waste-to-ethanol technology. In late 2008, Masada will open the Orange Recycling and Ethanol Production Facility in Middletown, NY, which will be the nation's first commercially owned municipal solid waste-to-	AL	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					ethanol plant.		
Renewable Energy	Biomass Energy	Small/ Emerging	Prometheus Energy	Biogas (converting landfill methane to liquefied natural gas)	Prometheus Energy produces, sells and distributes liquid natural gas derived from stranded and waste sources of methane. Such sources include landfill sites, stranded gas wells, wastewater treatment facilities and coal mines.	WA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Solazyme	Microbe-based biofuels and bio-products	Solazyme is an algal biotechnology company specializing in synthetic, directed evolution of specific algae to create pharmaceuticals, nutraceuticals, chemicals, and biofuel.	CA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Solix Biofuels	Microbe-based biofuels	Solix Biofuels is start-up company, working in partnership with Colorado State University to develop technology to produce biodiesel from mass-produced algae. Solix plans to commercialize its photo-bioreactor system within the next few years.	CO	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	SunEthanol	Engineering microbes to make hydrocarbons	SunEthanol is a new company that is commercializing a proprietary cellulosic ethanol production technology. The technology will be a flexible, low-cost, commercial-scale consolidated bio-processing (CBP) technology that can be used with a variety of feedstocks as well as low-grade agricultural waste.	MA	U.S.
Renewable Energy	Biomass Energy	Small/ Emerging	Verenium	Corn-based ethanol, cellulosic ethanol	Verenium specializes in enzymatic and fermentation technology to produce biofuels from cellulosic biomass. The Company owns a pilot cellulosic ethanol facility as well as a demonstration facility in Louisiana.	MA	U.S.
Renewable Energy	Wind Energy	Leading	Acciona	Wind farms	Acciona Energy is the largest developer, owner and operator of wind farms in the world, with 164 wind farms in nine countries representing over 4,500 megawatts (MW) of wind power installed or under construction.	-	Spain
Renewable Energy	Wind Energy	Leading	DeWind	Large wind turbines	DeWind wind energy converters meet the highest technical standards. The highly effective DeWind concept combines premium components for the manufacture of effective, grid-friendly and reliable wind energy converters.	-	Germany
Renewable Energy	Wind Energy	Leading	Ecotecnia	Large wind turbines	ECOTÉCNIA has been working in the wind power sector since 1981, designing, manufacturing and operating its own wind turbines and	-	Spain

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					the wind farms which it constructs as 'turnkey' ready-to-use installations for its clients.		
Renewable Energy	Wind Energy	Leading	Eozen	Large wind turbines	EOZEN's main activity is manufacture of wind turbines and large blades.	-	Spain
Renewable Energy	Wind Energy	Leading	FPL Energy	Wind power generation; wind farm ownership and operations	FPL Energy is a leading clean energy provider with natural gas, wind, solar, hydroelectric and nuclear power plants in operation across the nation. We are the U.S. leader in wind energy generation. Approximately 30 percent of our generating capacity comes from wind power, representing more than 4,000 net megawatts.	FL	U.S.
Renewable Energy	Wind Energy	Leading	Fuhrlander	Large- and mid-sized wind turbines; wind farms; consulting	With a wide turbine range – Fuhrlander is currently manufacturing turbines from 30 kW to 2.5 MW – we have the right wind energy turbine for every location in our product range. Our robust turbines are particularly proving themselves even in difficult wind conditions.	-	Germany
Renewable Energy	Wind Energy	Leading	Gamesa Corporacion Tecnologica	Large wind turbines; wind farms	Gamesa generates electric energy of renewable origin, essentially based on the promotion and running of wind farms, the manufacture of wind turbines and the providing of advanced services to the technology for energy sustainability sector.	-	Spain
Renewable Energy	Wind Energy	Leading	GE Energy	Large wind turbines incl. offshore	GE is one of the world's leading wind turbine suppliers. With over 7,500 worldwide wind turbine installations comprising more than 9,800 MW of capacity, our knowledge and expertise spans more than two decades. Our current product portfolio includes wind turbines with rated capacities ranging from 1.5 to 3.6 megawatts and support services ranging from development assistance to operation and maintenance.	GA	U.S.
Renewable Energy	Wind Energy	Leading	Goldwind Science & Technology	Large wind turbines	Goldwind plays a key role in the development of the Chinese wind industry. In less than 10 years since its foundation in 1997, the company has become the number one supplier of wind turbines in China. Until today, Goldwind has sold almost 1674 wind turbines with an overall capacity of around 1388 MW.	-	China
Renewable En-	Wind Energy	Leading	Harakosan	Large wind	2MW permanent magnet direct drive wind	-	Nether-

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy				turbines incl. offshore	turbines designed for near-shore and offshore applications.		lands
Renewable Energy	Wind Energy	Leading	Mitsubishi Power Systems	Large wind turbines	Since the 1980s, Mitsubishi has pioneered the development of high-efficiency wind turbines that make environmentally-benign wind generation more productive and profitable. Currently, more than 1380 Mitsubishi wind turbines are in operation worldwide, with an impressive record of availability. MPS brings Mitsubishi wind turbines to the Americas in a range of available ratings -- 200kW, 300kW, 500kW, 600kW and 1000kW – with 2000kW designs already in development.	-	Japan
Renewable Energy	Wind Energy	Leading	Multibrud	Large offshore wind turbines	Multibrud is a manufacturer of wind energy converters for offshore projects. The company develops and produces the 5MW offshore plant in Bremerhaven/Germany, a location which also offers best conditions for installation, service and maintenance on the high seas.	-	Germany
Renewable Energy	Wind Energy	Leading	Nordex	Large wind turbines	With the serial produced multi-megawatt wind turbines Nordex N90 and N80 as well as the powerful megawatt turbines Nordex S70 and Nordex S77, Nordex is able to offer high-efficiency wind turbines for onshore use. For the rapidly developing international markets we also offer the powerful small unit N60.	-	Germany
Renewable Energy	Wind Energy	Leading	REpower Systems	Large offshore wind turbines	REpower Systems AG is one of the leading turbine producers in the German wind energy sector with a market share in excess of 10%. In addition to the development, licensing, production and sale of reliable, state-of-the-art turbines, REpower offers intelligent professional services such as our comprehensive maintenance and service packages.	-	Germany
Renewable Energy	Wind Energy	Leading	Siemens	Large wind turbines incl. offshore	Siemens wind turbines are the preferred solution of leading utilities and developers for large demanding on- and offshore projects, not only because of their robustness but also due to their reliability and productivity. Siemens produces turbines that range in size and characteristics.	-	Germany

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Renewable Energy	Wind Energy	Leading	Suzlon Energy	Large wind turbines; full wind solutions (incl. wind farms)	Suzlon specializes in providing total solutions in Wind Power Generation with cohesive integration of consultancy, design, manufacturing, installation, operation and maintenance services. Suzlon has been ranked as the fifth leading wind turbine manufacturer in the world, and has developed some of the largest wind parks in Asia. Suzlon is today building what will be among the world's largest wind parks of its kind at 1,000 MW capacity.	-	India
Renewable Energy	Wind Energy	Leading	Vestas	Large wind turbines incl. offshore; full wind solutions	Vestas is the world's leading producer of high-tech wind power systems. Vestas' core business comprises the development, manufacture, sale, marketing and maintenance of wind power systems that use wind energy to generate electricity.	-	Denmark
Renewable Energy	Wind Energy	Small/ Emerging	Aerotecture International	Micro wind turbines for urban rooftops	Aerotecture International seeks to radically transform the dominant paradigm of energy production and consumption around the globe. Blending the concepts of aerodynamics and architecture, Aeroturbines are wind electric turbines designed to be attached to buildings or integrated into the very form of buildings. With Aeroturbines, buildings and other structures will not only consume electricity, but produce it on-site.	IL	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	AeroVironment	Micro wind turbines for urban rooftops	AeroVironment develops and produces Unmanned Aircraft Systems and Efficient Electric Energy Technologies. In a varied line of products, AV has developed small, micro wind turbines for use in an urban environment.	CA	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	Austin Energy	Wind power generation	Austin Energy is a community-owned electric utility and a department of the City of Austin. Austin Energy's portfolio of energy efficiency programs is among the most comprehensive in the nation. The US leader in Green Power, mostly wind power.	TX	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	Bergey Windpower	Small wind turbines	Bergey Windpower is one of the world's leading suppliers of small wind turbines. With 30 years experience, installations in 49 U.S. States and more than 90 countries, and an international network of 600 dealers, we have the products	OK	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					and experience to put the wind to work for you.		
Renewable Energy	Wind Energy	Small/ Emerging	Clipper Windpower	Large wind turbines	Clipper Windpower, Inc. is a rapidly growing wind energy technology company which manufactures the 2.5 MW Liberty turbine and actively develops wind power generating projects in the Americas and Europe. The patented technology of the Liberty turbine developed by Clipper substantially increases the efficiency of wind-generated electricity, providing a formidable increase in the potential geographic areas for turbine deployment.	CA	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	Energy Maintenance Service	Products and services for the wind industry	Energy Maintenance Service, LLC (EMS) provides quality, cost effective products and services to the wind industry. Our client base includes manufacturers, developers, owners, operators and industry consulting firms from throughout the world. As an independent service provider, we are committed to providing solutions that are tailored to the needs of our broad customer base.	SD	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	Enertech	Large- and mid-size wind turbines	Enertech is committed to providing the best equipment available to capture the tremendous renewable energy of our planet. Enertech develops large and mid-sized wind turbines.	KS	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	Horizon Wind Energy	Wind power generation; wind farm ownership and operations	Horizon Wind Energy, formerly Zilkha Renewable Energy, develops, constructs, owns, and operates wind farms throughout the United States. Horizon-developed wind farms operate in New York, Iowa, Pennsylvania, Washington and Oklahoma, and the company has projects under construction in Minnesota, Oregon, Texas and Illinois. On July 2, 2007, Energias de Portugal, S.A. ("EDP"), a major Portuguese utility, acquired 100% of the share capital of Horizon Wind Energy LLC from Goldman Sachs.	TX	U.S.
Renewable Energy	Wind Energy	Small/ Emerging	Southwest Windpower	Small single wind turbines for residential market	For 20 years, Southwest Windpower has been bringing low-cost, reliable wind energy to the world. As the world's largest producer of small wind generators, we've pioneered new technologies to make renewable energy simple.	AZ	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Renewable Energy	Wind Energy	Small/ Emerging	Windflow Technology	Large wind turbines; wind farm project management	<u>Windflow Technology Ltd., based in Christchurch, New Zealand, is a global innovator in wind power turbine design, development and manufacturing. Windflow engages in wind farm project management and does not manufacture its own turbines -- all manufacturing is outsourced.</u>	-	New Zealand
Renewable Energy	Wind Energy	Small/ Emerging	Windside Wind Turbines	Small wind turbines for harsh conditions	Windside wind turbines for battery charging are a unique and ecological solution for energy production wherever energy is needed. They have been developed to meet the requirements of the most demanding professional use in the harshest of environments: Their unique design features ensure, high efficiency, long life span, durability and an absolute minimum of maintenance.	-	Finland
Renewable Energy	Solar Energy	Leading	Alanod	Reflecting and absorption surfaces for solar thermal applications	Alanod is the global leader in the manufacture of aluminum high-performance reflecting surfaces and selective absorption surfaces on aluminum or copper for solar thermal applications.	-	Germany
Renewable Energy	Solar Energy	Leading	Amonix	High-concentration PV systems	Amonix developed a highly efficient silicon solar cell and is the global leader in the design and manufacture of proprietary High Concentration Photovoltaic (HCPV) power generation systems for large commercial and utility-scale applications.	CA	U.S.
Renewable Energy	Solar Energy	Leading	BP Solar	PV systems	BP Solar is a global company with over 2200 employees focused on the design, manufacture and marketing of solar electric systems for a wide range of applications in the residential, commercial and industrial sectors. The Company has installations in over 160 countries and manufacturing facilities in the U.S., Spain, India and Australia.	MD	U.S.
Renewable Energy	Solar Energy	Leading	Central Electronics	Solar PV systems	Central Electronic has two business unit: Special Electronics and Solar Photovoltaic. The Company is the pioneer and the largest manufacturers of Solar-Photovoltaic cells, modules and systems in India. Its integrated production facility manufactures mono-crystalline	-	India

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					silicon solar cells and modules with using screen-printing technology.		
Renewable Energy	Solar Energy	Leading	CentroSolar Group AG	PV systems	The CentroSolar group of companies is the European market leader for photovoltaic systems for private households. CentroSolar Group's two principal activities are production of solar integrated photovoltaic systems and production of solar components, such as glass covers and mounting systems.	-	Germany
Renewable Energy	Solar Energy	Leading	Conergy AG	Solar thermal systems, solar water pumps, PV systems	Conergy AG is one of the leading solar energy companies in Europe. The Company develops, produces and sells system components related to solar photovoltaics and solar thermal power. Conergy also produces and sells wind energy systems.	-	Germany
Renewable Energy	Solar Energy	Leading	ET Solar	Polycrystalline PV cells and modules	ET solar specializes in silicon ingot and wafer production. The Company is also developing capabilities in dual-axis solar trackers, inverters, and some Building Integrated Photovoltaic (BIPV) systems.	-	China
Renewable Energy	Solar Energy	Leading	Evergreen Solar	Multi-crystalline silicon solar panels	Evergreen Solar develops, manufactures, and markets solar power products primarily in Europe and the U.S. The Company uses a proprietary technology process in manufacturing crystalline silicon wafers. Evergreen Solar offers solar panels, solar cells, and solar systems.	MA	U.S.
Renewable Energy	Solar Energy	Leading	First Solar	Cadmium telluride-based thin films	First Solar designs and manufactures solar modules using a thin-film semiconductor technology that incorporates cadmium telluride as the active material. The Company manufactures its solar modules on high-throughput production lines in manufacturing plants located in Ohio and Germany (planned).	AZ	U.S.
Renewable Energy	Solar Energy	Leading	GE Energy	PV modules	GE Energy's renewable energy portfolio includes solar, hydropower, wind turbine, and geothermal technology. The Company's solar products include solar modules or pre-packaged systems for residential or commercial applications.	GA	U.S.
Renewable En-	Solar Energy	Leading	Green Energy	Solar wafers;	Green Technology Company is a manufacturer	-	Taiwan

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy			Technology	thin-film solar cells	of solar water heaters and accessories such as heat exchangers, heat pumps, and circulating pumps. The Company's primary product is an all-glass vacuum tube type solar collector water heater.		
Renewable Energy	Solar Energy	Leading	Heliodyne	Solar thermal products	Heliodyne is a leader in solar thermal technology. Products include solar water heaters for domestic hot water heating, space heating, or commercial processes.	CA	U.S.
Renewable Energy	Solar Energy	Leading	Kyocera Solar	PV modules	Kyocera Solar, of Japan's Kyocera Group, is one of the world's largest vertically integrated producers and suppliers of solar energy products. Kyocera Solar develops and sells solar-powered electric systems for rural homes, recreational vehicle sites, remote telecom and pipeline monitoring equipment, and traffic signal locations.	AZ	U.S.
Renewable Energy	Solar Energy	Leading	Mitsubishi	Polycrystalline PV modules	Mitsubishi Electric polycrystalline photovoltaic modules are designed for both commercial and domestic applications suitable for grid-connected systems. Mitsubishi also offers photovoltaic inverters and solar installations.	-	Japan
Renewable Energy	Solar Energy	Leading	Motech	Crystalline PV cells	Motech Industries, Inc. of Taiwan specializes in the R&D, manufacturing, marketing, and sales of mono-crystalline silicon and multi-crystalline silicon solar cells and solar electricity-related products. The Company is in the top 10 solar cell producers worldwide.	-	Taiwan
Renewable Energy	Solar Energy	Leading	Nanjing CEEG PV Tech	Mono and multi-crystalline PV cells	China Sunergy, via its operating subsidiary Nanjing PV, specializes in the production of photovoltaic cells used in the manufacture of solar energy panels. The Company is a leading manufacturer of mono- and multi-crystalline solar cell products in China for sale to module manufacturers and system integrators and is also conducting research into development of new types of solar cells, including negatively charged "N-type" cells.	-	China
Renewable Energy	Solar Energy	Leading	Photowatt	PV plates, cells and modules	Photowatt is a vertically integrated company that produces silicon ingots to make plates, cells, and multi-crystalline modules. The Company is one of the largest manufacturers of	-	France

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					photovoltaic components in Europe.		
Renewable Energy	Solar Energy	Leading	PowerFilm	Flexible thin-film solar panels	PowerFilm, Inc. focuses on the R&D and manufacture of solar cells and modules. The Company develops, manufactures, and sells a range of thin-film, flexible solar panels in a variety of sizes and configurations. The production process entails roll-to-roll manufacturing of solar cells using an amorphous silicon sunlight absorber layer deposited on a flexible plastic substrate.	IA	U.S.
Renewable Energy	Solar Energy	Leading	Q Cells	Mono and Multi-crystalline PV cells	Q-Cells AG specializes in the development, production and sale of mono- and polycrystalline, silicon-based solar cells. The Company supplies manufacturers of solar modules. Its subsidiaries are involved in the commercialization of thin film technologies, production of silicon thin-film modules, and copper indium gallium diselenide (CIGS) photovoltaics.	-	Germany
Renewable Energy	Solar Energy	Leading	Sanyo	Mono-crystalline and thin-film PV cells	Sanyo Electric Co. is among the top four leaders worldwide in production of solar cells. The Company is also active in solar cell technology R&D and recently broke its own record for the world's highest energy conversion efficiency in practical-size crystalline silicon-type solar cells composed of a single, thin crystalline silicon wafer surrounded by ultra-thin amorphous silicon layers.	-	Japan
Renewable Energy	Solar Energy	Leading	SCHOTT Solar	PV modules; solar thermal receivers	SCHOTT Solar manufactures and markets photovoltaic systems to residential, commercial, industrial clients, governmental, and utility companies. Products include crystalline and thin-film modules, modules for PV building solutions, and on-grid and off-grid applications.	CA	U.S.
Renewable Energy	Solar Energy	Leading	Sharp	Polycrystalline PV modules	Sharp is the world's largest manufacturer of photovoltaic solar cells. The Company recently introduced new thin-film solar modules and has also begun selling concentrated photovoltaic systems.	-	Japan
Renewable Energy	Solar Energy	Leading	Solargenix Energy	Solar thermal energy systems	Solargenix is in the business of maximizing patented solar collection technology. The Company's patents in solar thermal products	NC	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					and systems are based on the science of non-imaging optics. Solargenix systems can be stand-alone or integrated into greenhouse roof assemblies, covered parking areas, covers over fresh water canals, and industrial and commercial buildings.		
Renewable Energy	Solar Energy	Leading	Solarworld AG	Multi-crystalline silicon wafers, PV cells and modules	SolarWorld researches, develops, produces, and sells solar energy collection modules for residential to industrial applications. SolarWorld's Wafer and Raw Materials division is managed by subsidiary Deutsche Solar AG.	-	Germany
Renewable Energy	Solar Energy	Leading	Spire	Solar energy equipment	Spire is an integrated company that develops, manufactures and markets engineered products and services in three principal business areas: solar equipment and systems, biomedical devices, and optoelectronics. In the solar area, Spire specializes in equipment for the production of terrestrial photovoltaic modules from solar cells. The Company also provides custom and Building Integrated Photovoltaic (BIPV) modules, standalone emergency power back-up, and electric power grid-connected distributed power generation systems employing PV technology.	MA	U.S.
Renewable Energy	Solar Energy	Leading	Stirling Energy Systems	Concentrating solar power	Stirling Energy Systems (SES) develops equipment for utility-scale renewable energy power plants and distributed electric generating systems. SES holds the key patents on solar concentrator systems technologies. With its strategic partners, including NASA, the U.S. Department of Energy, and The Boeing Company, SES aims to build and operate renewable energy power plants.	AZ	U.S.
Renewable Energy	Solar Energy	Leading	Sun Energy Systems	Solar water heating systems	Sun Energy Systems is the largest manufacturer of solar water heating systems and wood-fired water heaters in India. The Company designs, manufactures, supplies, and installs solar heating systems for both domestic and industrial applications.	-	India
Renewable Energy	Solar Energy	Leading	SunEdison	Solar energy system installations and	SunEdison is the largest solar electricity provider in North America. The Company supplies solar power to residences, companies such as	MD	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
				operations	Wal Mart and Staples, utilities such as the Sacramento Municipal Utility District, and government agencies such as the California Department of Corrections.		
Renewable Energy	Solar Energy	Leading	SunPower	Solar multi-crystalline PV cells and panels	SunPower Corporation (SunPower) designs, develops, manufactures, and sells solar electric power products, systems and services. The Company's solar power products include solar cells, solar panels, inverters, and structures for mounting multi-megawatt solar power plant applications to track the sun.	CA	U.S.
Renewable Energy	Solar Energy	Leading	Suntech Power	PV modules	Suntech Power Holdings Co., Ltd. (Suntech) is the largest solar module provider worldwide. Suntech designs, develops, manufactures and markets a variety of photovoltaic cells and modules and provides PV system integration services for a range of residential, commercial, industrial and public utility applications.	-	China
Renewable Energy	Solar Energy	Leading	SunWize Solar	PV systems	SunWize Technologies, LLC, a 100% subsidiary of Mitsui & Co., Ltd. specializes in the design and manufacture of integrated solar photovoltaic systems. Products include manufactured specialty modules, prepackaged units, and site-installed systems.	NY	U.S.
Renewable Energy	Solar Energy	Leading	United Solar Ovanic	Thin-film solar cells	United Solar Ovanic, a wholly owned subsidiary of Energy Conversion Devices, Inc., is the world's leader in thin-film solar technologies and the manufacture of thin-film solar electric modules and laminates for residential, commercial, and government applications. The Company was recently awarded a \$4.6M, three-year agreement with the U.S. Department of Energy for the development of low-cost, building-integrated photovoltaic systems.	MI	U.S.
Renewable Energy	Solar Energy	Leading	Worldwater & Solar Technologies Corp.	Solar pumps; solar electrical systems	Worldwater & Solar Technologies is an international solar engineering and water management company. Solar energy products include solar-powered water pumps, refrigeration, and purification systems.	NJ	U.S.
Renewable Energy	Solar Energy	Leading	Yingli Solar	PV cells and modules	Yingli is one of the leading vertically integrated photovoltaic product manufacturers in China. The Company's products include polysilicon	-	China

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					wafers and ingots that are used to build PV cells and modules, which are in turn incorporated into solar energy systems.		
Renewable Energy	Solar Energy	Small/ Emerging	Advent Solar	Back contact solar cells/modules	Advent Solar, Inc., founded in 2002, is a manufacturer of advanced technology solar cells and modules based on a proprietary cell design known as "emitter-wrap-through." This design allows electric power to flow to the back surface of the cell where electric contacts carry away the current, unlike conventional cells with contacts on the front that inefficiently block sunlight.	NM	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Applied Materials	Wafer-based, flexible, and thin-film solar cells	Applied Materials, Inc. is the world's largest maker of semiconductor production equipment. With its 2006 acquisition of Applied Films, the company moved into the market for equipment used in making solar power cells.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	BlueTec	Absorber bands for solar systems	BlueTec is a German company specializing in the industrial manufacture of coating technologies. The Company produces solar collectors and absorbers used by the solar industry.	-	Germany
Renewable Energy	Solar Energy	Small/ Emerging	Energy Innovations	High-concentration PV systems	Energy Innovations has claimed the world's first high-concentration PV system designed for both commercial rooftop and ground-mounted applications. Additional technologies include custom-designed lenses and a unique self-powered two-axis tracking system.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Energy Photovoltaics	Thin-film solar cells	Energy Photovoltaics, Inc. (EPV) is a solar energy company that designs, develops, manufactures, and markets low-cost amorphous silicon thin-film photovoltaic solar modules for the renewable energy market. EPV currently offers several varieties amorphous silicon thin film modules based upon proprietary manufacturing technology.	NJ	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Greenray	Integration systems for PV modules and inverters	GreenRay is developing technology for simplifying the conversion of solar-generated electricity into a form that can flow directly into home appliances and lighting. The Company is designing a high-powered, ultra-high-efficiency solar module that contains an inverter, eliminating the need to install a separate inverter	MA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					and facilitating installation by homeowners.		
Renewable Energy	Solar Energy	Small/ Emerging	Heliovolta	Thin-film CIGS (copper indium gallium selenide)	Heliovolta's patented FASST™ method produces a photovoltaic thin film that is 100 times thinner than traditional films currently on the market. The Company's technology relies on CIGS (Copper Indium Gallium Selenide) rather than on silicon.	TX	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Konarka Technologies	Flexible PV material	Konarka is focused on the development of photovoltaic cells of lightweight, low-cost, flexible plastic. The materials are made from conducting polymers and nano-engineered materials that can be coated or printed onto a surface. The Company's photovoltaic technology can utilize a wider range of the light spectrum than conventional solar cells, absorbing both sunlight and indoor light.	MA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Miasolé	Thin-film solar cells	Miasolé manufactures a thin-film photovoltaic cell comprised of CIGS (copper indium gallium diselenide) photoactive material. The Company specializes in utilizing technologies proven in the computer hard disk industry for the deposition of CIGS semiconductor films on a large scale.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Nanosolar	Printed thin-film solar cells	Nanosolar has developed proprietary, high-yield, high-throughput thin-film process technology that enables the printing of solar cells that are efficient, durable, and low-cost. The Company is currently focused on building the world's largest thin-film solar factory and has selected manufacturing sites located in California and in Germany.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Nanosys	Flexible solar cells	Nanosys' core technology, which is based on inorganic nanostructures, is used for the development of products and solutions for multiple industries including flexible electronics, memory products, life sciences research, fuel cells, and solar cells. Of note, the Company is capable of developing a new type of solar cell that is configured like a light weight, flexible plastic.	CA	U.S.
Renewable En-	Solar Energy	Small/	Pacific So-	Concentrator	Pacific Solartech (PST) is develops and manu-	CA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy		Emerging	IarTech	crystalline silicon-based PV modules	factures concentrator photovoltaic (PV) modules for applications from utility-scale solar power plants to remote-power and grid-connected power systems. PST's core technology relies on dome-shaped lenses for concentrating sunlight and an advanced passive cooling design that dissipates heat more effectively than conventional flat panel PV modules.		
Renewable Energy	Solar Energy	Small/ Emerging	REC Group	Solar-grade silicon production; crystalline wafers, PV cells, modules	REC is an integrated solar energy company with business activities in three areas. REC Silicon produces silicon materials for the PV industry and for a limited number of electronics customers; REC Wafer produces multi- and mono-crystalline wafers for the PV industry; and REC Solar produces solar cells and solar modules.	-	Norway
Renewable Energy	Solar Energy	Small/ Emerging	SkyFuel	CSP technologies	SkyFuel designs and operates large-scale solar plants that use Concentrating Solar Power (CSP) to produce steam for power generation, desalination, waste water treatment, and other industrial applications. The solar plants can be integrated into existing facilities or be designed and built as stand-alone solar power plants.	NY	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Solaicx	Single crystal silicon wafers	Solaicx specializes in the manufacture of low-cost, high-efficiency single-crystal silicon wafers for the photovoltaic industry's major solar cell and module manufacturers. Specifically, Solaicx has developed a proprietary single crystal silicon wafer production system for production of Czochralski (CZ) m-Si ingots.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Solaria	Solar cells requiring less silicon	Solaria's technology platform involves the application of semiconductor and optics techniques to the production of low-concentration solar PV multiplying technology that produces twice the number of PV cells from the same amount of silicon material, essentially creating two silicon solar cells from one.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	SolFocus	Concentrator germanium-based PV modules	SolFocus' concentrating photovoltaic (CPV) technology combines the efficiency of multi-junction solar cells with patented high concentration, compound-reflective optical design. The Company's technology uses 1/1000 the	CA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					active material of traditional PV systems.		
Renewable Energy	Solar Energy	Small/ Emerging	Soliant	Solar concentrators	Soliant Energy, Inc., formerly known as Practical Instruments, designs and manufactures concentrating photovoltaic modules for commercial and residential applications. In early 2007, Soliant was awarded \$4M from the US Department of Energy's Technology Pathway Partnerships program for the development of the Heliotube™ product platform, a high-efficiency, low-cost concentrating solar panel that is optimized for the rooftop. Heliotube's concentrators have integrated tracking built into the panel.	CA	U.S.
Renewable Energy	Solar Energy	Small/ Emerging	Spectrolab	New materials for solar cells	Spectrolab, founded in 1956, is a global leader in the manufacturer and supply of solar cells and panels to the space industry. The Company's product portfolio includes terrestrial concentrator solar cells and modules, searchlight systems, solar simulators and photodetector products.	CA	U.S.
Renewable Energy	Fuel Cells (Micro)	Leading	Angstrom Power	"Micro Hydrogen" fuel cells for portable applications; prototype stage	In response to "endless" demand for powering portable electronics and cell phones, Angstrom Power is developing a unique Micro Hydrogen™ fuel cell technology, which can provide high energy density and fast "recharge" capability, as well as environmental benefits compared to the incumbent battery technologies. Angstrom Power fuel cells run off stored hydrogen and takes oxygen from the air. Angstrom Power's fuel cell technology is innovative, adaptable and scalable.	BC	Canada
Renewable Energy	Fuel Cells (Micro)	Leading	Jadoo Power Systems	Portable fuel cells, commercially available	Jadoo is the world's largest supplier of portable fuel cells, and the only company of its kind currently shipping commercial product. After perfecting its Proton Exchange Membrane-based fuel cell, Jadoo developed an integrated power system around this technology, and trademarked and patented the key components.	CA	U.S.
Renewable Energy	Fuel Cells (Micro)	Leading	Millennium Cell	Micro fuel cells using hydrogen	Millennium Cell develops hydrogen battery technology through a patented chemical process that safely stores and delivers hydrogen	NJ	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
				technology for portable applications	energy to power portable devices. The borohydride-based technology can be scaled to fit any application requiring high energy density for a long run time in a compact space.		
Renewable Energy	Fuel Cells (Micro)	Leading	MTI MicroFuel Cells	Developing micro DMFCs; power packs for portable electronics	MTI Micro Fuel Cells Inc., a subsidiary of Mechanical Technology Inc. develops and manufactures advanced cord-free rechargeable power pack technology for portable electronics. MTI Micro has developed a patented, miniaturized proprietary direct methanol fuel cell (DMFC) technology called Mobion®, which generates electrical power using 100% methanol as fuel.	NY	U.S.
Renewable Energy	Fuel Cells (Micro)	Leading	Samsung	DMFC (micro) for portable electronics	Samsung's Advanced Institute of Technology (SAIT) focuses on DMFC (Direct Methanol Fuel Cell) for mobile devices, and PEMFC (Proton Exchange Membrane Fuel Cell) for residential power supply. SAIT is developing mobile device DMFC for notebook PCs, ODA, and cellular phone applications; and residential PEMFC that can utilize both heat and electricity.	-	S. Korea
Renewable Energy	Fuel Cells (Micro)	Leading	UltraCell	DMFC (micro) for portable devices; utilizing "reformed" methanol system	UltraCell's fuel cell technology is a high power density fuel cell system for portable electronics. This reformed methanol system yields twice the power density of competitive direct methanol systems.	CA	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Motorola	Developing miniature DMFC— internal and external research	One of Motorola Lab's primary focus areas in alternative energy is developing miniature direct methanol fuel cells, which could one day serve to continuously charge portable electronic products. The research focuses on fuel cell materials, components, technologies (such as the mixing of small volumes of liquid in microfluidic (link) chambers) and system design. In addition to internal research , Motorola Labs works closely with outside partners and potential suppliers on the development of the components and sub-systems that will eventually be needed for manufacturing.	IL	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Tekion	Micro fuel	By integrating advanced battery technology	IL	Canada/

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy		Emerging		cells that use purified and modified formic acid for power packs	with a unique micro fuel cell technology, Tekion is creating a new "personal power source", known as a Formira™ Power Pack , that will be capable of fitting inside your mobile device. With a simple, safe fuel cartridge, which snaps in and out in one motion, you will be able to stay connected for as long as you need it. Tekion's Formira™ fuel cell technology combined with an advanced battery technology, such as lithium ion, in a "hybrid configuration" is a practical solution for this energy carrier problem. By combining these advanced power systems, we are able to take advantage of the strengths of each technology and integrate them into new portable electronic devices, which our customers will launch in the first quarter of 2008.		U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Medis Technologies	Direct liquid fuel cells (DLFC) for personal portable electronic devices (power packs)	Medis Technologies Ltd. is dedicated to the development of unique technologies designed to improve the quality of life in the energy and medical fields. Our first commercial product is the Medis 24-7 Power Pack; a portable fuel cell energy source for handheld electronics applications, which will be available in 2007. More Energy, Medis' fuel cell subsidiary, was formed in 1998 and developed a proprietary direct liquid fuel cell (DLFC) technology which lead to creating the world's first consumer fuel cell portable power product -- the Medis 24-7 Power Pack. We continue to develop our DLFC technology and intend to expand our product offerings in the future.	NY	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	PolyFuel	Developing new hydrocarbon membranes for portable micro fuel cell applications	PolyFuel is the world leader in engineered membranes for fuel cells. We have developed a new family of hydrocarbon membranes that exhibit performance characteristics never before simultaneously achieved with any other fuel cell membrane material. PolyFuel's innovative hydrocarbon membrane technology is either under test at or been selected by virtually every one of the world's leading portable and automotive fuel cell system developers.	CA	U.S.
Renewable En-	Fuel Cells (Micro)	Small/	Toshiba	DMFC (micro)	Toshiba has conducted R&D on micro fuel cells	CA	Ja-

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy		Emerging		for portable electronics	since the early 1990s, and has obtained patents in DMFC technology. Toshiba has demonstrated DMFC technology for portable PCs and has developed a prototype of the world's smallest DMFC. Still in prototype stage on main DMFC systems for PCs.		pan/U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Adaptive Materials	Portable SOFC	Adaptive Materials, Inc. (AMI) is leveraging its patented single step process in the manufacturing of micro-tubular fuel cells, AMI has been at the forefront of portable power innovation. AMI is the first company to develop, demonstrate and deliver a portable, affordable, and fuel flexible solid oxide fuel cell (SOFC) system.	MI	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Ball Aerospace & Technologies	Portable PEMFC systems; DMFC system	Ball Aerospace & Technologies has developed two small portable PEM fuel cell systems (50W and 100W) for military applications. They were designed to recharge military batteries and to power communication base stations and unmanned monitoring equipment. Ball has also designed low pressure hydrogen on demand sources for these units. Additionally, Ball is developing a 20W direct methanol fuel cell for the DARPA Palm Power Programme.	CO	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	CMR Fuel Cells	Fuel cell stacks for portable DMFC systems	CMR Fuel Cells plc is a high growth, UK AIM-listed developer of fuel cell stacks for portable and small stationary power generation applications. The Company plans to become a leading supplier of fuel cell products, based on its simple but revolutionary patented stack architecture which delivers longer run-time and lower costs than conventional fuel cell stacks.	-	UK
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Direct Methanol Fuel Cell Corp.	Methanol fuel cartridges; Licensing rights to DMFC intellectual property	Direct Methanol Fuel Cell Corporation (DMFCC) is a provider of disposable fuel cartridges and intellectual property protection for manufacturers of direct methanol and other liquid hydrocarbon fuel cells. The direct methanol fuel cell was invented and developed at the Caltech/NASA Jet Propulsion Laboratory and the University of Southern California (USC) and is protected by more than 56 issued and 62 pending patents worldwide. DMFCC has license rights to the Caltech intellectual property	CA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					portfolio for direct liquid hydrocarbon fuel cells (including direct methanol fuel cells, DMFC), electrode construction, membrane electrode assemblies (MEAs), fuel cell systems, methanol sensor and filter, electrolysis of methanol to form hydrogen, and methanol fuel cartridges.		
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Antig Technology	DMFC (micro) for portable electronics	As a professional energy solution provider, Antig strives to provide cleaner and more efficient energy solutions that power our client's products, ranging from the application of future energy solutions to the improvement of current energy solutions. Antig's current focus is on Direct Methanol Fuel Cell (DMFC) technology--a simple, clean, and efficient energy projected to power devices ranging from portable electronics to stationary and residential applications soon.	-	Taiwan
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	eVionyx	Micro fuel cells utilizing metals as fuel	eVionyx is an energy company dedicated to the development of metal fuel-cell technology through innovative solutions that benefit humanity. Our mission is to help the world take advantage of solid-metal fuels and, in the process, become a leader in the global energy marketplace. Formed in 1995 as a subsidiary of Reveo, Inc., eVionyx maintains approximately 100,000 square feet of facilities, including electrochemical laboratories, offices, and manufacturing space in Hawthorne, New York, and in Taiwan.	NY	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Manhattan Scientifics	Micro fuel cells (methanol-based) for portable applications	Soon there will be a new portable power solution - MicroFuel Cells™ from Manhattan Scientifics, Inc. (MSI). The first MicroFuel Cells we are developing are designed to be compatible replacements for conventional cellular phone battery packs. Better, smaller, less-costly, environmentally safe, and much more efficient, the patented technologies of the methanol-based MicroFuel Cell are expected to drive a digital cellular telephone on standby for 6 months as opposed to 2 weeks with lithium ion batteries.	NY	U.S.
Renewable En-	Fuel Cells (Micro)	Small/	Mesoscopic	DMFC and	Mesoscopic Devices designs, fabricates and	CO	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
ergy		Emerging	Devices (Protonex Technology Corp.)	SOFC technology for portable generators and electronics	integrates portable fuel cell generators for military and industrial applications. We have developed industry-leading direct methanol fuel cell (DMFC) and solid oxide fuel cell (SOFC) technology, and are now producing generators ranging from 20 W to 250 W and above.		
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Neah Power Systems	Micro fuel cells with a silicon-based design for portable applications; testing and prototype stages	Neah Power Systems is a micro fuel cell development company using a patented, silicon-based design to provide long-lasting, efficient, and safe power solutions for portable electronic devices, including notebook PCs and other power-hungry computer, entertainment, and communications products. As an emerging leader in fuel cell technology and design, Neah Power products are expected to allow users to extend the operating time of their devices multiple times beyond that of conventional batteries.	WA	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	Protonex Technology	Micro fuel cells for portable military applications; prototype stage	Protonex is a leading provider of advanced fuel cell power solutions for portable, remote and mobile applications in the ten to 1,000-watt range. Based on patented proton exchange membrane (PEM) and solid oxide fuel cell (SOFC) technology, these power systems are among the industry's smallest, lightest and highest performing fuel cell systems for portable power applications.	MA	U.S.
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	QinetiQ	Micro fuel cells for portable applications	QinetiQ is at the forefront of battery and fuel cell development and now your organization can take advantage of our products, expertise and facilities. Our Proton-Exchange Membrane Fuel Cell (PEMFC) technology is a hybrid fuel cell and battery system that promises a significant performance enhancement over standard battery packs for the same weight and size.	-	UK
Renewable Energy	Fuel Cells (Micro)	Small/ Emerging	SFC Smart Fuel Cell	Micro fuel cells for portable applications	SFC Smart Fuel Cell is the market leader in mobile power supply based on fuel-cell technology for leisure-time, industrial and military applications. In contrast to most other fuel-cell companies that are still in the development phase or that promote highly subsidized dem-	-	Germany

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					onstration facilities, SFC has been successfully commercializing fuel cells among industrial and private customers.		
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Albermarle	Chemicals	Albemarle is a leading supplier of specialty chemicals used in water treatment and pur	VA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Ashland Water Technologies	Chemicals	Ashland Water Technologies, a division of Ashland Inc., manufactures and supplies water treatment systems and chemicals to industrial, commercial, and municipal customers, for applications that include wastewater treatment, pathogen control, paint and coating additives, pulp and paper processing and mining chemistries	KY	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Ciba Specialty Chemicals, Water Treatment Business, U.S. Operations	Chemicals, Equipment	Ciba Specialty Chemicals offers water treatment solutions for the treatment of potable and process water, industrial effluents, wastewater, and sludge, and its product range includes corrosion inhibitors, flocculants, odor control chemicals, and heavy metal removal chemicals. Its customer base covers the municipal and industrial segments	VA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Ciba Specialty Chemicals, Water Treatment Business, Global Headquarters	Chemicals, Equipment	Ciba Specialty Chemicals offers water treatment solutions for the treatment of potable and process water, industrial effluents, wastewater, and sludge, and its product range includes corrosion inhibitors, flocculants, odor control chemicals, and heavy metal removal chemicals. Its customer base covers the municipal and industrial segments	-	Switzerland
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	The Dow Chemical Company, Dow Water Solutions	Chemicals, Equipment	Dow Water Solutions, a business unit of Dow Chemicals, makes and supplies filtration membranes, reverse osmosis systems, deionization systems, and wide range of water treatment chemicals	MI	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	GE Water & Process Technologies	Chemicals, Membranes, Instrumentation	General Electric Water, a unit of the General Electric Company, isa leading global supplier of water treatment equipment, chemicals, wastewater treatment systems, and water quality instrumentation	PA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Millipore Corporation	Membranes, Equipment	Millipore is a leading supplier of membrane based water treatment systems used by the bioprocess industry, lifescience companies, the food and beverage, and the larger chemical process industry	MA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Nalco Chemicals	Chemicals	Nalco is one of the world's largest water treatment chemicals and supplies manufacturer. It offers products and services for a number of industries including the thermal power sector, public water utilities, and the paper industry. It also offers a complete range of chemicals used in membrane filtration systems that remove suspended impurities and enhance filtration efficiency	IL	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Nitto Denko	Membranes	Nitto Denko manufactures reverse osmosis membranes, and ultrafiltration capillary membranes	-	Japan
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Nitto Denko - Hydranautics	Membranes	Hydranautics is a U.S. based subsidiary of Nitto Denko, founded in 1960 and acquired in 1974. It is a pioneer in membrane technology and manufactures reverse osmosis membranes and systems, nanofiltration and ultrafiltration systems for municipal water treatment, bioscience applications, and the food and beverage industry	CA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Rohm and Haas	Chemicals	Rohm and Haas water treatment solutions includes a broad range of products including ion exchange resins, used to remove contaminants from feedwater used in industrial processes, thermal power plants, electronics manufacturing, and municipal water supplies	PA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Siemens – US Filter Division	Chemicals, Membranes, Instrumentation	The USFilter Division of Siemens is a U.S. based business unit coordinating the parent company's global operations in the area of water treatment. The USFilter business unit offers treatment solutions ranging from bench-top lab water systems to large scale water purification and reuse systems used by industrial customers and municipalities. The product and service range extends to chemicals, membranes, control systems and instrumenta-	PA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					tion, and consulting services		
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Suez	Treatment, consulting, engineering	Suez is one of the world's largest environmental services companies. It designs and builds large scale water treatment and wastewater treatment systems for municipalities and industrial customers, as well as undertaking environmental remediation projects for watersheds and coastal regions	-	France
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Leading	Veolia Water	Equipment, Purification Systems	Veolia Water a division of Veolia Environment specializes in the outsourced management of water utilities and industrial water supply systems, and also designs, builds, and operates turnkey water and wastewater systems	-	France
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	Aqua Sciences	Water Source Development	Aqua Sciences markets innovative water technologies including a water capture and purification system that is fed with moisture extracted from the atmosphere	FL	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	Argonide Corp.	Filtration Systems	Argonide is the inventor of the nano alumina filter sold under the name NanoCeram, and currently is working on applying the technology to design a HEPA air filter. The nanoCeram is a water filtration medium that blocks the flow of viruses and bacteria while maintaining high flow rates	FL	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	Blue Water Technologies, Inc.	Primary Treatment Methods, Filters	Blue Water offers a broad platform of water treatment technologies for primary treatment, removal of phosphorous impurities, and tertiary treatment water treatment	ID	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	eMembrane	Membranes/Filters	eMembrane is in the process of developing a nano-grafting technique that can impart multiple functions to an existing membrane. For instance a microporous membrane with grafted functionalized brushes can be used for filtration as well as removal of toxic ions	RI	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	EnviroTower	Water Conditioning	Envirotower has developed an advanced water treatment system for cooling towers that completely eliminates the use of chemicals for descaling and corrosion inhibition, while reducing operating costs and eliminating toxic chemical discharge	ON	Canada

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	HaloSource	Purification, Disinfectants	Halo Source makes a filtration based point-of-source water treatment systems used for residential and recreational water supplies	WA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	MIOX Corp.	Purification	MIOX has developed a safe method of water purification that uses salt electrolysis to generate chlorine disinfectant to treat water and purify it for industrial and commercial use. By producing the disinfectant onsite, MIOX eliminates the risks and costs involved in transporting toxic chemicals to the site	NM	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	NanoH2O	Membranes/Filters	NanoH2O uses nanotechnology to produce membrane materials that have a high energy efficiency and high resistance to fouling, thereby improving baseline costs. The membranes are used in desalination and water recycling systems	CA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	Novazone	Ozone Purification, Disinfectants	Novazone is a leading supplier of water treatment solutions for the food processing industry. Novazone proprietary ozone generator cycle technology is used by over 300 customers in 16 countries	CA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	Pionetics	Purification	Pionetics is a manufacturer of residential water purification systems that use a membrane based system to remove ionic impurities	CA	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	Synergene, Inc.	Decontamination Technologies	Synergene's SIAD technology uses a filter with multiple micro matrices in which pathogens are filtered and destroyed. The SIAD system is considered superior to UV and filtration based systems due to its better rate of flow and its capability to kill the pathogens and prevent them from being lodged in the filter	NY	U.S.
Water Quality and Water Resources	Water Filtration, Purification, Desalination, and Other Treatment Technologies	Small/ Emerging	WaterHealth International	Purification/Disinfection Systems	WaterHealth is a global supplier of drinking water purification systems based on a combination of UV purification and membrane filtration technologies	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	YSI, Inc.	Monitors/Instrumentation	YSI is a manufacturer of water quality instrumentation systems used in purification systems, groundwater monitoring, lab process water systems, and surface water bodies. YSI	OH	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					offers a range of instrumentation that can be used to measure several parameters including temperature, contaminant levels of dissolved solids and particulates, and turbidity levels		
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	Analytical Technology, Inc.	Monitors	Analytical Technology manufactures water quality instrumentation to measure conductivity, dissolved chlorine and sulfides, and turbidity; and gas monitors to measure ozone levels, combustible residue levels, and other toxic substances. Its customers include municipalities and industrial water users	PA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	Hach Co.	Test Kits, Distribution Monitoring Systems	Hach is a manufacturer of lab and field kits used to measure the levels of chlorine and turbidity in surface water bodies	CO	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	HF Scientific	Test Kits	HF Scientific is a supplier of instrumentation used to monitor water quality by the measurement of chlorine and turbidity levels in samples, and large online batches of process water	FL	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	Foxboro, Inc.	Test Kits	Foxboro automation and control solutions to the process industry. Its systems are widely used in water purification and treatment plants by industrial customers and utilities	MA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	Emerson Process Management	Test Kits, Monitors	Emerson is a diversified manufacturer of control and automation products and systems, and the process industry is one of its largest market segments. Its Rosemount range of environmental monitoring instruments and systems are used to monitor water and effluent stream conditions	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Leading	Teledyne Isco	Monitors	Teledyne Isco manufactures a wide range of products used in water pollution monitoring, pollution abatement, and wastewater processing	NE	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	ETwater	Sensors/Monitors for Irrigation	ETWater designs and builds smart controller systems that integrate weather data and soil conditions to optimize landscape irrigation schedules	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	Fluid Conservation Systems	Sensors	Fluid Conservation Systems markets leak detection equipment including pressure control-	OH	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
sources	Instrumentation				lers and data loggers to minimize leakage losses in water distribution networks		
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	HydroPoint	Sensors/Monitors for Irrigation	HydroPoint irrigation controllers use smart systems to control irrigation schedules and optimize water use in landscape management operations	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	Intelligent Automation Corp.	Monitors	Intelligent Automation is diversified manufacturer of control and automation systems and has designed the IAC 1090 iABS, a first of a kind web based real time biomonitoring system that is meant to detect toxicity in public water supplies by detecting changes in the health levels of aquatic organisms	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	JMAR Technologies, Inc.	Monitors	JMAR Technologies' BioSentry is a real-time system that can be used to monitor the concentration of microorganisms. It uses laser scattering to generate distinct signatures for several pathogens and continuously monitors water conditions using light scattering to identify the emergence of these signatures	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	Pocket Water, Inc.	Water Quality Monitoring	Pocket Water is a provider of water consulting services whose offerings include water quality monitoring, data analysis, fisheries habitat evaluation, and compliance with environmental law	ID	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	Puresense, Inc.	Monitors	Puresense designs and installs complex water optimization systems for irrigation use, and water and air quality monitoring systems for the process industry	CA	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	Sensicore	Sensors	Sensicore makes handheld water quality measurement instruments based on microsystems technology that can be used a wide range of parameters in industrial and utility water treatment plants	MI	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	Sensor Research & Development	Sensors	Sensor Research & Development designs micro sensor arrays that are used for trace gas detection in pollution monitoring systems.	ME	U.S.
Water Quality and Water Resources	Water Sensors and Analysis/Monitoring Instrumentation	Small/ Emerging	ThermoFisher Scientific	Monitors	Thermo Scientific, a division of ThermoFisher, manufactures analytical instrumentation used to analyze gas and fluid samples in labs, and industrial process operations	MA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	AECOM Technology, Inc.	Water Resources & Wastewater Consulting	AECOM is a diversified engineering services company that designs and builds infrastructure for water treatment, and wastewater processing; and plans and executes air pollution and environmental remediation projects	CA	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Black & Veatch	Environmental Management, Construction, Engineering	Black & Veatch is a leading global engineering and consulting company that offers a wide range of water and environmental services in the areas of water treatment, air quality, environmental remediation, coastal environmental management, and watershed improvement	KS	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	CDM	Environmental Management, Construction, Engineering	CDM is a consulting and engineering firm that designs and builds water supply and treatment infrastructure, plans and executes environmental remediation projects	MA	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	CH2M Hill Companies	Environmental Management, Water & Wastewater Infrastructure Engineering	CH2M is a diversified engineering services company that designs and builds water infrastructure, and offers environmental management services	CO	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Earth Tech, Inc.	Water Resources & Management Consulting	Earth Tech is a consulting and engineering firm that designs and builds water infrastructure and offers environmental management solutions	CA	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	ERM Group	Water & Wastewater Management	ERM working offers strategic advisory services in the water infrastructure and environmental areas including permitting, development impact assessments, risk management, and contaminated site management	PA	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Infiltrator Systems, Inc.	Wastewater Solutions	Infiltrator Systems is a world leading manufacturer of plastic leachfield drainage chambers for onsite wastewater containment	CT	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Kiewit Corporation	Water Infrastructure Construction	Kiewit is a diversified construction company that is among the nation's largest contractors in the building of water infrastructure	NE	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Layne Christensen Company	Water & Wastewater Treatment,	Layne Christensen is an infrastructure company that builds wastewater treatment plants, water supply networks, and maps groundwater	KS	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
				Source and Infrastructure Engineering	sources		
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	MWH Global	Environmental Management, Water & Wastewater Treatment, Source and Infrastructure Engineering	MWH, an engineering services firm, is considered among the world's leading experts in water and wastewater systems	CO	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Skanska	Construction & Project Development	Skanska is one of the world's leading construction groups in the area of water and environmental management infrastructure	-	Sweden
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Stantec, Inc.	Environmental Management	Stantec provides design and consulting services geared towards the delivery of sustainable water supply infrastructure	AB	Canada
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Tetra Tech, Inc.	Water Resources & Environmental Management	Tetra tech is a diversified engineering company that provides water resource and environmental management solutions to large communities and industrial customers	CA	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	The Walsh Group	Preconstruction & Construction Engineering	The Walsh Group is a diversified construction company that executes water infrastructure projects	IL	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Leading	Veolia Environment	Environmental Consulting	Veolia Water a division of Veolia Environment specializes in the outsourced management of water utilities and industrial water supply systems, and also designs, builds, and operates turnkey water and wastewater systems	-	France
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Small/ Emerging	HydroPoint	Water Management Systems	HydroPoint irrigation controllers use smart systems to control irrigation schedules and optimize water use in landscape management operations	CA	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Small/ Emerging	Hydrotech Water Resource Consultants, LLC	Water Resource Management Consulting	Hydrotech Water Resource Consultants specializes in watershed management, stream design and restoration, aquatic habitat enhancement, stream stabilization, riparian management,	MT	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					water quality improvement, environmental permitting, grant writing for project implementation and grants management		
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Small/ Emerging	Integrated Water Solutions	Water Resource Management Consulting	Integrated Water Solutions, a water resources consulting firm, specializes in providing services to municipalities, counties, water supply authorities, developers, landowners, engineering and environmental firms, agriculturalists, and mining enterprises	FL	U.S.
Water Quality and Water Resources	Water Engineering and Watershed/Resource Management Consulting	Small/ Emerging	New England Environmental, Inc.	Freshwater, Stormwater & Watershed Management	New England Environmental Technologies offers a complete spectrum of services to industrial clients that address federal, state and local environmental regulatory compliance issues	MA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Alcoa	Metal roofing	Alcoa Architectural Products (USA) offers cladding products for exterior and interior applications, including specialty applications such as signage, corporate identity programs, displays, exhibits and open office products. As part of Alcoa, we are associated with the world's leading producer of primary aluminum, fabricated aluminum and alumina, Alcoa is active in all major aspects of the industry-from technology, mining, refining and smelting to fabricating and recycling. Alcoa offers a varied line of metal wall and roof panels.	PA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	ALSCO Metals	Residential aluminum building products	Since its founding in 1947, ALSCO has reigned supreme as the largest supplier of residential aluminum building products in North America. ALSCO manufactures a broad range of residential aluminum building products for the new home, home-improvement and remodeling markets including aluminum trim coil, soffits, accessories, siding, rainware, roof moldings and painted aluminum coil.	NC	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	BASF Corp. (N. America)	Cool roof coatings & technology for metal roofs	BASF is the world's leading chemical company. Its portfolio ranges from chemicals, plastics, performance products, agricultural products and fine chemicals to crude oil and natural gas. BASF is a leader in developing innovative coatings for all construction applications. BASF's broad portfolio of coating products for building	NJ	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					applications includes premium siliconized polyester (PC3200® and SuperI® SP II ULTRA-Cool®); economically priced siliconized polyester (PanelGuard™); and premium PVDF (Fluoroceram® and Fluoroceram® ULTRA-Cool®).		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	BaySystems	Spray polyurethane foam roofing; cool roofing; metal roofing	BaySystems NorthAmerica LLC is the leading manufacturer of SPF spray applied polyurethane foam roofing systems - with over a billion square feet of SPF roofing and coatings applied in a wide range of environments.	TX	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Berridge	Metal roofing & siding	Berridge Manufacturing Company has been in business for more than thirty years and distributes its products worldwide. Berridge specializes in research and development of new architectural sheet metal products. The unique Berridge Total Program, which includes a full range of precision tolerance portable roll forming machines, painted coil and flat sheet, twenty-nine different factory products, all backed by technical and marketing support, has placed Berridge in the forefront of the architectural metal panel industry.	TX	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Boise Cascade	Engineered lumber	Boise Engineered Wood Products manufactures and markets engineered wood products, which are building products with improved structural characteristics and use our forests more efficiently. Today Boise owns and operates the two largest laminated veneer lumber (LVL) and I-joist manufacturing plants in the world in Alexandria, Louisiana and White City, Oregon.	ID	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Bonded Logic	Cotton insulation (no VOC)	Bonded Logic manufactures innovative natural fiber insulation products that are safe for you and the environment you live in. Utilizing almost exclusively natural fibers, Bonded Logic combines over 25 years of experience with a patented manufacturing process to create a superior performing insulation.	AZ	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Dow Chemical Co.	Spray polyurethane foam roofing	With the STYROFOAM™ Spray Polyurethane Foam (SPF) Roof System by Dow, you get more than just great materials – you get an effective solution to many of the most common	MI	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					roofing concerns. Sustainable and lightweight, the SPF Roof System provides superior R-value, improved foam and coating yields, and excellent wind uplift performance.		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Follansbee Steel	Metal roofing (stainless steel)	Follansbee Steel is the only manufacturer of a pre-painted or natural Terne roof and is a leading supplier of metal roofs for new and retrofit commercial, institutional, residential and historic preservation projects. The secret to Follansbee Roofing's longevity is a proprietary zinc/tin alloy developed through years of metallurgical research and testing. ZT Alloy creates the most corrosive resistant terne roofing materials ever, while providing the classic aesthetic you expect from terne.	WV	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Gentek Building Products	Metal siding (aluminum, steel)	With an extensive range of materials, Gentek is a single source for residential, new construction and light commercial projects. We carry a comprehensive selection of vinyl, aluminum and steel siding, soffit, trim and accessories — as well as a full line of vinyl replacement and new construction windows.	ON	Canada
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Georgia-Pacific	Engineered lumber; OSB sheathing	Georgia-Pacific manufactures engineered lumber joists, beams, headers and rim boards. These products offer cost-effective, high-performance solutions for floor and wall systems, and frame construction. Engineered lumber products outperform conventional lumber with higher strength and greater stability over long spans - making them ideal for today's popular open floor plans. Georgia-Pacific engineered lumber brands include Wood I Beam™ joists, Fiberstrong® rim board, and GP Lam® laminated veneer lumber (LVL) beams.	GA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Homasote	Green structural sheathing (fiberboard, recycled wastepaper)	An internationally known environmental icon, Homasote Company is the oldest manufacturer of building products made from recycled materials in the U.S., and the only manufacturer of its kind in the Americas. Homasote® structural fiberboard products are used in residential and commercial building. Among its applications are exterior vertical sheathing, sound control,	NJ	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					roof decking, concrete forming, expansion joint, insulation and, under the Pak-Line® brand, industrial packaging.		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	International Cellulose	Recycled cellulose insulation	International Cellulose (ICC) is the world's leading developer and manufacturer of cellulose spray-applied thermal insulation and acoustical finishes.	TX	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	LP Building Products	Engineered lumber; OSB sheathing; composite decking; cellulose insulation	Headquartered in Nashville, Tennessee, LP is a leading manufacturer and distributor of building products. LP® SolidStart® LVL (laminated veneer lumber) has consistent dimensions and density and is stronger and straighter than traditional lumber. Everyone knows LP® OSB as a cost-effective alternative engineered to meet the same performance standards as plywood. Made from a high-quality mix of plastics and wood, LP® WeatherBest® decking resists termites, rot, decay, and warping.	TN	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	McFarland Cascade	Composite decking	McFarland Cascade is one of North America's leading suppliers of fine building materials for outdoor construction projects and a leading global supplier of utility poles. McFarland Cascade is made up of two divisions: Our pole division, which supplies utility poles to North America and other parts of the world. And our sawn products division which is the West's largest supplier of treated lumber, premium composite decking, stone decking, railings and a variety of other unique decking accessories.	WA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Met-Tile	Metal roofing (tile panel); cool roofing	Met-Tile offers the classic beauty of a tile roof with the high performance of metal. Met-Tile uses a low VOC paint finish for environmentally friendly performance, low maintenance and long life. Plus, Met-Tile is made of recyclable metal for added environmental benefit.	CA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Norandex/Reynolds	Metal (aluminum, steel), fiber cement, & engineered wood siding	As a leading manufacturer and distributor of quality exterior siding, exterior accents, windows and doors, Norandex/Reynolds continually strives to provide the innovative edge that offers homeowners energy efficiency, durability, exceptional weather resistance and superior performance with absolutely beautiful,	OH	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					curb-appealing results.		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Nu-Wool	Recycled cellulose insulation	Nu-Wool has remained a family owned and operated business since 1949, and is the world's oldest and fastest growing manufacturer of cellulose insulation. The Nu-Wool WALLSEAL System, a spray-in-place cellulose insulation system, has led our rapid growth, while our 2-hour firewall designs are expanding our business in the multi-unit residential market.	MI	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Regal Industries	Recycled cellulose insulation	Regal Cellulose Insulation is an investment that saves you money by making your home more energy-efficient, while providing you with the best all round protection available, year in and year out. Regal Cellulose Insulation is non-toxic, non-carcinogenic, and requires no special health warning labels.	IN	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	TAMKO Building Products	Metal roofing; composite decking	TAMKO Building Products, Inc. is the nation's leading independent manufacturer of residential and commercial roofing products, waterproofing, composite decking and railing systems, and cements and coatings. EverGrain and Elements composite decking by TAMKO offers a natural wood grain look with a deep lasting grain.	MO	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Trex	Composite decking, railing, fencing; uses recycled wood & plastic	Trex Company, Inc. is the manufacturer of Trex® decking and railing, the leading brand of alternative decking lumber in North America. Trex Company turns millions of pounds of recycled and reclaimed plastic and waste wood each year into Trex decking. Most of these raw materials come from recycled plastic grocery bags, reclaimed pallet wrap and waste wood.	VA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	United States Seamless	Metal siding (seamless steel)	United States Seamless is the recognized leader in the manufacturing of seamless steel siding and coordinating accessories.	ND	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Universal Forest Products	Engineered lumber; composite decking	Universal Forest Products is the nation's leading manufacturer and distributor of wood and wood-alternative products to retail/dealer, site-built construction, manufactured housing and industrial markets. Universal is the leading	MI	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					producer of pressure-treated wood and North America's largest manufacturer of engineered roof systems for manufactured housing and site-built construction.		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Leading	Weyerhaeuser	Engineered lumber for structural framing & industrial applications	Weyerhaeuser Company is an international forest products company with annual sales of \$21.9 billion. We are: One of the world's largest private owners of merchantable softwood timber. One of the world's largest producers of softwood and hardwood lumber, engineered lumber, softwood market pulp and container-board. Among the largest producers of structural panels and distributors of wood products in North America.	WA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	AEP Span	Metal roofing; cool roofing	AEP Span is a leading manufacturer of architectural metal products. Using state-of-the-art technology, AEP Span is continually raising the bar of industry standards for the engineering and manufacturing of new and retrofit roof systems, mansards, equipment screens, fascia and soffit systems. AEP Span's extensive product offering allows architects and engineers to design and specify fully engineered architectural metal roofing and framing systems for new construction, retrofit and re-roofing applications.	TX	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	BioBased Systems	Soy-based polyurethane spray foam insulation	BioBased Insulation is an award winning manufacturer and marketer of soy-based polyurethane spray foam insulation products. BioBased Insulation and its Certified Dealers (installers) have revolutionized the construction industry by providing high quality insulation products at affordable pricing through the integration of breakthrough environmental technologies.	AR	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Carlisle SynTec	Roof garden systems for green roofs	Carlisle has been the leader in roofing and waterproofing for more than 40 years. And we are now leading in the development and manufacturing of environmentally responsible products and systems for the construction marketplace. Carlisle's technologies support the Building Green concept with the focus on	PA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					promoting sustainable sites, protecting the atmosphere, and conserving energy, materials and resources. Centuries old, the roof garden concept has been most recently embraced in Europe. Both functional and aesthetically-appealing, this technology improves the structure's energy efficiency while adding plant life in populated areas.		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Custom-Bilt Metals	Metal roofing; cool roofing	Custom-Bilt Metals is a leading metal roofing manufacturer and supplier of seamless rain gutter systems, standing seam metal roofing systems fabricated from steel, aluminum, and copper as well as Kynar-500 finished steel tiles and shingles, aluminum shake, copper shingles, and various stone-coated products. Thanks to a new premium coating, Custom-Bilt Metals standing seam roofs greatly reduce heat absorption, which can save energy, lower cooling costs, and increase the life expectancy of the roofs by reducing expansion and contraction. The key to these benefits is the introduction of new ULTRA-Cool high reflective roofs, and new technology developed by BASF Corporation's Industrial Coatings Division.	CA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	GreenKrete Building Systems	Wood/plant fiber-cement materials	GreenKrete is a biotech company focused on manufacturing and distributing innovative, world-class, alternative building materials that surpass the performance and functionality of existing systems. Our mission is to provide whole-house solutions, which have a tradition of success in solving the fundamental problems of building construction: toxicity, energy efficiency, mold & mildew, depletion of resources, embodied energy, durability & ease of use. Our building concepts are biomass based, which means they can be created with sustainable plant fibers grown in the local farming community.	IA	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Hamilton Manufacturing	Recycled cellulose insulation	Hamilton manufactures quality cellulose insulation and hydroseeding products, which help to protect the environment and those who live in it. We reuse millions of pounds of newspaper and cardboard every year to produce green	ID	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					building and erosion control products that contribute to a sustainable future.		
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Mountain Fiber Insulation	Recycled cellulose insulation	Mountain Fiber Cellulose Insulation makes it possible to achieve the optimum insulatory values in single family dwellings, commercial and industrial facilities, and in new construction and the retrofitting of structures with presently inadequate insulation. Cellulosic fiber insulation has been used in the building industry for over a half of a century. It is recycled cellulose fiber made from selected newsprint. In the manufacturing process these fibers are treated with 100% Borate (boric acid / sodium poly borate) flame retardant chemicals.	UT	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Re-New Wood	Recycled roofing shingles (vinyl & cellulose)	Re-New Wood offers the eco-shake, an innovative roofing material comprised of 100% recycled materials, reinforced vinyl and cellulose fiber. The eco-shake shingle is designed to resemble and replace wood shake shingles.	OK	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Rollex	Metal siding	Rollex came on the scene in the early 1950's - as a manufacturer and distributor of aluminum and metal moldings for the kitchen, bath and siding industries. In the '80s, Rollex extended its expertise into siding. Its highly successful aluminum line was followed with steel and vinyl. Today, no one offers a more attractive selection in pre-finished siding and accessories.	IL	U.S.
Green Buildings and Sustainable Design	Green Structural and Exterior Finish Materials	Small/ Emerging	Ryerson	Metal roofing; cool roofing (metal fabricators/distributors)	Ryerson is a leading distributor and processor of metals in North America. Ryerson offers an unparalleled range of products, leading processing and fabricating capabilities, a broad geographic reach, and an established commitment to superior service.	IL	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	GE Lighting	Lighting (Compact Fluorescents)	GE Lighting manufactures a full line of compact fluorescent lights (CFLs) for consumers, lighting distributors, OEMs, and engineers.	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Interface Flooring	Carpet Tiles	Interface, Inc. designs, is a floor coverings and fabrics company that produces and sells modular carpet. It also manufactures and markets other products for the commercial interiors industry.	GA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Milliken	Wall Covering	Privately held Milliken is one of the world's largest textile companies. The Company produces finished fabrics for rugs and carpets and synthetic fabrics for apparel, automobiles, tennis balls, and specialty textiles. It also makes chemicals and petroleum products.	SC	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Philips Lighting	Lighting (Compact Fluorescents)	Philips Lighting Company is a global leader in lighting for the residential and commercial sector. The Company produces a full range of CFLs and lamps.	NJ	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Shaw Contract Group (Eco-Worx)	Carpet/Carpet Backing	Shaw Contract Group is the leading flooring provider to the commercial market. EcoWorx, the industry's first 100% sustainable, non-PVC tile backing system and the predominant backing used for Shaw Contract Group tile products, has received numerous awards for its environmental attributes	GA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Sherwin Williams	Paint	The Sherwin-Williams Company, founded in 1866, is engaged in the manufacture, distribution, and sale of paint, coatings and related products to professional, Industrial, commercial and retail customers primarily in North and South America. The Company offers both low-VOC and no-VOC interior paints.	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Summitville Tiles, Inc.	Recycled Content Tiles	Summitville Tiles is one of the nation's oldest continuously operating tile manufacturers. The Company is one of the nation's premier manufacturers of ceramic products and installation materials from brick products to quarry tiles to its full line of tile installation and tile care materials.	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Valspar	Paint	The Valspar Corporation is a coatings and paint manufacturer and distributor. The Company's two primary business segments are Coatings and Paints for manufacturing, automotive, and food-packaging companies, as well as for consumers.	MN	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Leading	Wausau Tile	Countertops	Wausau Tile is a leader in the production of precast concrete and thermo-coated metal site furnishings, recreation equipment, paving products, terrazzo floor tiles, and architectural specialties. The Company also offers an array	WI	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					of recycled glass products.		
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	AlterECO	Cabinetry	AlterECO creates custom bamboo cabinets. Currently, the cabinets are exclusive only to the San Francisco Bay Area.	CA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	American Clay Enterprises, LLC	Coatings, Plaster	American Clay Enterprises, LLC, offers American Clay Earth Plaster - an environmentally friendly alternative to cement, gypsum, acrylic, and lime plasters. It is made from natural clays, recycled and reclaimed aggregates.	NM	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	BamStar	Flooring	BamStar is widely recognized as being one of the leaders in the bamboo flooring industry. The Company offers solid bamboo flooring, engineered bamboo flooring, colored bamboo flooring, bamboo panels and veneer, and bamboo accessories (moldings, stair-treads, vents).	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Coverings Etc.	Recycled Content Countertops, Flooring, Panels	Coverings Etc. sources natural stone and mosaics to produce eco-friendly, engineered stone-surface materials that can be used as countertops or other surfaces for residential or light commercial applications. The Company's latest line of products is naturally occurring, recycled, and/or manufactured using resource and energy conservation measures.	FL	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	CREE	Lighting (LED)	Cree, Inc. develops and manufactures semiconductor materials and devices, focusing primarily on the production of light emitting diodes (LEDs). Cree's products include LED chips, LED lamps, power devices, wireless devices, and materials for advanced electronic and opto-electronic applications.	NC	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Environ Biocomposites	Cabinetry	Environ Biocomposites is a manufacturer of bio-based materials for decorative interior applications. The Company's manufacturing process does not destroy trees but rather it utilizes recycled materials and abundant renewable agricultural resources	MN	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Green Planet Paints	Paint	Green Planet Paints is a "boutique color house" that produces natural, non-toxic, zero-VOC paints. The Company's products include interior clay paints, pigments, resins, and glazes.	AZ	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Green Products	Adhesives; Coatings	Green Products produces bio-based cleaners, coatings, and adhesives from U.S.-grown corn and soybeans. Applications for the Company's coating products are in roofing, metal, and masonry.	IL	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Holophane	Lighting	Holophane produces energy-efficient lighting systems and controls. The Company offers lighting systems for commercial, industrial, emergency and outdoor applications. The hallmark of Holophane lighting is the borosilicate glass reflector/refractor, which provides a combination of uplight and downlight to illuminate any environment evenly without creating dark spots or glare.	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Humabuilt	Panels, Doors, Cabinetry	Humabuilt markets itself as a provider of healthy, high-performance building solutions. The Company's products include an aerated-concrete wall forming system, wheat-based doors and cabinetry, and water and air filtration systems.	OR	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	IceStone	Countertops	IceStone produces durable countertops made from recycled glass and concrete. The product is produced by an environmentally friendly manufacturing process in the Company's day lit factory in Brooklyn, New York.	NY	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	ITW TACC	Adhesives; Coatings/Sealants	ITW TACC is a leading manufacturer of high-strength adhesives used in building construction, woodworking, HVAC, manufactured housing, and automotive, marine, and recreational vehicles. The Company is a division of Illinois Tool Works (NYSE: ITW), a Fortune 200 diversified manufacturing company.	MA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Neil Kelly Cabinets	Cabinetry	Neil Kelly Cabinets is an industry leader in the design and manufacture of fine kitchen and bath cabinetry using environmentally friendly materials and techniques. Materials include low-VOC finishes and sustainably harvested woods and veneers.	OR	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Ortech/Durra Building Materials	Wall Panels	Durra Panels are made from straw and bound together using only high heat and pressure. The recycled paperboard finish is fire-resistant and nontoxic.	TX	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	PaperStone (Paneltech Int'l/KlipTech)	Recycled Content Countertops/Wall Panels	PaperStone Certified Countertops are made with 100% post-consumer recycled paper and non-petroleum-based resins. The original PaperStone product line is made with 50% post-consumer recycled content.	WA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	PermaGrain Products	Flooring	PermaGrain Products, Inc. offers the hard surface flooring industry's widest selection of specialty flooring materials designed for high traffic commercial applications. Its three product lines are based on acrylic impregnated or vinyl bonded natural hardwood flooring.	VA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Richlite	Recycled Content Countertops	Richlite is a manufacturer of paper-based fiber composites used for a variety of architectural, food service, recreational and industrial applications. All Richlite® materials are manufactured out of environmentally sustainable resources harvested from certified managed forests in North America.	WA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Safecoat (AFM)	Paint	AFM Safecoat is a leading provider of environmentally responsible, sustainable and non-polluting paints, stains, wood finishes, sealers and related green building products. Safecoat products contain no unhealthy ingredients such as solvents, heavy metals, chemical residuals, formaldehyde and other harmful preservatives.	CA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Sea Gull Lighting	Energy Efficient Lighting Fixtures	Sea Gull Lighting, offers the most comprehensive product line of energy saving lighting available today, and was recently named as ENERGY STAR'S Partner of the Year and Sustained Excellence Winner for 2007. Light fixtures by Sea Gull Lighting are the most sought after decorative, functional and specialty indoor lighting and outdoor lighting fixtures. As your single source lighting supplier, Sea Gull Lighting manufactures and distributes over 3,500 light fixtures and lighting products that serve the residential, commercial, and architectural markets.	NJ	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Smith & Fong Plyboo	Flooring, Panels, Veneers	Smith & Fong Plyboo, founded in 1989, manufactures Plyboo® bamboo - the company's term for laminated bamboo - and Durapalm® coconut palm. Products made from these	CA	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
					materials include flooring, trim molding, veneers, paneling, and plywood.		
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Studio eg Inc.	Furniture (office)	Studio eg, founded in 1991, is a design firm that utilizes recycled, reused and nontoxic materials to produce office furniture and accessories. The firm also provides Ecologically Sound Design consulting services to manufacturers, designers, and other clients.	CA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Syndesis Studio	Recycled Content Tiles	Syndesis, Inc. is a design firm that manufactures, fabricates, and installs custom architectural products and surfaces using Syndecrete® as a primary medium. Syndecrete® is a solid pre-cast lightweight concrete material developed as an alternative to limited or nonrenewable natural materials.	CA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	TCP, Inc.	Lighting	TCP Inc. is the leading manufacturer of energy efficient compact fluorescent CFL light bulbs and lamps.	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Tectum, Inc.	Wall Coverings, Panels	Tectum manufactures wall panels, ceiling panels, and acoustical roof decks as "noise solutions" for commercial and industrial applications. Tectum products are cementitious wood fiber acoustical panels manufactured using only renewable wood and other sustainable raw materials.	OH	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Teknion	Furniture	Teknion, founded in 1981, manufactures office systems (cubicle walls, desks, and full-height relocatable walls) and other office products including seating, tables, credenzas, bookshelves, task lighting, ergonomic furniture, and workplace accessories. The company incorporates sustainable practices into all activities and was the first office furniture manufacturer to receive Greenguard certification for indoor air quality for all major products.	ON	Canada
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Teragren	Flooring, Panels, Veneers	Teragren is a manufacturer of bamboo products such as flooring, panels, veneers, stair treads and risers. The Company also offers coordinating flooring accessories.	WA	U.S.
Green Buildings and Sustainable	Green Interior, Surface, and Finish Materials	Small/ Emerging	Terra Green Ceramics	Recycled Content Tiles	Terra Green Ceramic tiles are made with 55% post industrial recycled glass. The Company's	IN	U.S.

Major Segment	Technology Subcategory	Firm Type	Company	Technology/ Application	Company Overview	State or Prov.	Cnty
Design					product lines include a full range of wall and floor tiles for commercial and residential installations.		
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Vetrazzo	Countertops	Vetrazzo uses discarded or recycled glass and transforms it into countertops or other home surfaces such as shower floors.	CA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Watt Stopper/Legrand	Electronics/Sensors	Watt Stopper/Legrand offers a range of electronic and sensor controls. Products include lighting control panels, occupancy sensors, automatic daylighting controls, bi-level HID controls, DALI dimming controls, and plug load controls for commercial and residential applications. The Company's sustainability tools include lighting control products and strategies.	CA	U.S.
Green Buildings and Sustainable Design	Green Interior, Surface, and Finish Materials	Small/ Emerging	Yolo	Paint	YOLO Colorhouse® is a collection of zero-VOC interior paints with a durable washable finish. The Company's paints and primer are certified by Green Seal®, an independent non-profit setting standards for environmentally responsible products.	OR	U.S.

APPENDIX D

COMPETITIVE ASSESSMENT OF CENTRAL UPSTATE NEW YORK'S ENVIRONMENTAL AND ENERGY SYSTEMS INDUSTRY CLUSTER:

REGIONAL PROFILES

INTRODUCTION

Central Upstate New York is not the only region trying to grow its energy and environmental industry cluster. Multiple regions across the country are branding themselves as locations for “green” businesses and implementing policies and actions to promote the use of green building practices, renewable energy, and practices that promote environmental quality. Battelle conducted an analysis to assess the competitiveness of Central Upstate New York’s environmental and energy sector and to identify policies and programs that are being used to promote this sector in other regions of the country.

Upstate Central New York is compared to the following five regions in this report:

- Eugene, Oregon
- Fort Collins, Colorado
- Grand Rapids, Michigan
- Pittsburgh, Pennsylvania
- Sacramento, California

These regions were chosen because 1) they are actively promoting at least one of the industry subsectors included in the energy and environment sector, 2) they have policies and programs in place to promote the region’s “green” industry sector, 3) they each have a university presence with capabilities in the energy and environmental area, 4) they are pursuing a regional approach to economic development, and 5) the region has some similarities to Central Upstate New York in terms of size or composition of the economy. Not every region chosen for this competitive assessment met all five criteria but an effort was made to find regions that met as many of the criteria as possible. The regions were chosen in consultation with the Project Steering Committee.

Below is an initial assessment of key findings. This is followed by profiles of each region.

Key Findings

- For the most part, the initiatives to grow the energy and environmental sector are being driven by a citizenry that values sustainability and sees the industries that make up this sector as compatible with maintaining the region’s quality of life.
- Most of these communities have adopted public policies aimed at promoting “green” practices and businesses. These include setting goals for the use of renewable energy, adopting “green” building practices for municipal buildings, committing to purchase sustainable products and technologies and providing incentives for businesses that use sustainable practices, among others.

- Communities are trying to build their energy and environmental industry sectors by 1) encouraging the growth of start-up companies, 2) helping to create a market for “green” products by conducting education and outreach activities, and 3) encouraging existing companies to offer new “green” products or enter new markets. It is much less common to seek to attract energy and environmental companies from outside the region, although this has happened in Sacramento with some international firms opening operations to meet the demand for renewable energy, which has developed as a result of state policy actions.
- The competitor communities have, so to speak, put their money where their mouth is. They can show, for example, that they have a significant percentage of buildings constructed to green performance standards.
- In some instances, including in Fort Collins and Pittsburgh, the presence of university centers focused on specific aspects of the energy and environmental sector are playing an important role in fostering the growth of energy and environmental businesses. Colorado State University is in fact a primary driver of the region’s Clean Energy Cluster. In other region, such as Sacramento, the region has not been able to engage the university in its efforts to grow this industry sector.
- The most common tool used to help grow the environmental and energy industry is to promote networking and the formation of cluster initiatives.
- Eugene and Fort Collins are the only two regions that have a specialization in the overall environmental and energy industry sector. Most of the competitor regions are focused on only one or two of the industry subsectors that are included in the larger environment and energy sector.
 - Eugene is highly specialized in green buildings and sustainable design and renewable energy.
 - Fort Collins is specialized in energy and environmental consulting services and water quality and water resources.
 - Grand Rapids is not specialized in any of the subsectors.
 - Pittsburgh is specialized in energy and environmental consulting and water quality and water resources.
 - Sacramento is specialized in energy and environmental consulting but has rapidly growing green buildings and sustainable design, renewable energy and water quality and water resource sectors.
 - Central Upstate New York is specialized in three subsectors: indoor environmental quality (IEQ), renewable power generation and water quality and water resources. None of the competitor regions are specialized in either IEQ or renewable power generation. Fort Collins is much more specialized in water quality and water resources than is Central Upstate New York.

- Sacramento is experiencing the greatest employment growth in its energy and environmental industry sectors and both Eugene and Fort Collins are experiencing growth in specific subsectors. Grand Rapids, Pittsburgh and Central Upstate New York, all of which are manufacturing intensive, have experienced employment declines in most of the energy and environmental industry sectors. Central Upstate New York has experienced growth in its energy and environmental consulting sector.
- It should be kept in mind that there is no easy way to identify the specific companies that are involved in producing green products. To determine whether policies are being effective, regions are finding that they have to collect data and track progress at the regional level. Thus several of the regions have developed directories or other lists of firms involved in the sector that they are targeting.
- The focus on promoting the growth of “green” industry sectors is at an early stage of development and it will take time to see where the industry takes hold and what types of incentives are effective in accelerating its growth.

Strategy Rationale

Like most of Oregon as a whole, Eugene (seat of a one-county MSA) believes it has the opportunity to “brand” itself as a center of sustainable business development, based on the intense interest of its citizenry in the topics, which in turn has supported a vigorous market for green buildings. Eugene is university town in a watershed setting, and has long had a high profile in green power, wetland preservation, and related areas. Long committed to inventorying and then reducing greenhouse-gas emissions,⁴ Eugene now has a broader Environmental Policy⁵ that includes specific goals addressing the environment itself, the economy, and social equity. Several years ago, Mayor Kitty Piercy launched a **Sustainable Business Initiative**,⁶ and the city followed in 2006 with a formal **Green Building Policy**⁷ and this year with a standing **Sustainability Commission**.⁸ The Eugene strategy should be seen in the context of statewide efforts centered on Portland. Among the eight sectors identified for possible investment by the **Oregon Innovation Council (Oregon InC)**, three have sustainability as part of their context with two of these (bio-based fuels/products and ocean-wave energy) receiving funding for specific academic/industrial collaborative research initiatives.”⁹

Background

In founding the Mayor’s Sustainability Business Initiative in April 2005, Eugene Mayor Kitty Piercy wrote:

In Eugene, we want a healthy economy that conserves the environment and ensures equitable access to living wage jobs, health care, and other vital amenities to support our families. The connections between economy, equity and environment form a three-legged stool that is often called the “triple bottom line.” This initiative will help expand our community's emphasis on the “triple bottom line.” The goal is to make Eugene a nationally known 'center of excellence' in this rapidly growing field.

⁴ See http://www.eugene-or.gov/portal/server.pt/gateway/PTARGS_0_0_8438_730_3713_43/http%3B/ceppcontent.eugene1.net%3B7087/publishedcontent/publish/sustainability/sustainability_news/ghg_inventory.html.

⁵ See <http://www.eugene-or.gov/portal/server.pt?space=CommunityPage&control=SetCommunity&CommunityID=730&PageID=0>.

⁶ See http://www.eugene-or.gov/portal/server.pt?open=514&objID=1469&parentname=CommunityPage&parentid=9&mode=2&in_hi_userid=2&cached=true.

⁷ Resolution 4884 requires city construction of more than 10,000 square feet to obtain LEED Silver certification, encourages Gold where feasible, and requires best efforts with smaller projects.

⁸ See Ordinance 20379 of Feb. 2007.

⁹ See http://governor.oregon.gov/Gov/P2007/press_072607.shtml.

Among the five steps in the initiative was creation of a Sustainable Business Task Force, staffed by the Resource Innovations program at Institute for a Sustainable Environment (ISE, see below), the focal point of sustainability programming at the University of Oregon/Eugene. Released in August 2005, the Task Force report made the following recommendations to the city, most of which are now in the process of implementation:

- Commit to supporting businesses that use sustainable practices
- Establish an Office of Sustainability to highlight city's commitment
- Establish a board or commission to help expand efforts in city and business (done)
- Become carbon neutral in city facilities by 2020
- Purchase and use sustainable products and technologies
- Adopt sustainability criteria for all aspects of city operations, requiring triple bottom line analysis of propose policies or actions for city council and sustainable purchasing
- Adopt goal of zero waste to landfills and incinerators form city facilities by 2020 and develop specific plan to reach this goal
- Adopt sustainability indicators to assess city operations and community-wide progress
- Educate city employees
- Provide incentives and recognition for businesses using sustainable practices and remove barriers
- Form partnerships with private, public and nonprofit entities

The Task Force, addressing the community as a whole including nonprofit and economic-development organizations, added the following recommendations:

- Help all interested local businesses apply or expand sustainability measures;
- Commit to expanding sustainable business cluster;
- Recruit new businesses that can fill niches and increase dynamism within these clusters;
- Help businesses form local associations or networking mechanisms to increase communications on common problems;
- Implement public-education program and grow the local market for sustainable products and services;
- Improve access to loans, grants and other forms of business financing;
- Form a task force on social equity.

Industry

According to a state-level cluster-analysis by Dr. Jennifer Allen of Portland State University's Center for Sustainable Processes and Practices,¹⁰ some 15 percent of all new building projects in Oregon are now constructed to green or high-performance standards, and the state has a "significant concentration" of firms with deep expertise. Those firms she listed, however, were predominantly in Portland, not Eugene. Locally, industrial leadership is expressed through the **Eugene Branch of the Cascadia Region Green Building Council**.¹¹

Employment in Key Energy and Environmental Systems Sectors

The Eugene metropolitan area is home to 182 individual business establishments in industries connected to the energy and environmental systems sectors (E&E sector). The regional sector is growing and employment reached 4,394 in 2005 after adding 8.4 percent to its employment base since 2001. The region outpaced the U.S. in the E&E sector which declined by 5.6 percent. Eugene's relative employment concentration in the overall E&E sector has lifted and its location quotient is now 1.67 indicating a specialized industry sector. (See table 1.)

Table 1. The energy and environmental sector in the Eugene, OR MSA and U.S., 2005

Energy & Environmental Sectors	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Eugene, OR MSA						
Total Private Sector	10,070	3.7%	121,750	5.7%	1.00	\$31,448
Total Energy & Environmental Sector	182	-10.7%	4,394	8.4%	1.67	\$48,333
Energy & Env. Consulting Services	90	1.1%	557	15.6%	0.51	\$49,309
Green Buildings and Sustainable Design	77	-21.8%	2,639	-4.2%	3.53	\$42,561
Indoor Environmental Quality	5	25.0%	60	1.7%	0.30	\$29,488
Renewable Energy	3	0.8%	1,111	64.2%	3.32	\$62,782
Renewable Power Generation	1	-31.2%	1	-91.1%	0.02	\$63,031
Water Quality and Water Resources	6	-23.1%	26	-63.6%	0.13	\$38,754
United States						
Total Private Sector	8,308,128	7.4%	110,634,500	1.2%	1.00	\$40,499
Total Energy & Environmental Sector	140,747	10.7%	2,388,397	-5.6%	1.00	\$58,627
Energy & Env. Consulting Services	93,592	20.0%	985,884	9.0%	1.00	\$67,252
Green Buildings and Sustainable Design	29,806	-5.9%	679,703	-7.8%	1.00	\$36,876
Indoor Environmental Quality	2,548	-7.2%	179,257	-16.9%	1.00	\$44,167
Renewable Energy	3,405	4.9%	303,951	-21.1%	1.00	\$86,704
Renewable Power Generation	1,766	-4.8%	54,532	-33.2%	1.00	\$85,403
Water Quality and Water Resources	9,630	0.2%	185,070	-10.0%	1.00	\$52,563

Source: Battelle analysis of BLS QCEW data from IMPLAN.

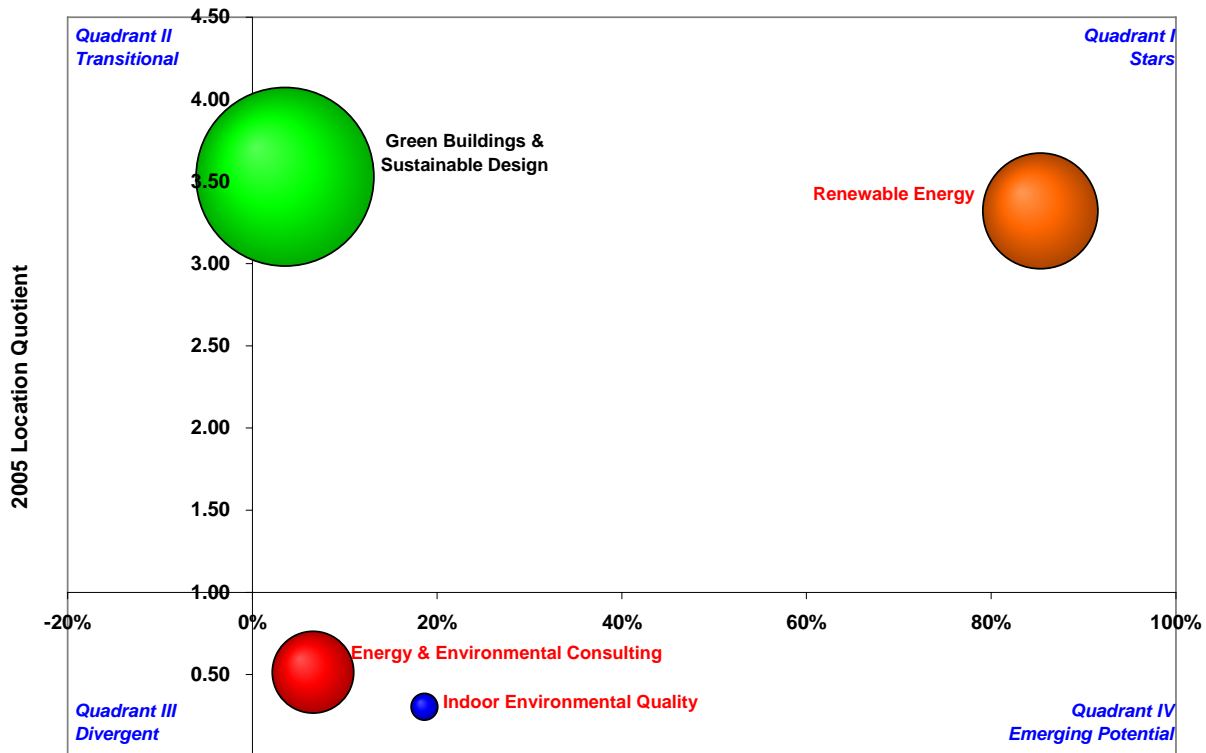
¹⁰ See <http://www.oregonclusters.org/Docs/Green%20Building%20Cluster%20PowerPoint.ppt>.

¹¹ See <http://www.cascadiagbc.org/branches/oregon-branches/Eugene>

The primary E&E industry subsectors in and around Eugene are green buildings and sustainable design (2,639 jobs); renewable energy (1,111 jobs); and energy and environmental consulting (557 jobs). These reflect, to some extent, regional efforts and focus on growing the region's inventory of green buildings and producing green building materials. The green building subsector is highly specialized with a concentration of jobs more than three times that for the U.S. Much of the activity within the local green building sector is focused on hardwood and engineered lumber manufacturing.

Just as Eugene is highly specialized in green building materials, its renewable energy subsector has a location quotient that exceeds three (3.32) for 2005. The local industry is thriving, adding more than 60 percent to its job base during the 2001 to 2005 period. The bubble chart in figure 1 highlights this strong growth relative to the U.S.

Figure 1. Energy and environmental sector employment in Eugene, OR, degree of specialization, and growth relative to the U.S., 2001-2005



Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job growth.

Employment Growth Relative to the U.S. (2001-05)

Role of the University Sector

Each of the members of the multicampus Oregon University System has assets in sustainable technology, but in Eugene itself the leader is the University of Oregon's **Institute for a Sustainable Environment (ISE)**,¹² an umbrella for collaborative and applied research and outreach. The main programs of the ISE are:

- **Geographic Information Systems Lab**, analyzing landscape change over large regions;
- **Ecosystem Workforce Program**, outreach to rural forest communities focused on interplay between ecology and economic opportunity;
- **Resource Innovations**, providing general technical-assistance outreach to governments, business and community.
- **Climate Leadership Initiative**, a program for public education and communication that has worked closely with the City of Eugene on its Sustainable Business and Climate Change Initiative;¹³ and
- **Social Acceptability of Forestry Practices in the Pacific Northwest**, an opinion measurement project focusing on alternative timber harvesting methods

ISE is linked to a variety of other campus-based programs,¹⁴ including planning and policy, green chemistry, and ecological design.

Next Steps

According to a SWOT analysis included in Dr. Allen's analysis of the statewide cluster, the **weaknesses** of the sustainable sector in Oregon are:

- The wood products, green chemistry, community infrastructure, and green-building industries are fragmented with no mechanism for joint strategies/action;
- The forest products industry is focused on raw material, not on high value-added products consistent with green-building products; and
- The academic/research community is fragmented and not strategically focused.

According to the same analysis, competition in university/industry partnering comes from: the Pittsburgh Green Building Alliance and CMU; the Berkeley Center for the Built Environment; Simon Fraser (in British Columbia) Centre for Sustainable Community Development; the Center for Sustainable Engineering, an NSF/EPA funded

¹² See <http://gladstone.uoregon.edu/~enviro/>

¹³ See <http://climlead.uoregon.edu/checklist/checklist.html>.

¹⁴ All links available at <http://gladstone.uoregon.edu/~enviro/links.html>.

center involving CMU, University of Texas and Arizona State University; the University of Florida; and Oak Ridge National Laboratory.

Next steps recommended by Dr. Allen were:

- Support a development of a “conscious” economic cluster
- Pursue untapped federal funding opportunities especially through Pacific Northwest National Laboratory.
- Oregon Innovation Council should fund a “Signature Research Center” in this area (done).
- Invest in relationships with China using LEED as major market driver for similar systems developing there and elsewhere.
- Grow a high value-added forest industry that is integrated with green building materials.
- Develop networks of multiple industries.
- Enhance connections between and among the architecture/engineering, urban planning, construction, and wood-product industries.
- Form more university/industry partnerships.

Implications for Syracuse

Eugene’s aggressive approach demonstrates the power of municipal government to shape the terms of discussion, by explicitly linking economic strategy to sustainability goals that are broadly endorsed by community residents. While Eugene is not necessarily the primary center of industrial activity, it has developed a reputation for activism that places it on nearly equal footing with the much larger Portland metro.

Strategy Rationale

Fort Collins, the largest city and county seat of Larimer County (a Metropolitan Statistical Area unto itself and commonly known as Northern Colorado) believes it can build on its university and industrial assets, its engaged citizenry, and its quality-of-life attributes to develop a **Northern Colorado Clean Energy Cluster**.¹⁵ That is the name for both the concept and a specific public/private partnership that is trying to advance the sector. Interestingly, this effort has emerged in the north, not in the better-known technology area of Boulder, nor near Golden, the home to the National Renewable Energy Laboratory.¹⁶

The goal of the Clean Energy Cluster is “to position Northern Colorado as the ‘Go To’ region for smart grid technologies, renewable energy, biofuels, and cleaner and more efficient engines.” Launched in May 2006, the Clean Energy Cluster has raised \$1.5 million in cash and in-kind commitments, enough to sustain a paid staff, a web presence, and a 350-member network that convenes for occasional summits and special events. The Cluster organization has an organizing committee supported by professional-service providers and special committees on R&D, economic development, community infrastructure, branding, outreach and funding, and programs and events.

Background

There seems little question that a citizenry committed to sustaining its quality of life has impelled the political and civic leadership of Fort Collins to an ever-higher commitment to clean energy. As early as 1997, City Council committed Fort Collins to the Cities for Climate Protection Campaign.¹⁷ By 2004, the city had produced an **Action Plan for Sustainability**¹⁸ which has been operationalized by city government through a range of programs¹⁹ addressing the “triple bottom line” of environmental, financial and social health. Among these programs are **Climate Wise**,²⁰ an industry oriented program of technical assistance for waste reduction and energy savings; a **Local Action Plan to Reduce Greenhouse Gas Emissions**,²¹ a community-wide program with goals for both the public and private sectors; and an **Economic Action Plan**²² that specifically endorses a cluster strategy, community branding, and “economic gardening” (growing your own companies rather than re-

¹⁵ See <http://www.nccleanenergy.com/>

¹⁶ See <http://www.nrel.gov/>.

¹⁷ See <http://www.iclei.org/index.php?id=800>.

¹⁸ See <http://fcgov.com/sustainability/pdf/sustainability-plan.pdf>.

¹⁹ See <http://fcgov.com/sustainability/?departments>

²⁰ See <http://fcgov.com/climatewise/resources.php>.

²¹ See <http://www.fcgov.com/airquality/lap.php>.

²² See <http://fcgov.com/business/pdf/economic-action-plan.pdf>.

lying on recruiting). It is in this context that the Clean Energy Cluster effort developed, with support from the Northern Colorado Economic Development Corporation.

Industry

The Economic Advisor for the City of Fort Collins has estimated²³ that the clean energy cluster represents 5.2 percent of the business establishments in Fort Collins compared with 3.1 percent countrywide. He also estimated that the sector accounts for .4% of the workforce compared with 0.3 percent nationally and found that the number of firms grew from 31 in 2001 to 40 in 2006, an increase of 29 percent. Among the occupations he listed as important to the sector were: biochemists/biophysicists, electrical engineers, environmental engineers, and electro-mechanical equipment assemblers. The advisor listed Fort Collins fourth in a ranked list of metro areas with the highest concentration of clean energy employment, following Richland, WA.; Santa Fe, NM.; and Springfield, IL.

Among the local firms that took major roles in the **Northern Colorado Clean Energy Utility Summit**²⁴ were:

- **Woodward Governor**,²⁵ founded in 1870, a manufacturer of energy control systems for engines of all types;
- **Spirae**,²⁶ a developer of grid modeling software and systems;
- **Solix**,²⁷ a developer of algae-based biofuels whose CTO is the co-director of the EECL at CSU; and
- **Vestas Blades**, a U.S. facility of the Danish wind turbine maker, based in Windsor just over the Weld County line.

Employment in Key Energy and Environmental Systems Sectors

In 2005, the Fort Collins metropolitan region employed 3,626 in its energy and environmental systems sector. These local jobs span more than 300 establishments and pay a substantial premium compared with average private sector jobs-- \$54,796 vs. \$35,580 in 2005. Though the Fort Collins E&E sector contracted during the 2001 to 2005 period, the region continues to boast a specialized concentration of jobs relative to the U.S. Its 2005 location quotient was 1.64. (See table 2.)

²³ See <http://www.nccleanenergy.com/events/greensummit/greensummit-cityoffc.pdf>.

²⁴ See <http://www.nccleanenergy.com/summit.html>.

²⁵ See <http://www.woodward.com/>.

²⁶ See <http://www.spirae.com/index.php>.

²⁷ See <http://www.solixbiofuels.com/>

Table 2. The energy and environmental sector in the Fort Collins MSA and U.S., 2005

Energy & Environmental Sectors	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Fort Collins, CO MSA						
Total Private Sector	9,563	12.7%	102,655	1.9%	1.00	\$35,580
Total Energy & Environmental Sector	306	7.4%	3,626	-8.2%	1.64	\$54,796
Energy & Env. Consulting Services	244	22.6%	1,916	4.4%	2.09	\$53,945
Green Buildings and Sustainable Design	42	-36.4%	628	11.9%	1.00	\$34,833
Indoor Environmental Quality	2	20.0%	10	577.0%	0.06	\$48,669
Renewable Energy	9	55.5%	291	-26.7%	1.03	\$95,782
Renewable Power Generation	1	-	33	-	0.64	\$59,391
Water Quality and Water Resources	8	-34.8%	748	-35.1%	4.36	\$57,693
United States						
Total Private Sector	8,308,128	7.4%	110,634,500	1.2%	1.00	\$40,499
Total Energy & Environmental Sector	140,747	10.7%	2,388,397	-5.6%	1.00	\$58,627
Energy & Env. Consulting Services	93,592	20.0%	985,884	9.0%	1.00	\$67,252
Green Buildings and Sustainable Design	29,806	-5.9%	679,703	-7.8%	1.00	\$36,876
Indoor Environmental Quality	2,548	-7.2%	179,257	-16.9%	1.00	\$44,167
Renewable Energy	3,405	4.9%	303,951	-21.1%	1.00	\$86,704
Renewable Power Generation	1,766	-4.8%	54,532	-33.2%	1.00	\$85,403
Water Quality and Water Resources	9,630	0.2%	185,070	-10.0%	1.00	\$52,563

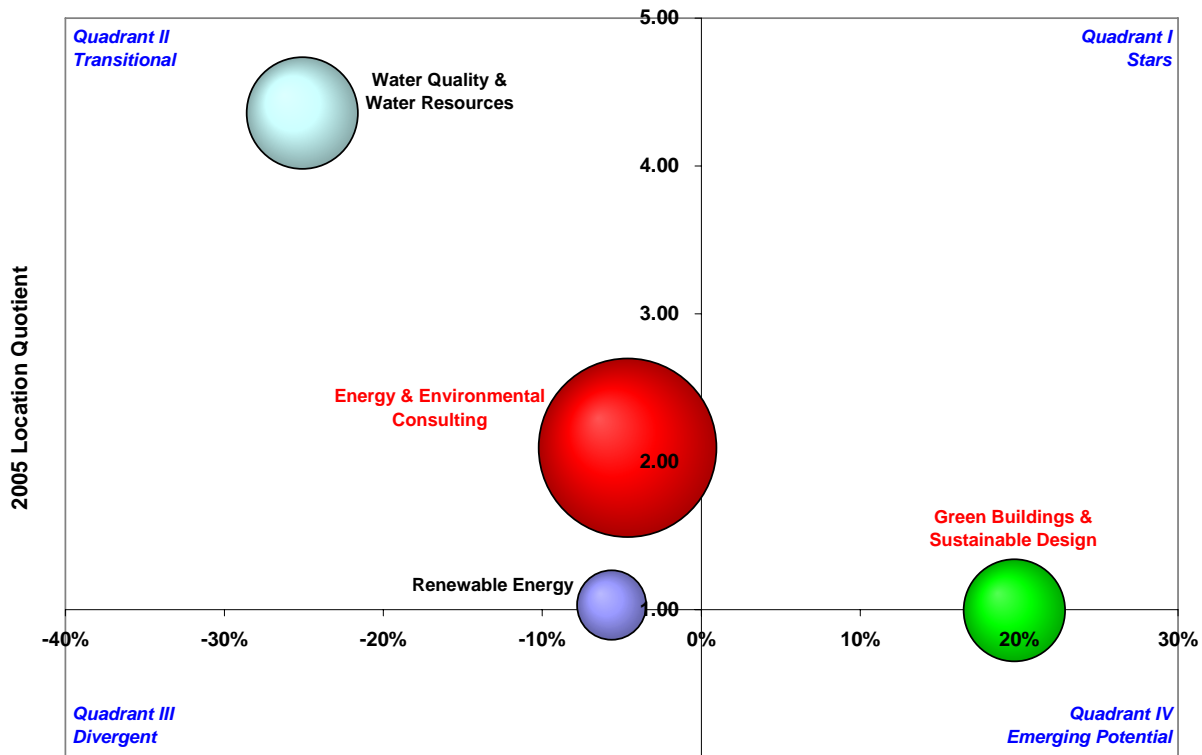
Source: Battelle analysis of BLS QCEW data from IMPLAN.

Fort Collins' E&E sector is primarily formed across three major subsectors. Energy and environmental consulting leverages regional technical expertise to provide services to clients and contributes nearly 2,000 jobs to the local E&E sector. At the regional level, this consulting sector has twice the concentration of jobs as the national average (LQ is 2.09) and has grown by 4.4 percent since 2001. Like the national sector, the majority of local jobs are in the engineering services component.

The water quality and resources subsector is also a specialized local employer with 748 jobs and a LQ of 4.36 in 2005. Jobs in this sector are primarily in the instrumentation industry that includes, among other products, water sensors and monitoring instruments. This sector might be considered to be in a "transition" (see figure 2) as it is highly specialized but contracting relative to the national sector.

The Fort Collins region has a growing green building and sustainable design subsector, which has added 11.9 percent to its employment base since 2001 and now employs more than 600. Its LQ matches the national average concentration (1.00) and continued job growth would likely lead to some degree of specialization in the future.

Figure 2. Energy and environmental sector employment in Fort Collins, CO, degree of specialization, and growth relative to the U.S., 2001-2005



Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job growth.

Employment Growth Relative to the U.S. (2001-05)

Role of University Sector

The primary university driver of the Clean Energy Cluster is Colorado State University, the state's land-grant university. According to the Associate Dean for Research and Economic Development of the CSU College of Engineering,²⁸ the interdisciplinary "Clean Energy Cluster" at CSU now involves 80 faculty across several colleges and attracted \$9.2 million in total federal funding in FY06.

The centerpiece of the cluster is the **Engines and Energy Conversion Lab**,²⁹ a university-recognized "Program of Research and Scholarly Excellence." EECL is one of the few centers nationally that has made the transition from a strict focus on internal combustion engines (with long-time partnering from major national firms like Caterpillar, John Deere and Cummins) to a diverse program that also encompasses alternative and renewable technologies and alliances with a number of regional companies in the clean energy space.

²⁸ See <http://www.nccleanenergy.com/events/greensummit/greensummit-csu.pdf>.

²⁹ See <http://www.eecl.colostate.edu/>.

EECL maintains a Global Innovation Center that emphasizes transferring to developing nations new technologies in cookstoves, retrofit diesel conversions, small-scale power, water purification, etc. Other assets in CSU include the **Materials Engineering Lab**³⁰ in the Department of Mechanical Engineering, an algae biofuels partnership with Solix, etc.

In its own operations, CSU was an early signer of the Talloires Declaration by University Leaders for a Sustainable Future.³¹ The university has announced it will partner with a private developer to build up to 200MW of wind power on 11,000 acres of university-owned land at the Wyoming Border. When fully developed this wind farm will meet the campus's entire 16MW peak load and yield extra energy that can be sold to the grid. Also, CSU will participate along with CU Boulder and NREL in the first "collaboratory" funded by the state's Colorado Renewable Energy Authority—the Colorado Center for Biorefining and Biofuels.

Next Steps

UniversityCity Connections³² – a community-planning initiative funded by the Community Foundation of Northern Colorado to link the CSU, Downtown, and Cache la Poudre River neighborhoods—has identified as a priority of its "sustainable energy" and "economic development" task forces the creation of a **Fort Zero Energy District**.^{33,34}

As part of the ZED, the Clean Energy Cluster is seeking funding from U.S. DOE for a 5MW demonstration project that would allow the District to reduce peak load energy demand through a mix of renewable and distributed technologies and load-shedding practices. The long-term goal of the District is for a region within 50 miles of the three neighborhoods to produce as much energy as it uses, without imports.

The District strategy focuses not just on the technology but on creating a live/work attraction for teachers, researchers, and entrepreneurs who will be necessary to build the cluster. As part of the District strategy, the city has been asked to create space within the study area for significant expansion of both the EECL and the **Fort Collins Technology Incubator**,³⁵ a general purpose technology incubator that is *not* currently part of the Clean Energy Alliance of incubators coordinated by NREL.

Implications for Syracuse

The Fort Collins situation demonstrates how a civic commitment to environmentalism and sustainability can easily be transformed into a key aspect of a city or region's economic-development strategy. It also demonstrates the reinforcing nature of quality-of-life issues: the citizenry believes that by focusing on renewable energy

³⁰ See <http://www.engr.colostate.edu/me/facil/mel/index.html>.

³¹ See http://www.ulsf.org/programs_talloires.html.

³² See <http://www.universitycityconnetions.org/>

³³ See <http://www.nccleanenergy.com/jumpstart.html>.

³⁴ See <http://www.univercityconnections.org/docs/FortZED-final-report-web.pdf>.

³⁵ See <http://www.fortcollinsincubator.org/>

it can sustain its quality of life, and it also believes that by promoting its quality of life it can attract the human resources necessary for it to be a leader in clean energy technology. The energy strategy is now deeply imbedded in the foundation-funded strategy for physical development of downtown and adjoining districts.

Strategy Rationale

Sustainability is emerging an important focus for the six-county combined MSA anchored by Grand Rapids, Muskegon, and Holland, and known locally as the Metro Tri-Plex and in tourism literature as “Michigan’s West Coast.” The **West Michigan Strategic Alliance**³⁶ believes that preserving environmental quality is central to the “brand” identity of the region, and **The Right Place**³⁷ increasingly sees sustainability as an opportunity for the region’s distressed manufacturing sector. The two groups are now collaborating, for example on a \$400,000 grant from EPA to increase participation in a Green Suppliers Network.

While Grand Rapids (the largest of the three cities and the farthest inland) has staked its technology investments largely on the life sciences,³⁸ it also happens to be the center of the Midwestern office-furniture and design sector. These companies³⁹ and their suppliers (networked by a **Manufacturers Council** housed within the Right Place Program) see green design as a product differentiator in the global marketplace, and are supporters of the vigorous West Michigan Chapter of the U.S. Green Building Council. Grand Rapids claims 11 percent of LEED certifications nationally, which for a city of moderate size places it first in the nation per capita. As a sign of the degree to which sustainability is now “in the air,” last year the City of Grand Rapids government replaced its overall strategic plan with what it now calls a Sustainability Vision Statement.⁴⁰ For example, two years ago Mayor Heartwell committed the city to purchase 20 percent of its power from renewable sources by 2008.

At the lakefront community of Muskegon, emphasis has been instead on renewable energy as a way both to preserve the lakefront ecosystem and to brand the region. Muskegon has used the Michigan **SmartZones Program**,⁴¹ which allows existing local development financing agencies to apply to the **Michigan Economic Development Corporation** for designation of their development zones as “certified technology parks” known informally as SmartZones. The essence of this program is to allow local development agencies to apply Tax Increment Financing to creation of business incubators that support targeted technology sectors and involve universities.

³⁶ A strategic planning alliance founded in 2000. See <http://www.wm-alliance.org/Brix?pageID=2>.

³⁷ A regional economic-development alliance founded in 1985. See <http://www.therightplace.org/>.

³⁸ The privately endowed Van Andel Institute has brought life sciences to a region that never had it before.

³⁹ **Steelcase** is based in Grand Rapids; both **Herman Miller** and **Haworth** are situated in nearby Holland, MI.

⁴⁰ See http://www.grand-rapids.mi.us/index.pl?page_id=4003%20. Or in more detail the full plan at http://www.ci.grandrapids.mi.us/download_upload/binary_object_cache/executive_Sustainability%20Plan%20FY%202007%20101706.pdf.

⁴¹ See <http://medc.michigan.org/smartzones/>.

Background

At Muskegon, the SmartZone is 34 acres of lakefront property⁴² targeted for sustainable commercial and residential development, and anchored by the **Michigan Alternative and Renewable Energy Center (MAREC)**,⁴³ a distributed generation demonstration center first conceived in 1999 and opened in 2003 as an incubator/outreach arm of Grand Valley State University. Other partners in MAREC include the regional chambers of commerce, local community foundations, Muskegon Community College, and **WIRED West Michigan**.⁴⁴

Equipped with microturbines, fuel cells, a solar roof, and advanced batteries, the 25,000 square-foot MAREC is itself designed to be self-sufficient and has a LEED gold rating. It cost a total of \$7 million, of which \$4 million came from the Michigan Economic Development Corporation (MEDC)-approved TIF financing, and a \$3 million grant from the state Public Service Commission for equipment acquisition. It has a staff of 4, laboratory space allocated to renewable energy training programs at the community college, and 4,000 square feet dedicated to business incubation. MAREC has begun seeking its own grant support for projects like a biomass demonstration effort at the local water treatment plant.

Industry

The startup companies initially being incubated at MAREC in Muskegon are:

- **E-Village**,⁴⁵ a developer of integrated battery/solar/wind systems;
- **JetScrub**, environmental abatement technology; and
- **E-net**, combined heat and power technology.

Aside from the office-furniture sector and its suppliers, Grand Rapids is home to the nonprofit **Alliance for Environmental Sustainability**,⁴⁶ a national effort to bring sustainability (and specifically LEED certification) to the residential home-construction sector. The city's Metro Health hospital is also one of the few full-service hospitals with a green roof, and LEED certified.

Employment in Key Energy and Environmental Systems Sectors

The Grand Rapids region employs 4,553 in jobs that span 279 individual business establishments engaged in activity connected to energy and environmental systems. Though the region has made some of these component industries areas of intense focus, the sector has lost jobs, on net, since 2001 (down 21 percent). It is important to keep in mind that the traditional industry classification system used here (NAICS) is often not specific enough with respect to new industries and activi-

⁴² See <http://www.muskegonlakefront.com/ourstory.htm>.

⁴³ See <http://www.gvsu.edu/marec/>.

⁴⁴ See http://www.wiredwestmi.org/index.asp?it=about_westmi

⁴⁵ See <http://www.energy-village.com/contact.htm>.

⁴⁶ See <http://www.alliances.org/>.

ties like green energy and systems. Thus some of these activities are embedded in larger manufacturing and other industries that have experienced job declines in recent years. (See table 3.)

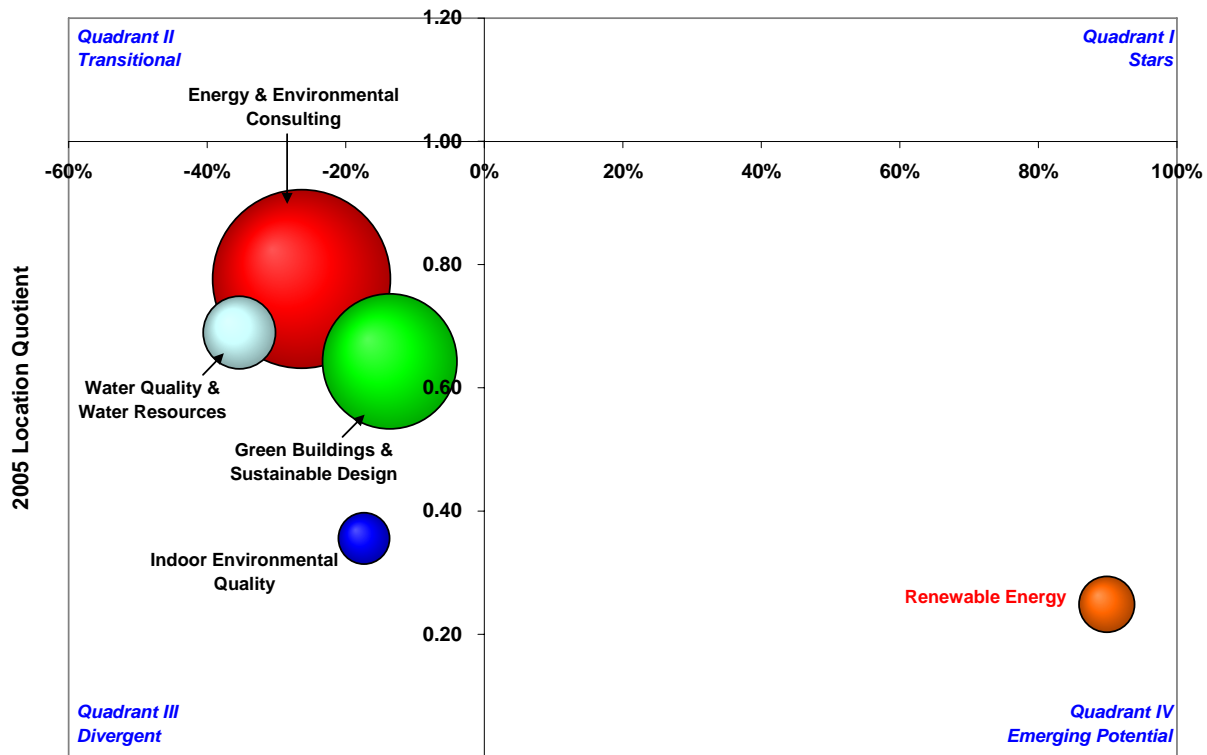
Table 3. The energy and environmental sector in the Grand Rapids MSA and U.S., 2005

Energy & Environmental Sectors	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Grand Rapids, MI MSA						
Total Private Sector	17,025	0.2%	342,587	-0.1%	1.00	\$36,581
Total Energy & Environmental Sector	279	-24.7%	4,553	-21.0%	0.62	\$52,841
Energy & Env. Consulting Services	179	-10.3%	2,371	-17.4%	0.78	\$60,195
Green Buildings and Sustainable Design	67	-17.7%	1,353	-21.4%	0.64	\$41,176
Indoor Environmental Quality	8	-9.1%	198	-34.3%	0.36	\$47,839
Renewable Energy	3	-42.0%	234	68.7%	0.25	\$60,761
Renewable Power Generation	2	-60.5%	1	-85.8%	0.01	\$42,073
Water Quality and Water Resources	20	-71.7%	395	-45.4%	0.69	\$46,507
United States						
Total Private Sector	8,308,128	7.4%	110,634,500	1.2%	1.00	\$40,499
Total Energy & Environmental Sector	140,747	10.7%	2,388,397	-5.6%	1.00	\$58,627
Energy & Env. Consulting Services	93,592	20.0%	985,884	9.0%	1.00	\$67,252
Green Buildings and Sustainable Design	29,806	-5.9%	679,703	-7.8%	1.00	\$36,876
Indoor Environmental Quality	2,548	-7.2%	179,257	-16.9%	1.00	\$44,167
Renewable Energy	3,405	4.9%	303,951	-21.1%	1.00	\$86,704
Renewable Power Generation	1,766	-4.8%	54,532	-33.2%	1.00	\$85,403
Water Quality and Water Resources	9,630	0.2%	185,070	-10.0%	1.00	\$52,563

Source: Battelle analysis of BLS QCEW data from IMPLAN.

The majority of E&E sector jobs in Grand Rapids lie in the component energy and environmental consulting sector (2,371 jobs) and in green buildings and sustainable design (1,353 jobs). Kent County's engineering services sector contributes the vast majority of the consulting jobs. Within the green building sector, jobs are widespread with clusters in sheet metal, hardwoods and wood furniture, and paints and coatings. Each of these industries includes green building activity within the larger manufacturing industry.

Figure 3. Energy and environmental sector employment in Grand Rapids, MI , degree of specialization, and growth relative to the U.S., 2001-2005



Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job growth.

Employment Growth Relative to the U.S. (2001-05)

Role of the University Sector

The precise purpose of the Michigan SmartZone program is to bring universities into partnership with incubators in development zones that are not otherwise proximate to academic research. MAREC is fulfilling this function in Muskegon, although it is too early to measure any economic impacts. Meantime, Grand Valley State University—which also participates in the Grand Rapids life science SmartZone—is assessing demand for a certificate program in alternative energy technology that would be offered in conjunction with MAREC.

Next Steps

The stakeholders have not yet defined precise economic-development goals or outcomes for MAREC or the green suppliers network.

Implications for Syracuse

Somewhat like Central Upstate New York, West Michigan is a mid-sized metro region with perceived high quality of life, but a business identity traditionally connected to manufacturing rather than the university knowledge base. With MAREC, it is making an important transition that links it to startup technology sector more

tightly than ever, and which may hold lessons for Central Upstate New York. Grand Rapids itself is clearly embracing sustainability as a whole as a way of branding itself as “more than the furniture city.”

Strategy Rationale

Although energy and environment are not among the sectors currently targeted by the Pittsburgh Regional Alliance, there is emerging a strong consensus that the 15-county Western Pennsylvania region⁴⁷ has a chance to lead nationally in green-building products and design. Using its leverage as funder of so much civic and charitable infrastructure, the Heinz Endowments (Heinz) has insisted on green construction (e.g., the Gold-certified David Lawrence Convention Center⁴⁸) and has brought green buildings to the forefront of the civic dialogue.⁴⁹ Already, Pittsburgh has 120 LEED-accredited professionals and 36 LEED-registered buildings in the USGBC data system.

In 1997, Heinz funded formation of the **Green Building Alliance** (GBA),⁵⁰ which is focused exclusively on greening the commercial building sector in the region. Over the last three years, with support from Heinz and the RK Mellon Foundation, GBA has convened a Green Building Product Industry Initiative, which has issued two separate reports in partnership with Carnegie Mellon's Center for Economic Development on how the region can target a \$30 to \$40 billion national market opportunity in green-building products. Among the key findings of the latest report justifying a strategic initiative were:

- Western PA has a diverse number of building-product companies (GBA identified 1,800 firms with 68,000 employees crossing 29 subsectors of building products manufacturing);
- Western PA is a known leader in innovation (GBA counted \$119 million in federal R&D funding over 15 years for green-building research from DOE, NSF and EPA);
- Western PA is well positioned to service several major real-estate markets (Pittsburgh, Chicago, New York, Washington, Cleveland, Philadelphia and Boston); and
- Western PA is nationally recognized for the promotion and adoption of green buildings (many "first of type" LEED certified).

Background

The defined goal for the program is for the region "to position itself to both meet the demand for the creation of local green buildings, but also to position the local

⁴⁷ With the 10-county Southwestern Pennsylvania (Greater Pittsburgh) region at its core.

⁴⁸ See <http://www.pittsburghcc.com/html/index.htm>.

⁴⁹ See http://www.heinz.org/programs_cms.aspx?SectionID=5&ParentID=61.

⁵⁰ See <http://www.gbapgh.org/>.

building product manufacturers to take advantage of the U.S. and international growth markets.”⁵¹ Specific recommendations of the strategy include creating:

- Green Building Product Industry Network, a forum for product companies to interact with the architectural, engineering, and construction community
- Green Building Product Investors Council, including a structure for industry/university partnerships.
- Green Building Products Initiative Partners, comprising economic development groups, investment firms, and “Keystone Innovation Zones” that link these actors on a regional basis around universities and colleges.
- Green Building Alliance Infrastructure, meaning an IT tool to allow tracking of specific interests by individuals and firms.

Industry

The GBA has actually published the names of the 1,800 building products companies it is targeting for its Network. However, it does note that among the recipients of federal R&D funding in the region have been large industrial companies like Siemens Westinghouse Power (the remnants of the power divisions of the now-dismembered Westinghouse) and local operations of Air Products and Chemicals (based in Allentown in Northeastern Pennsylvania).

Developers are also an important industrial constituency. One resource that the Alliance plans to use to better involve regional developers is the **Green Building Fund (GBF)**⁵² that has been created within the CL Fund, a community development loan fund serving greater Pittsburgh. GBF will assist owners and developers with loans ranging from \$200,000 to \$400,000 to help finance both hard and soft costs of LEED certification. Recently, the City of Pittsburgh Urban Redevelopment Authority announced it will also make low-interest loans for green construction, as the mayor has bought in to the green buildings strategy.

The region also has a smattering of startup companies relevant to the sector, such as **Plextronics**,⁵³ a Carnegie Mellon spin-off in printed electronic devices, with additional applications to solar photovoltaics. Plextronics is venture-capital backed but also an investee of **West Penn Power Sustainable Energy Fund**,⁵⁴ a regional energy venture fund created as part of the state’s electric deregulation plan for Allegheny Power’s 23-county service area.

⁵¹ Green Building Alliance. *Green Building Products: Verifying and Defining the Opportunity for Western Pennsylvania*. October 2006. Available online. Previous report was *Green Building Products: Positioning Southwest Pennsylvania as the U.S. Manufacturing Center*. Also available online.

⁵² See http://www.gpapgh.org/WhatWeDo_GreenBuildingFund.asp.

⁵³ See <http://plextronics.com/>.

⁵⁴ See <http://www.wppsef.org/history.html>.

Employment in Key Energy and Environmental Systems Sectors

The Pittsburgh metropolitan area has the highest employment totals in the overall E&E sector among the regions selected for this analysis. This is not be surprising, however, because the MSA is by far the largest with nearly 1 million in total private sector employment and regional manufacturing capabilities that tie in well with the manufacturing-oriented industry analysis undertaken here.

The Pittsburgh E&E sector employed 18,769 in 2005 in more than 1,000 local business establishments. This employment total is down nearly 28 percent since 2001 reflecting a more broad-based regional and national contraction in the manufacturing sector. Average wages in the E&E sector reflect a relatively high-skilled workforce that earns a substantial premium over the average private sector worker—approximately \$60,000 vs. \$38,000 in 2005. (See table 4.)

Table 4. The energy and environmental sector in the Pittsburgh MSA and U.S., 2005

Energy & Environmental Sectors	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Pittsburgh, PA MSA						
Total Private Sector	59,829	-4.0%	959,448	-1.9%	1.00	\$38,397
Total Energy & Environmental Sector	1,039	-8.2%	18,769	-27.7%	0.91	\$59,697
Energy & Env. Consulting Services	707	-0.6%	10,873	-4.3%	1.27	\$64,245
Green Buildings and Sustainable Design	178	-32.5%	4,034	-16.3%	0.68	\$52,345
Indoor Environmental Quality	13	-43.8%	388	-73.3%	0.25	\$57,351
Renewable Energy	24	3.9%	544	-44.3%	0.21	\$57,828
Renewable Power Generation	9	-8.2%	318	-92.9%	0.67	\$73,629
Water Quality and Water Resources	108	6.3%	2,614	-9.3%	1.63	\$51,172
United States						
Total Private Sector	8,308,128	7.4%	110,634,500	1.2%	1.00	\$40,499
Total Energy & Environmental Sector	140,747	10.7%	2,388,397	-5.6%	1.00	\$58,627
Energy & Env. Consulting Services	93,592	20.0%	985,884	9.0%	1.00	\$67,252
Green Buildings and Sustainable Design	29,806	-5.9%	679,703	-7.8%	1.00	\$36,876
Indoor Environmental Quality	2,548	-7.2%	179,257	-16.9%	1.00	\$44,167
Renewable Energy	3,405	4.9%	303,951	-21.1%	1.00	\$86,704
Renewable Power Generation	1,766	-4.8%	54,532	-33.2%	1.00	\$85,403
Water Quality and Water Resources	9,630	0.2%	185,070	-10.0%	1.00	\$52,563

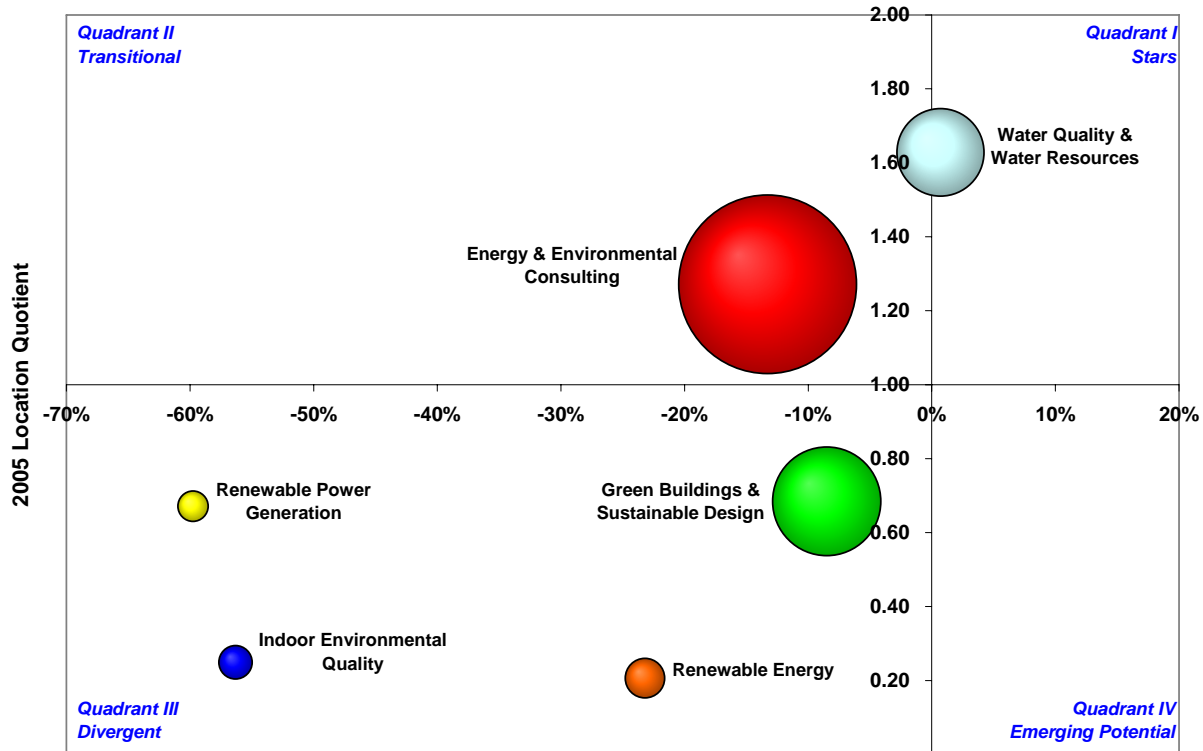
Source: Battelle analysis of BLS QCEW data from IMPLAN.

Pittsburgh and surrounding communities are known for technical expertise in engineering. Thus it is engineering service activity that provides the bulk of employment within the large energy and environmental consulting services subsector. This large subsector employs nearly 11,000 in the Pittsburgh MSA and is considered to be a regionally specialized industry group (LQ is 1.27). Contributing to the sector is a modest job concentration (over 500) in environmental consulting.

The water quality and resource subsector in the Pittsburgh region can also be considered a specialized industry. Its LQ measured 1.63 in 2005, meaning it exceeds the national average job concentration by more than 60 percent. Despite this con-

centration, though, the sector has shed jobs since 2001 (down 9 percent). Though it did contract locally, this job loss was not as severe as that for the U.S. sector (down 10 percent) and thus it lies just inside Quadrant 1 in the bubble chart below. (See figure 4.)

Figure 4. Energy and environmental sector employment in Pittsburgh, PA, degree of specialization, and growth relative to the U.S., 2001-2005



Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job growth.

Employment Growth Relative to the U.S. (2001-05)

Role of the University Sector

GBA has identified the following recognized R&D and educational assets as key to the regional strategy:

- Carnegie Mellon's **Center for Building Performance & Diagnostics**,⁵⁵ This center includes the Intelligent Workplace testbed and also the Advanced Building Systems Integration Consortium (ASBIC), an NSF industry/university cooperative research center created in 1982. Though ASBIC has long since "graduated" from the NSF program, it still has eight corporate and four governmental members in its industry consortium, spanning the U.S., Canada and France. This entire research complex is the rough analogue to the Syracuse COE. Built around six core faculty members in architecture, it

⁵⁵ See <http://www.arc.cmu.edu/cbpd/index.html>.

has formal ties with UC Davis, Texas A&M, Georgia Tech, UC Berkeley and University of Houston.

- Pitt's **Mascaro Sustainability Initiative**,⁵⁶ a center funded by the Mascaro family, the Bevier Estate and the Heinz Endowments. Its purpose is to provide seed grants that enable Pitt faculty to secure larger external funding for research on green construction and sustainable water use. Mascaro was a construction contractor who was engaged in an early green project for direct use by the Heinz Endowments.
- Though located in Central rather than Southwestern Pennsylvania, Penn State's reach through its satellite campuses and other mechanisms is essentially statewide, and so GBA cites as other key assets Penn State's **Indoor Environment Center**⁵⁷ and its **Lean and Green Initiative in HPB**,⁵⁸ as well as its materials research programs.

Next Steps

GBA recently received an additional \$1 million grant for the Pennsylvania Ben Franklin Technology Development Authority (matched by \$250,000 more from the Heinz Endowments) to carry its strategy forward. Metrics being tracked by GBA during this phase are:

- Number of firms participating in the programs recommended above
- Reported generation of employment, revenues, exports, partnerships
- National recognition through news coverage
- Number of new green building products introduced, new employees hired as a result, new patents and participant satisfaction
- Increase in green building research expenditures at colleges and universities, and increased patents and licenses

No interim reports have yet been published.

Implications for Syracuse

Pittsburgh demonstrates how demand for green buildings can focus attention on a region's potential to supply materials, expertise, and technology. Without the market power of Heinz, there would be far fewer green buildings in Pittsburgh, and less of a legacy for GBA to plan with. However, as has been noted in Battelle's interviews, the university contribution to the Pittsburgh effort is mainly in the architectural disciplines, and less so in the engineering disciplines where Syracuse is gathering strength.

⁵⁶ See <http://www.engr.pitt.edu/msi/>.

⁵⁷ See <http://www.engr.psu.edu/ae/iec/about.htm>.

⁵⁸ See <http://www.engr.psu.edu/leanandgreen/index.aspx>.

Strategy Rationale

The 4-county Sacramento Metropolitan Statistical Area believes it can brand itself as a center of cleantech, based on its status as home to the agricultural research complex at UC Davis, several specialized energy technology centers on and off campus, and the state capital's technology and regulatory apparatus (mainly the **California Energy Commission** and the **California Air Resources Board**), which in turn attract certain segments of the private sector.

Many of the necessary assets have been in place for some time, but the impetus for change came in 2005 from **CleanStart**,⁵⁹ a project established by the Sacramento Regional Technology Alliance (SARTA, established in 2001) and the McClellan Technology Incubator, a general purpose technology incubator created in 2001 as an outcome of the BRAC process at McClellan Air Force Base. Also in 2005, clean energy was recognized⁶⁰ as a key element of the "regional business plan" put forward by the Partnership for Prosperity, a regional collaborative.

With the region's key business groups now all in broad agreement, the strategy has forward momentum but could still be fairly described as "early stage."

Background

CleanStart defines the targeted cleantech sector somewhat more broadly than clean energy, including:

- **Renewable energy** – solar, wind, bio-energy, and environmentally friendly hydro
- **Energy efficiency and demand response** – end-use, buildings, and grid applications
- **Environment-enhancing technologies** – advanced flue gas cleanup, ultra low emissions generation, and exceptionally efficient generation
- **Enabling technologies** – power electronics, storage, low-loss cables and wires, sensors and instrumentation, control systems, materials and manufacturing, and integrated applications.

CleanStart's mission is to assist entrepreneurs in these sectors "by empowering them with knowledge, capital, and connections critical to creating a successful new business." So similar is this to the SARTA mission itself that the two sponsoring organizations of CleanStart announced in April that they plan to merge. The range of services provided to cleantech entrepreneurs includes mentoring, coaching, partici-

⁵⁹ See <http://www.cleanstart.org/>.

⁶⁰ See <http://www.valleyvision.org/partnership/New-cleantech.html>.

pation in a cleantech-oriented business plan competition, and access to several partnering networks of investors at all stages interested in cleantech.

Industry

When CleanStart began in 2005, the region claimed 30 active cleantech companies, and recent estimates put the number at between 55 and 70. This is still a small share of a large and diversified economy, but with some high-profile successes.

Among the several early-stage companies frequently mentioned as anchoring the new cleantech sector are **Jadoo Power**⁶¹ of Folsom, a portable fuel cell company founded by a former executive with the local defense contractor Aerojet, and Sacramento-based **Pacific Ethanol**,⁶² one of the early ethanol producers to go public on Wall Street. With a boost from the Energy Commission's vigorous programs to promote consumer use of solar energy, the region has also attracted several international solar-energy companies, including turnkey developers **Ecostream**⁶³ (from Holland) and **Suntechnics**⁶⁴ (Germany).

Several larger companies are represented in the region through their participation in the **California Fuel Cell Partnership**⁶⁵, created in 1999 by the state Energy Commission, the Air Resources Board, and cooperating companies. With a small staff office in West Sacramento, the Partnership coordinates trials among 31 members including auto companies, the nation's major fuel-cell developers, owners of energy infrastructure, and state and federal agencies. It is about to enter its third stage of activity which will culminate in commercialization of a fuel cell vehicle by 2012.

The explicit business-development goals of CleanStart are to:

- Add 10 new CET companies and 100 net new jobs by 2008
- Add 25 new CET companies and 1,000 net new jobs by 2010
- Develop a commercialization assistance approach for entrepreneurs
- Establish acceleration programs relevant to university technologies

Employment in Key Energy and Environmental Systems Sectors

Sacramento and its surrounding communities are home to a large and growing energy and environmental systems sector. The region has grown its establishment base in recent years by nearly 40 percent to 1,158 in 2005. These businesses employ 15,552 in the region and pay wages that are roughly \$20,000 more, on average, per year than their overall counterparts in the private sector. Of the six major

⁶¹ See <http://www.jadoopower.com/>.

⁶² See <http://www.pacificethanol.net/>.

⁶³ See <http://www.ecostream.com/>.

⁶⁴ See http://www.suntechnics.com/us/welcome_1st.htm.

⁶⁵ See <http://www.cafcp.org/>.

E&E subsectors, all but one had net job growth during the 2001 to 2005 period and grew the region's E&E job base by 34 percent. (See table 5 and figure 5.)

Table 5. The energy and environmental sector in the Sacramento MSA and U.S., 2005

Energy & Environmental Sectors	Estab.	Estab. Change, 01-05	Employment	Empl. Change, 01-05	Location Quotient	Avg. Annual Wages
Sacramento, CA MSA						
Total Private Sector	60,026	20.9%	671,659	9.3%	1.00	\$39,773
Total Energy & Environmental Sector	1,158	39.8%	15,552	34.0%	1.07	\$59,381
Energy & Env. Consulting Services	853	56.5%	8,931	31.9%	1.49	\$64,337
Green Buildings and Sustainable Design	188	-5.3%	4,272	42.4%	1.04	\$35,053
Indoor Environmental Quality	20	28.0%	286	-19.0%	0.26	\$52,497
Renewable Energy	39	180.2%	1,218	34.3%	0.66	\$105,811
Renewable Power Generation	2	-77.8%	90	23.7%	0.27	\$49,742
Water Quality and Water Resources	56	21.3%	755	50.0%	0.67	\$67,289
United States						
Total Private Sector	8,308,128	7.4%	110,634,500	1.2%	1.00	\$40,499
Total Energy & Environmental Sector	140,747	10.7%	2,388,397	-5.6%	1.00	\$58,627
Energy & Env. Consulting Services	93,592	20.0%	985,884	9.0%	1.00	\$67,252
Green Buildings and Sustainable Design	29,806	-5.9%	679,703	-7.8%	1.00	\$36,876
Indoor Environmental Quality	2,548	-7.2%	179,257	-16.9%	1.00	\$44,167
Renewable Energy	3,405	4.9%	303,951	-21.1%	1.00	\$86,704
Renewable Power Generation	1,766	-4.8%	54,532	-33.2%	1.00	\$85,403
Water Quality and Water Resources	9,630	0.2%	185,070	-10.0%	1.00	\$52,563

Source: Battelle analysis of BLS QCEW data from IMPLAN.

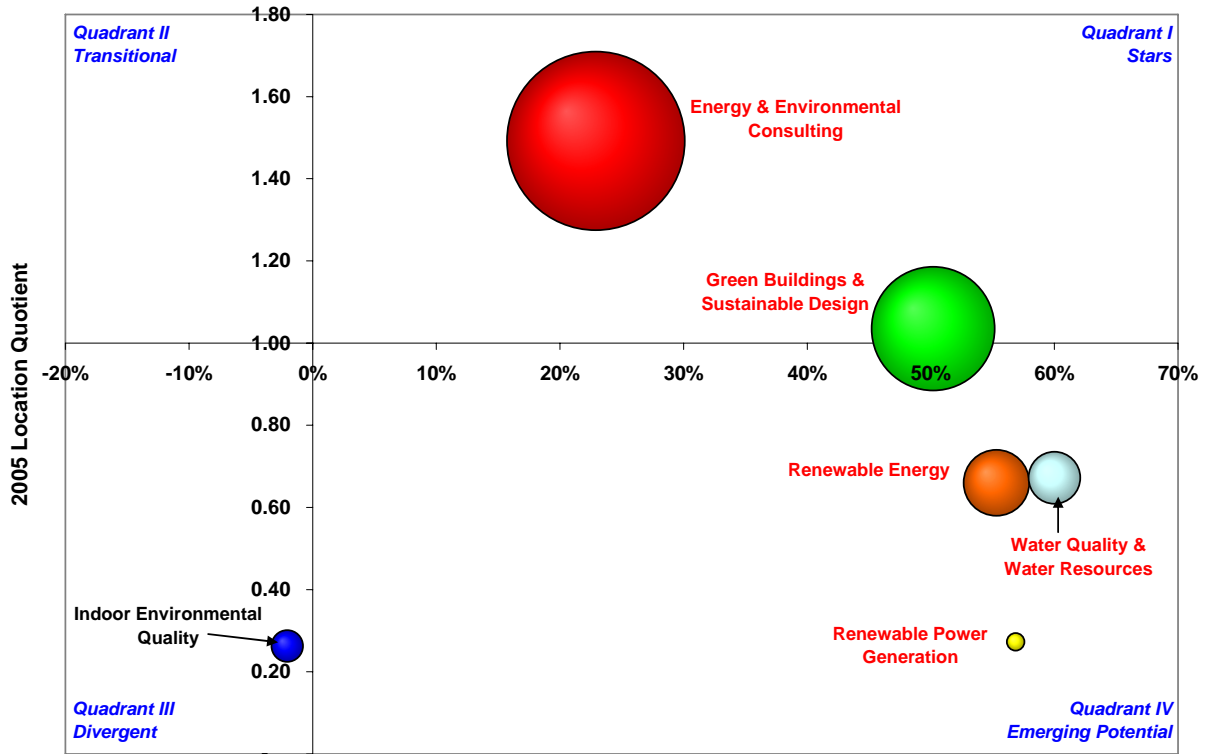
Overall E&E systems sector growth in the Sacramento MSA has been led by a large and specialized energy and environmental consulting industry. This regional "star" (see bubble chart in figure 5) has added about 32 percent to its employment base since 2001 and has a concentration of regional jobs that is about 50 percent greater than the national average (LQ is 1.49). The vast majority (84 percent) of this national consulting sector is made up of engineering services jobs compared with just 65 percent in the Sacramento region. Of particular interest in this analysis is that the consulting sector in Sacramento has a significantly greater share of jobs in the environmental consulting component—20 percent regional share vs. 7 percent at the national level.

The green buildings and sustainable design subsector in Sacramento has also shown impressive job growth since 2001—up 42 percent to 4,272 in 2005. The building materials sectors included in this definition are typically driven by population/employment growth and the increased demand for housing associated with it. The impressive growth in total employment in the MSA—up 9 percent compared with the national 1 percent growth—is likely helping to drive the local building and embedded green building sector.

The primary component of the Sacramento MSA's renewable energy subsector is the semiconductor manufacturing industry which includes the regional micro fuel cell and other related fuel cell manufacturers. Though overall renewable energy

employment is modest in the region, these local jobs pay premium wages (over \$100,000, on average for 2005) and reflect the highly sought-after technical jobs associated with this clean energy technology.

Figure 5. Energy and environmental sector employment in Sacramento, CA, degree of specialization, and growth relative to the U.S., 2001-2005

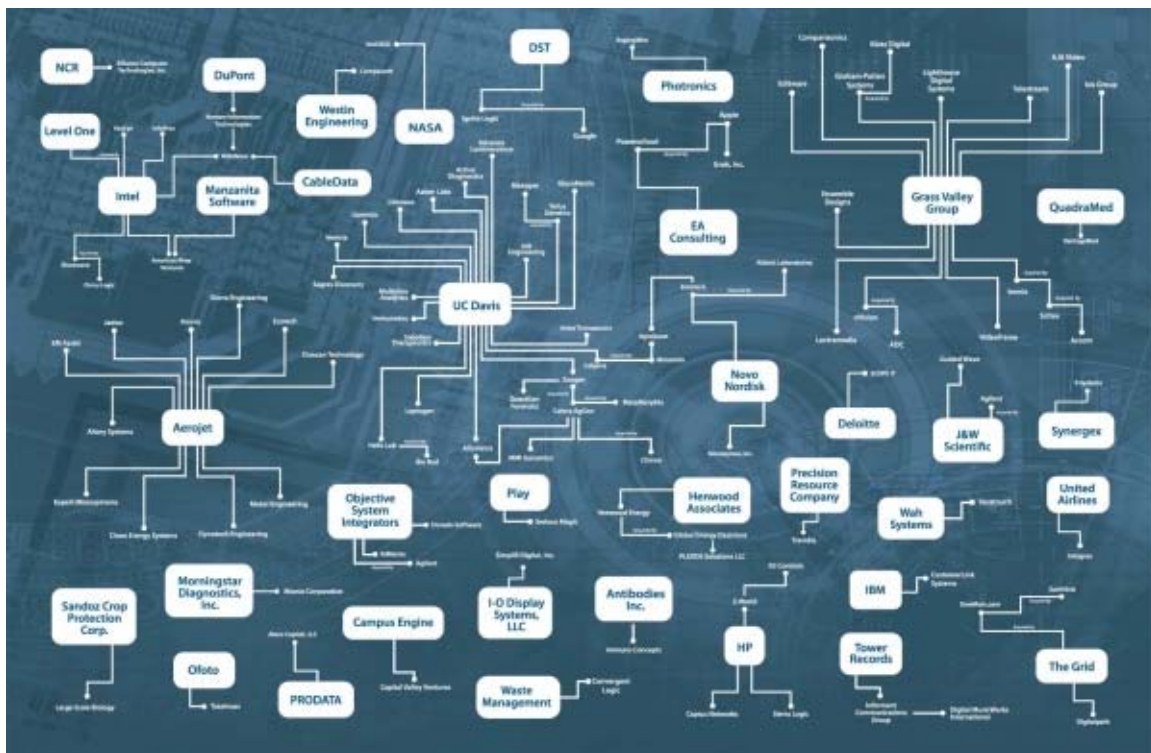


Note: Size of bubble represents employment.
Subsectors in Red had positive absolute job growth.

Employment Growth Relative to the U.S. (2001-05)

Role of the University Sector

A regional corporate “genealogy” of the kind published by many technology councils shows (see below and also at <http://www.sarta.org/default/resources/genealogy/index.cfm>) a range of traditional technology industry and also some small, startup ag-bioscience companies having some connection with UC Davis, but to date, not many cleantech entries.



Existing resources at UC Davis—including the Lighting Technology Sector, the Institute for Transportation Studies, and others—are now coordinated by the **Energy Efficiency Center (EEC)**.⁶⁶ Established in April 2006, the center’s mission is “to establish California’s leading university center supporting the development of viable businesses that advance energy efficiency.” Relying on the physical plant of other centers, and on faculty and graduate students from across the campus, the EEC conducts technology evaluations and demonstrations, convenes stakeholders including investors, provides a focal point for publicity, and scans for early-stage technology and market opportunities. The EEC’s main external sponsor is the **California Clean Energy Fund**,⁶⁷ a \$30 million nonprofit seed-stage equity investment fund established as part of the PG&E bankruptcy. As such its focus is statewide, and regional development is not a top-line component of its mission. Other assets at UC

⁶⁶ See <http://eec.ucdavis.edu/>.

⁶⁷ See <http://www.calcef.org/>.

Davis include the **California Biomass Collaborative**,⁶⁸ established by the California Energy Commission to serve as a statewide clearinghouse.

Next Steps

In March 2007, a local consultancy named Frameworks published a study of *Sacramento's Environmental Economy*,⁶⁹ highlighting the large set of scientists and other professionals with skills relevant to the environmental industry clusters. According to Frameworks's analysis of government data, the four-county metro area houses a percentage of relevant professionals far out of proportion to its 5.8 percent of the state's population. These people are employed predominantly by the state of California itself and by UC Davis, though increasingly by law firms and consultants. The paper laid out a challenge for greater Sacramento to "diversify its environmental employment 'portfolio' beyond these institutional drivers in the direction of the higher-risk, higher-return private sector." Recommended steps included:

- UC Davis should establish an environmental business incubator and otherwise "step up to the plate" and commit to a regional strategy at the senior administrative level
- The region should replace an outdated and vague brand identity (Capital Corridor) with one that directly addresses its potential to become a "Clean Tech Valley"
- Government should provide infrastructure investments including incubators, targeted training programs, etc.
- The California Energy Commission's Public Interest Energy Research (PIER) Program should be revamped to place more emphasis on pre-seed and seed-stage financing for energy and environmental ventures.
- UC Davis's true core competencies should be assessed in detail, with attention to making connection with the regional economic strategy.

These recommendations were warmly received in the local business press, but have not yet been comprehensively adopted by any single entity.

In some respects urgency is growing due to increasing competition from the larger San Francisco Bay region. In July 2007, the Bay Areas Science and Innovation Consortium (a network of research universities and R&D companies that does include UC Davis but as an outlying partner dominated by Stanford and Berkeley) published a study entitled *Innovative Energy Solutions from the San Francisco Bay Area: Fueling a Clean Energy Future*.⁷⁰ While UC Davis is home to a \$25 million clean energy initiative funded by Chevron, Berkeley now hosts a far larger biofuels initiative funded by BP, and the race between the regions is now launched. There have been several instances in which a Bay Area firm won a Sacramento cleantech business

⁶⁸ See <http://biomass.ucdavis.edu/>.

⁶⁹ Available online at <http://www.frameworksprojects.com>.

⁷⁰ Available online at <http://www.bayeconfor.org/basic/basicpublications.html>.

plan competition, or where a startup was relocated by its later-stage investors from Sacramento to San Jose. As a result, the business leadership seems to be placing great stress on steering locally anchored sources of institutional capital to those startups that show potential sources of growth. However, no specific programs have yet been articulated.

Implications for Syracuse

The Sacramento experience should be watched closely because it is clearly one of those regions that will emerge as a competitor in energy and environmental technology. Not unlike any other area of the nation, it will struggle against the attractive forces of venture capital in Silicon Valley.

In some respects, Syracuse and Central Upstate New York have two distinct advantages: (1) Syracuse is eager for economic growth, unlike several communities such as the City of Davis in the Sacramento region where that commitment is unclear; and (2) the universities in Central Upstate New York understand explicitly they have been advanced certain public resources as part of a regional development strategy, while in Sacramento the community is leveraging a UC Davis asset that sees its major role as statewide.

On the negative side, Syracuse lacks immediate access to the state government apparatus in Albany that parallels the California Energy Commission. To some extent, NYSERDA has pre-empted some of this attractive affect through its Saratoga Technology + Energy Research Park initiative north of Albany. However, this has no direct impact on non-energy environmental businesses.

APPENDIX E

COMPETITIVE ASSESSMENT OF CENTRAL UPSTATE NEW YORK'S ENVIRONMENTAL AND ENERGY SYSTEMS INDUSTRY CLUSTER:

LIST OF INTERVIEWEES

Chuck Akers
President and CEO
Isolation Air

Ken Barker
V-P Research
SUNY Upstate Medical University

Ed Bogucz
Director
Syracuse CoE

Jon Braun
Hampton Biofuels

Terry Brown
Managing Partner
O'Brien and Gere

Lisa Cleckner
Asst Director of Operations
Syracuse CoE

Lew Daly
President
HAP Control LLP

Frank DiSalvo
Director
Cornell Fuel Cell Center

Sandra Downey
Executive Vice-President
CoE Office for Industrial collaboration
(formerly NYIEQ)

Charles Driscoll
Professor of Environmental Engineering
Syracuse University

Steve Effler
Director of Research
Upstate Freshwater Institute

John Fox
CEO
Innovation Fuels

Gina Lee Glauser
Associate Vice-President for Research
Syracuse University

Pat Govang
President and CEO
E2E

Tracie Hall
US Green Building Council
Upstate New York Chapter

Linda Hartsock
Executive Director
Cortland County Business Development
Corp.

Michael Hooker
Executive Director
Onondaga County Water Authority

Phil Hopke
Director
Center for Air Research Engineering and
Science
Clarkson University

Peter Kent
President and CEO
Orthosystems and Allocast

Ezzat Khalifa
Director
STAR EQS, SU

Peter King
Managing Partner
King and King Architects

John McAuliffe
Honeywell Syracuse Program Director
Honeywell Inc.

Ed McGraw
Principal
Ashley McGraw

Jim Miller
President and CEO
NuClimate Air

Neil Murphy
President
SUNY ESF

Melissa Perry
Destiny USA

Susan Powers
Assistant Dean for Research, Engineering
Clarkson University

Rick Robertson,
Co-Director
Center Future Energy
Rensselaer Polytechnic Institute

Omowunmi Sadik
Director, CASE Center
SUNY Binghamton

Norm Scott
Professor of Biological Engineering
Cornell University

Eric Spomer
President
Catalyst Renewables Inc.

Michelle VandeHalle
Center for Composite Materials
Cornell University

John Vasselli
Chief of Technology for IAQ
Carrier Corporation

Larry Wetzel
President
Air Innovations

Ed White
Director,
Center for Sustainable and
Renewable Energy, SUNY ESF
Associate Director of Syracuse CoE

Eric Will
President
Northeast Biofuels