CLEAN TECH INITIATIVE

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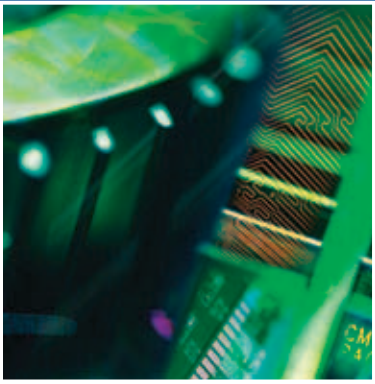

# CLEAN TECH: An Agenda for a Healthy Economy

## HOW MASSACHUSETTS CAN BE THE CENTER OF CLEAN TECHNOLOGY INNOVATIONS THAT SERVE THE WORLD

JANUARY 2010

University of Massachusetts Lowell

The Lowell Center for Sustainable Production at the University of Massachusetts Lowell helps to build healthy work environments, thriving communities, and viable businesses that support a more sustainable world.

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***The following documents were developed as part of the Clean Tech Initiative's research and are referenced in this report. They can be found at http://sustainable production.org/proj.tech.abou.shtml***

*Clean Tech: An Agenda for a Healthy Economy*, Initial Report, December, 2007

*Economic, Environmental, and Social Benefits of Clean Tech*, Economic Development Research Group

*Case Study: Complying with Clean Product Mandates for the European Market*, Economic Development Research Group

Regional Roundtable proceedings and attendees:

- Western Massachusetts
- Merrimack Valley
- 495/MetroWest Corridor

*Telephone Survey of Boston Small Businesses Regarding the Adoption of Green Business Practices*, University of Massachusetts Donahue Institute

Database of Massachusetts College and University Clean Tech Research

Summary of State Responses to Survey on Clean Tech Activities

# Executive Summary

An estimated $209 billion market exists in the U.S. for goods and services focused on health, the environment, social justice, personal development, and sustainable living.[1] By building upon its existing strengths, Massachusetts could take hold of the clean technology segments of this market, if specific actions are taken at the policy level. With state-level leadership, the Massachusetts economy could grow by helping to solve some of the world's most pressing problems—resource depletion, climate change, and increasing rates of cancer and other diseases—while meeting the demand for cleaner, safer, healthier products and technologies.

The Lowell Center for Sustainable Production at the University of Massachusetts Lowell founded *The Massachusetts Clean Tech Initiative* in 2007 to identify specific opportunities and benefits of making Massachusetts a leader in a range of clean technologies that serve the world, and recommend a path to get there.

Since then, the Initiative has worked with a diverse Advisory Committee, conducted research, carried out interviews, and convened labor, health, environment, business, investor, legislative, and academic leaders in eight different industry and regional stakeholder roundtables to discuss how to build a vibrant Clean Tech economy and identity in the state.

Based on this research, the Initiative published its Initial Report in December, 2007, which made the case for a Clean Tech economy in Massachusetts, and provided preliminary recommendations to get there. The Initial Report was distributed to stakeholders and policy makers to begin the discussion on growing a Clean Tech economy in the state.

This Final Report builds on the information identified in the earlier report, and adds original new research. The purpose of this Final Report is to:

- further make the case for supporting the broad approach to creating a Clean Tech economy,
- provide guidance to policymakers and others about steps to grow this economy,
- refine and prioritize policy recommendations and other actions,
- identify additional needs and opportunities,
- look at our strategic advantage compared to other states, and
- identify roles that key players can take in implementing these recommendations.

### Clean Tech Initiative Purpose

- Realize the opportunities inherent in a Clean Tech economy
- Make the case for orienting the Massachusetts economy around the full range of clean technologies
- Identify those technologies in which Massachusetts is already poised to lead
- Provide guidance to policy-makers and others about steps to grow this economy

Many of the recommendations have little to no cost and involve public leadership and coordinating of existing programs and agencies. Others are higher cost but, given market trends, increasingly limited resources, and growing information about the impacts of exposure to toxic substances, climate change, and resource depletion, the economic benefits should well outweigh the costs.

## Five Areas of Leadership

The Clean Tech Initiative identified five areas where Massachusetts already has a leadership position:

1. **Safer Alternatives/Green Chemistry:** the design and use of safer alternatives to toxic chemicals in products and manufacturing processes.
2. **Green Buildings:** products and services that reduce the health and environmental impacts of constructing, renovating, and operating building structures.
3. **Materials Reuse:** the return of products and materials back into the economic mainstream through reuse, remanufacturing, composting, and recycling.
4. **Emerging Materials:** materials such as safe and green biobased materials and nanomaterials which, when

designed responsibly, have the ability to yield significant efficiencies in energy and materials use.

5. **Clean Energy:** the use of cleaner or more efficient energy sources and production methods that create less pollution —from fuel extraction to energy generation to reduced demand.

## Ten Ways to Support a Clean Tech Economy

In the stakeholder roundtables, Advisory Committee meetings, and individual discussions held for this project, ten consistent recommendations about actions the state can take to elevate the importance of Clean Tech in the state's economic development, environmental, and health agendas emerged:

1. **Create a "Clean Tech Blueprint" for Massachusetts:** establish a clear vision, goals, metrics, and leadership roles, as well as direction for how the nine recommendations below will be implemented.
2. **Create a Massachusetts Brand or Identity for All Clean Tech Activity:** promote the state as a center for all kinds of clean technology innovation and adoption
3. **Track Massachusetts Clean Tech Competitiveness:** create an Index of the Massachusetts Green Economy
4. **Create a State Office of Clean Technology (or Clean Tech Coordinating Council):** build on the state government's capacity to coordinate and advance the Clean Tech Blueprint
5. **Create Regional Clean Tech Centers of Excellence :** bring together key players to identify research and opportunities, create partnerships, and disseminate information
6. **Stimulate Collaboration and Cross-Fertilization of Technologies:** foster industry-education-government partnerships, set priorities, and disseminate information
7. **Support Manufacturing as a Viable Sector:** nurture and market the strengths of the state's manufacturers
8. **Develop a Trained Workforce:** advance training in all skill levels, for existing and projected green jobs
9. **Regulate, Procure, and Invest:** create competitive conditions for the continued growth of clean technologies
10. **Take Risks to Spur Innovations:** be willing to invest in innovations that may be risky but they may lead to significant environmental or economic benefits

## Five Technology-Specific Recommendations

In addition, for each of the five areas of leadership, the Clean Tech Initiative recommends specific technology actions and roles that will further position Massachusetts as a leader:

1. **Safer Alternatives to Toxic Chemicals:** Pass key policies on Safer Chemicals and Products.
2. **Green Building:** Adopt the recommendations of the Governor's Zero Net Energy Building Task Force and create an implementation plan.
3. **Materials Reuse and Recycling:** Reestablish a stable funding mechanism adequate to double the state's recycling and waste reduction rates.
4. **Emerging Materials**
   a. ***Biobased materials:*** Adopt the Sustainable Biomaterials Collaborative guidelines as criteria for state purchasing as well as investments in research and development
   b. ***Nanomaterials:*** Advocate that more federal funding be dedicated to assessing health and safety related aspects of nanomaterials, and strive to double Massachusetts' share of federal research funds in this area to create a Signature Research Center Initiative.
5. **Clean Energy:** Define what constitutes an energy source or technology as "clean."

These recommendations are described in more detail in this report.

Massachusetts has a unique opportunity to take advantage of its many inherent strengths in the five technology areas. Its ability to attract public and private capital, its key export ties, research institutions, skilled manufacturing sector, and educated workforce could enable our state to become the international hub of clean technology innovation and adoption. An increasing market for environmental products and services provides a rich and timely opportunity to invest in our own clean technology infrastructure and create a thriving hub of activity. By producing commercial innovations based on clean technologies, Massachusetts could lead in improving the quality of life, the health of the planet, and the economy.

Advancing this broader Clean Tech platform will require continued leadership from the governor's office and legislature, working together with businesses, labor, researchers, public workforce development systems, and others. While this may appear monumental given the current economic downturn, trends indicate that policies and investments today to grow Massachusetts' Clean Tech strengths will provide extensive long-term benefits to industry, the environment, and health of the citizens of the Commonwealth. Such efforts are vital for positioning the Commonwealth for the economy of the future.

# The Clean Tech Opportunity

Environmental protection used to be seen as a business cost. Today, protecting the environment has become a vibrant, new business opportunity—an opportunity for innovative, green products, for renewable and clean energy, for smart and efficient materials, for reusing and recycling, for new transportation and housing options, and for conserving water and other resources. Now is the time for Massachusetts to take key actions that will promote and build a productive and sustainable economy based on these clean technologies.

**Clean technologies, or "Clean Tech," are products, services, and production processes that greatly reduce or eliminate environmental and health impacts throughout a product's lifecycle—from mining to manufacturing to product use and disposal—while maintaining the same or better levels of quality.**

Clean technologies, or "Clean Tech," are products, services, and production processes that greatly reduce or eliminate environmental and health impacts throughout a product's lifecycle—from mining to manufacturing to product use and disposal—while maintaining the same or better levels of quality. They reduce our exposures to toxins in our work, homes, and environment; reduce pollution, waste, energy, and water use; and provide jobs from entry level to executive, and from manufacturing to services.

Local and international markets are increasingly demanding these cleaner technologies. The organization Lifestyles of Health and Sustainability (LOHAS) describes an estimated $209 billion U.S. marketplace for goods and services focused on health, the environment, social justice, personal development, and sustainable living.[2] Programs such as the LEED™ green building rating system, European policies such as REACH, and individual US state policies including recycling, green chemistry, and biobased materials are creating opportunities for less toxic, recyclable, and energy-efficient products and services.

Public and private entities that identify innovative ways to create long-term sustainable value, support research and development, and reduce health and environmental costs associated with economic activities through clean technologies will distinguish themselves in the marketplace. This is especially key in light of the current economic downturn.

Despite this, no state yet has developed a comprehensive economic development strategy to reorient its economy around the broad definition of Clean Tech. Internationally, only Germany is undertaking a strategic initiative to build its economy on these principles.

Under the leadership of Governor Patrick and the legislature, the Commonwealth of Massachusetts has already made tremendous advances in the area of clean energy, passing a host of policies that encourage the development and use of renewable energy end energy efficiency, and reaching out to attract and retain businesses in the clean energy sector. This same enthusiasm and leadership could be tapped and directed towards nurturing a broader range of clean technologies that includes:

- Safer Alternatives/Green Chemistry
- Green Building
- Materials Reuse
- Emerging Materials
- Clean Energy

***Advancing this broader Clean Tech agenda will require continued leadership from the governor's office and legislature, working together with businesses, labor, researchers, advocates, public workforce development systems, and others.***

Massachusetts is well positioned to fill this gap and lead a worldwide transition towards a cleaner, healthier way of doing business. It can supply the knowledge, products, technologies, materials, instruments, and equipment that can lead the world to this new post-carbon, resource-wise economy.

# Five Areas for Clean Tech Leadership in Massachusetts

There are five fields in which Massachusetts has the knowledge, culture, infrastructure, and technologies to be on the leading edge of creating a Clean Tech economy:

- **Safer Alternatives/Green Chemistry:** the design and use of safer alternatives to toxic chemicals in products and manufacturing processes.
- **Green Buildings:** products and services that reduce the health and environmental impacts of constructing, renovating, and operating building structures.
- **Materials Reuse:** the return of products and materials back into the economic mainstream through reuse, remanufacturing, composting and recycling.
- **Emerging Materials:** such as safe and green biobased materials and nanomaterials which, when designed responsibly, have the ability to yield significant efficiencies in energy and materials use.
- **Clean Energy:** the use of cleaner or more efficient sources and production methods that create less pollution—from fuel extraction to energy generation to reduced demand.

These fields can stand alone, or overlap with each other as well. For example, advanced nanomaterials are being used to increase the efficiency of solar panels, and recycled and less toxic materials are being used in green buildings. Massachusetts' strengths in each area include:

## Safer Alternatives/ Green Chemistry

Massachusetts is home to world-renowned leaders and programs in green chemistry. Our experts serve as national and international advisors on safer alternatives:

- UMass hosts the first Green Chemistry PhD program in the world.
- The Massachusetts Toxics Use Reduction Program has helped hundreds of companies cost-effectively eliminate millions of tons of chemicals and reduce business costs. It continues to be a model for other states.
- The Warner Babcock Institute for Green Chemistry and the Beyond Benign Foundation based in Burlington create green chemistry innovations, and educate our next generation in safer chemistry. These organizations are run by a co-founder of the green chemistry field and by the first green chemistry PhD graduate in the world.
- The Lowell Center for Sustainable Production at UMass Lowell coordinates the national Green Chemistry and Commerce Council, comprised of large and small corporations working to develop policies and practices that reduce toxins.
- UMass Amherst's top-ranked polymer science program has a key research focus on green chemistry
- Massachusetts experts have served on numerous federal advisory committees, as well as advisors on green chemistry initiatives in California and Michigan.

**Massachusetts is well positioned to lead a worldwide transition towards a cleaner, healthier way of doing business. It can supply the knowledge, products, technologies, materials, instruments, and equipment that can lead the world to this new post-carbon, resource-wise economy.**

## Materials Reuse

Thanks to a history of supportive state policies and private sector innovations, Massachusetts has a strong base of jobs, manufacturing, and research assets in materials reuse:

- Massachusetts manufacturers turn 4 million tons of waste and scrap each year into a wide range of new products.
- Massachusetts' recycling industry is comprised of approximately 2,018 businesses that employ close to 14,000 people, have a total annual payroll of $498 million, total receipts of approximately $3.2 billion,[3] and turn millions of tons of recyclables into new products each year.
- Massachusetts colleges and universities host top researchers in textiles, plastics and rubber recycling, as well as civil engineering, who have developed, patented and licensed innovative new uses for these materials.
- UMass Lowell hosts one of the top plastics engineering departments in the country, and includes a focus on recycled plastics.

## Green Building

Massachusetts has a high concentration of architects, designers, engineers, builders and researchers who are actively working with policymakers to expand green buildings and develop new technologies:

- Greater Boston's U.S. Green Building Council (USBGC) affiliate, the Green Roundtable, has over 15,000 subscribers active in its policy, education, and market transformation programs. The Berkshires recently formed a USGBC affiliate.
- 700 projects in Massachusetts have registered with LEED™; 100 of those have gone through the LEED™ certification process. Genzyme's Science Center in Framingham is LEED Gold Certified, only one of ten such certifications in the US.
- The Zero Net Energy Building Task Force of the Executive Office of Energy and Environmental Affairs has recommended actions that will reduce the energy demand of buildings.
- MIT's Building Technology Program brings together a number of departments to innovate in materials, manufacturing, and other areas for more efficient operation of existing and new buildings.
- UMass Amherst faculty has been tapped for a 15 member expert panel to explore the scientific and technical issues related to implementing energy and sustainability initiatives in the 25 buildings comprising the U.S. Capitol Complex.
- Massachusetts companies have established expertise in controls and software that have been and can continue to be applied to help reduce the environmental impacts of buildings.
- Boston was the first city in the US to require commercial developments of over 50,000 square feet to meet LEED™ requirements.

## Emerging Materials

Massachusetts receives billions of dollars from the National Science Foundation, Department of Defense, and National Institutes of Health that fund research centers at Northeastern University, UMass Lowell, UMass Amherst, Boston University, Harvard University, and MIT. These centers are creating practical innovations using advanced materials and technologies.

### Biobased Materials:

- UMass Lowell's Biodegradable Polymer Research Center (BPRC) leverages the research capacity of university researchers, government laboratories, and global companies to lead in the development of the next generation of plant-based biodegradable polymers.
- The BPRC's research has led to numerous patents, and three new business start-ups based in the state.

- The Director of the BPRC was awarded the Lifetime Achievement Award by the Bio-Environmental Polymer Society, and is the editor for the *Journal of Polymers and the Environment*, a leading journal in this field.

### Nanomaterials

- The Center for High Rate Nanomanufacturing, a partnership between UMass Lowell, Northeastern University, and the University of New Hampshire, is one of only four centers in the US that focus on nanomanufacturing.
- An August, 2009 study by the Project on Emerging Technologies of the Woodrow Wilson International Center for Scholars found that two of the top six "nano metros" in the US are in Massachusetts. And Massachusetts is one of the top four states overall for nanotechnology activity.
- *Small Times Magazine* consistently ranks Massachusetts as one of the top states in the nation for "small tech," including nanotechnology.
- Massachusetts is adept at attracting venture and federal funding for nanotechnology, ranking second after California in 2005, and, at $8 billion, twice as much as third-ranked Texas.
- Over 50 faculty investigators from eight departments in three colleges at UMass Amherst are working in the field of nanotechnology, generating over $36 million in research funding since 1997 from a variety of federal and industry sources

## Clean Energy

Massachusetts is home to a growing clean energy sector,[4] programs promoting clean energy, and research in new technologies to generate, transmit and store energy, as well as reduce energy use:

- Massachusetts is home to at least 566 clean energy companies working in renewable energy, energy efficiency/demand response, consulting, and support.
- The renewable energy sector in Massachusetts employs an estimated 14,400 people and, as of 2007, experienced a 26% annual growth rate.
- Massachusetts is an incubator for clean energy start-ups, with 116 companies founded from 2001 to 2007. Nearly half of those companies had less than five employees; 68 percent of firms had less than $10 million in annual revenues, 41% below $1 million.
- University research centers are developing a range of energy generation, storage, and monitoring innovations.
- Massachusetts received $25 million in federal funding to host the country's largest wind turbine blade testing facility in collaboration with the National Renewable Energy Laboratory.
- Massachusetts has two key clean energy programs to promote clean energy innovation and adoption, job training and related economic development in the Commonwealth: the new Clean Energy Center and the Renewable Energy Trust.

## Small Businesses Provide a Market for Cleaner Technologies

A 2008 telephone survey conducted for the Clean Tech Initiative of 442 small businesses in Boston assessed opportunities and attitudes related to their adoption of green business practices. The survey,[11] conducted by the Donahue Institute of the University of Massachusetts, found that:

- Sixty-two percent of small businesses report that the most significant challenge they face is the financial impact of rising energy costs. This ranks ten-percent above the next most significant concern, rising health care costs. Thirty-four percent of businesses ranked water and sewer costs as significant issues.
- Small businesses already engage in environmental practices, such as recycling, turning off lights and equipment, purchasing energy efficient equipment, and reducing waste.
- The majority of businesses recycle to some degree, but many materials, such as metals, glass, textiles, and pallets, are not being recovered.
- Some 38–50% of businesses are more interested in financial incentives, such as discounts or grants, than in education and training to increase their adoption of green practices. Between 30 and 36% prefer education and training.
- Commercial property owners tended to be more interested in engaging in green practices than renters.

# Massachusetts' Business and Technology Assets

The Milken Institute's 2008 State Technology and Science Index lists Massachusetts as being in the best position of any state to achieve high-quality economic growth, thanks to its world-class research institutions, cutting-edge firms, and its ability to leverage these assets in attracting and retaining a skilled work force.[5] These and other business assets were identified in the Clean Tech Initiative's Initial Report as crucial for supporting the transition to a Clean Tech economy:

- A strong, specialized, and educated **manufacturing base**
- A successful history of public/private partnerships in **toxics use reduction**
- A strong **innovation economy**, built on a richness of colleges, universities, and entrepreneurs
- **Core technologies** that can be applied to a range of new products
- **Key industry clusters**, including information technology, finance, defense, and pharmaceuticals, that play important roles in the Clean Tech infrastructure
- **Major export ties** to Europe and Asia, key Clean Tech markets
- Legislation, business assistance programs, task forces, technology transfer activities, and more indicate strong **institutional support** for environmental technologies and behaviors

## Manufacturing Still Has a Vital Role

*Staying Power: The Future of Manufacturing in Massachusetts,*[6] published by the Center for Urban and Regional Policy at Northeastern University, establishes not only the importance of manufacturing as a potent contributor to the regional economy but its role as a catalyst for future growth. It finds that almost 10 percent of the state's workforce is employed in manufacturing, creating almost $40 billion worth of goods annually. The sector retains more than 8,600 firms that are technologically sophisticated and well positioned to compete successfully in the emerging global economy.

The report cautions that as Massachusetts becomes a leader in "green" building and energy technology, the state's manufacturers should not be forgotten.

- A track record of **attracting public and private investment**, such as federal research funds, venture capital, and business incorporations
- A **regulatory environment**, including the Green Communities Act, bans on recyclable material disposal, the Toxics Use Reduction Act, and the Regional Greenhouse Gas Initiative, that promotes the development and utilization of clean technologies
- Strong **public awareness** of environmental issues on the part of industry leaders and consumers
- High-quality **college and university research** creating breakthroughs in the five clean technology areas
- A **well-educated workforce** in both blue and white collar jobs, with labor unions taking leadership in educating their members about renewable energy and safer alternatives to toxics
- A sophisticated environmental **advocacy community** that educates the public and advocates for policies that are better for public health and the environment.

Feedback from the regional Clean Tech roundtable discussions particularly highlighted the importance of manufacturing to the local economy. With existing building stock, specialized and efficient manufacturing processes, and a highly trained workforce, Massachusetts could capitalize on its ability to do high-end, first-run, niche manufacturing to grow the clean technology sector.

# Three Massachusetts Regions—Assets, Barriers, and Opportunities

The Clean Tech Initiative convened three Roundtable discussions in suburban, rural, and urban regions of the state,[7] co-sponsored with local legislators and economic development organizations. The purpose of these regional Roundtables was to learn more about unique strengths, challenges, and opportunities for growing the Clean Tech economy in different parts of the state, to raise awareness about the importance of Clean Tech to the environment and economy, to gain information that will inform key policy makers and activists, and to help create partnerships that will ultimately help move the Clean Tech economy forward.

The Roundtables attracted over 100 people, and were held in Western Massachusetts, the Merrimack Valley, and the 495/MetroWest corridor. Below is a summary of the key points that came out during these discussions.

## Western Massachusetts

### ASSETS

Berkshire, Hampshire, Hampden, and Franklin counties have a host of regional employment boards, workforce investment boards, and one-stop career centers focusing on green jobs training, and employers are already hiring people that have been through these programs. The region has a highly educated populace with a strong awareness of environmental issues, in part due to an active environmental NGO sector and proximity to UMass Amherst. It has a highly valued legislative delegation that is sensitive to environmental and economic development issues, industrial assets that reduce the need for new construction, and companies currently involved in materials reuse, clean energy, and green chemistry, with advanced materials emerging. The region's quality of life, natural and built resources, highly educated populace, and proximity to major markets in New York and Massachusetts are part of what make this region attractive for Clean Tech.

### BARRIERS

In Western Massachusetts, the relative costs of doing business are high, businesses are older, and college and university students don't stay in the region to develop the next generation of clean businesses and green jobs. The need exists to create partnerships to identify, support, and share information about business opportunities. On the state level, it is difficult to get products accepted into the state's Environmentally Preferable Purchasing Program, and lengthy and expensive permitting is a hindrance to supporting clean industries and should be improved.

### OPPORTUNITIES

Opportunities to overcome these regional barriers exist in creating jobs and job training programs in weatherization and efficiency, retrofitting existing building stock to be more energy efficient, hydroelectric energy, materials reuse industries, and working with existing traditional industries to help them become part of the cleaner technology network. Infrastructure needs include retrofitting existing building stock to be more energy efficient, a better rail system to move goods, and lab or incubator space to support early stage companies. UMass and other colleges and universities can play more of a role in the region in fostering partnerships, commercializing technologies locally, serving as clearinghouses of information, and encouraging students to stay in the area and start new businesses. The state can help by providing a regional permitting circuit-rider to shepherd state and federal environmental permits. Clean Tech businesses that could be supported in the region include markets for recyclables, weatherization and energy efficiency, green building, and green chemistry.

## Merrimack Valley

### ASSETS

The Merrimack Valley is a more affordable place to live and work than many other parts of the state, and has significant resources available for Clean Tech companies. Manufacturing is a strong part of the Merrimack Valley's identity—the region incorporates three industrial cities that are well experienced in manufacturing (representing the birth of the American industrial revolution) and have room for growth. Manufacturing accounts for 20% of the region's employment, providing good wages. The diversity of products made in the region also allows companies to find much of their supply chain needs

within a short distance. For instance, Solectria, a company that makes inverters for the solar industry, contracts for 70% of its supply chain within the Merrimack Valley. Finally, access to industrial infrastructure is well suited to a range of manufacturing needs.

The region also has a high concentration of schools, from UMass Lowell to Middlesex and Northern Essex Community Colleges, to Greater Lawrence and Greater Lowell technical schools, and boasts leading research activity in ethanol, plastics, nanomaterials, biomaterials, less toxic manufacturing, and green chemistry.

### BARRIERS

The Merrimack Valley is challenged by the state-level emphasis on a knowledge economy over a manufacturing economy, and the lack of clarity about how the two can intersect to give Massachusetts a competitive advantage. State leadership on environmental education and on improving environmentally preferable purchasing contract procedures could also be improved.

### OPPORTUNITIES

The intersection of knowledge and manufacturing in the Merrimack Valley provides unique opportunities for early-stage companies and related product development, especially in high-end manufacturing that uses sophisticated processes. Additional opportunities for growth include building partnerships among schools and businesses to identify future job needs, as well as business-to-business partnerships to create more local supply chain links. Businesses and others can also come together to build the region's identity as *the* place for taking innovative ideas into production, and providing information to companies and individuals that will support the transition to Clean Tech. And the proximity of farms, existing building stock, experience in lead-free manufacturing, and the presence of plastics manufacturing and UMass Lowell's Plastic Engineering Department create Clean Tech business opportunities in composting, energy efficiency retrofitting, green chemistry, and biobased and recycled plastics.

## 495/MetroWest

### ASSETS

The 495/MetroWest region, comprised of thirty-two communities stretching along I-495 from Route 2 in the north to Route 1 in the south, hosts a number of large companies that have already adopted sustainable practices in several of the priority areas of the Clean Tech Initiative, as well as in other sustainable practices, such as water conservation and reuse. For example, EMC and Intel treat and recycle their waste water for use in toilets, industrial cooling, and manufacturing; Genzyme's Framingham office is LEED™ Gold certified; Staples is conserving energy and generating and purchasing renewable energy, as well as sourcing environmentally preferable products; Bose uses less toxic materials; and Evergreen Solar is manufacturing solar panels.

The 495/MetroWest region is a major economic leader in the state, with a payroll of close to $17 billion, and manufacturing jobs accounting for close to one quarter of that payroll. The region's workforce is highly educated—about half have a college degree and almost 20% have a graduate degree or professional equivalent—and includes scientists, engineers, and retired software engineers. The workforce also tends to stay local, with 82 percent of the graduates from MassBay Community College staying in the region. The area's mix of urban and open space, and proximity to Boston, also make it a desirable place to live and work.

### BARRIERS

The 495/MetroWest region is challenged by its infrastructure, including congested roads and limited water, zoning that restricts placement of wind turbines, a lack of state leadership in creating incentives for Clean Tech development, and a lack of appreciation as well on the state level of the role of manufacturing in the regional and state economy.

### OPPORTUNITIES

Opportunities to grow the Clean Tech sector in the 495/Metrowest region include business expansion in LED lighting, connecting the strong information technology sector to new industries, developing businesses around water use reduction, educating businesses and the potential workforce about Clean Tech, and providing education and assistance to businesses regarding partnership building, business opportunities, and available resources.

# Academic Research and Education Assets

At least 13 of Massachusetts' public and private colleges and universities are hosting research in one or more of the five Clean Tech areas of focus (as well as in other related fields such as transportation, planning, sustainable development, water conservation, and more).[8] And community colleges are increasingly adding training programs relating to green jobs.

Boston College, Boston University, Bridgewater State College, Clark University, Harvard, MIT, Northeastern, Tufts, four of the UMass campuses, and Worcester Polytechnic Institute together have over 200 research centers and research projects working on such challenges as:

- Incorporating green chemistry practices and creating less toxic products
- Developing new forms of energy conservation and efficiency, renewable energy generation (both land and water-based), energy transportation and storage, and alternative vehicles
- Studying the social, political, health, environmental and/or economic impacts of cleaner technologies
- Improving the ability to diagnose and treat diseases, as well as the efficiency of solar and other energy generating technologies, through the manufacture and use of nanoparticles
- Developing ways to turn plants and microorganisms into biodegradable plastic resins, pharmaceuticals, industrial surfactants, and fuels
- Creating new ways to turn waste plastics, textiles, tires, shingles, and other materials into new products
- Developing monitoring, ventilation, and construction systems, as well as new materials, that make buildings greener

RESEARCH HIGHLIGHT:

## Materials Reuse

The Plastics Engineering Department at the University of Massachusetts at Lowell, and the School of Engineering at Tufts University joined together to create a product, Synthetic Lightweight Aggregate (SLA) made from two wastes—post-consumer mixed plastics and fly-ash. Fly-ash is a by-product of burning coal, and mixed plastics are the plastics left over after the valuable plastics are sorted out and recycled from curbside recycling programs.

Synthetic Lightweight Aggregate (SLA) was developed, produced and evaluated for use in construction applications such as concrete masonry units (CMU), lightweight concrete, and asphalt pavement. Tests have shown that while the aggregate is not as strong as the sand and gravel it replaces in these uses, it has more ductility, meaning it may provide beneficial properties in construction, especially in earthquake-prone areas. The SLA samples were also tested for Los Angeles Abrasion and outperformed every other aggregate tested in this study for comparison. This test is crucial for the use of aggregate in asphalt pavement and results show high potential. UMass and Tufts are now looking at taking the SLA from the lab to full scale production. At present,

a year-long license agreement has been granted to neco-Plastics, LLC to further develop applications for SLA, whether in construction or as input into another product.

RESEARCH HIGHLIGHT:

## Green Building

MIT's Building Technology (BT) Program brings together its Departments of Architecture, Civil and Environmental Engineering, and Mechanical Engineering to apply recent advances in the fields of materials, manufacturing, and thermo-fluid sciences to the construction of new buildings, to the retrofit or rehabilitation of existing buildings, and to the efficient operation of buildings. The program is conducting research on natural ventilation of buildings to improve indoor air quality and reduce energy consumption, building designs that reduce energy use, energy efficient data centers, and integration of energy-efficient measures with indoor air quality considerations. The program is also carrying out research projects in the US as well as in a number of countries in the developing world.

Major decisions that most influence the sustainability of a new building are made early in the design process. The BT group is developing a suite of software tools specifically aimed at assisting designers and developers to assess the impact of different scenarios on day lighting, heating, cooling and natural ventilation during the early conceptual phase of design. One of the tools is currently available online.

RESEARCH HIGHLIGHT:

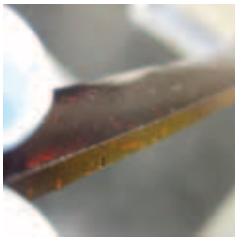
## Emerging Materials—Nanomaterials

The Center for High Rate Nanomanufacturing (CHN) is a partnership among three universities: Northeastern University, University of Massachusetts Lowell, and the University of New Hampshire, Durham. This collaborative effort combines the skills of 39 engineers, physicists, chemists, material scientists, humanities investigators, and businesses. CHN identifies barriers to high rate/high volume nanoscale manufacturing so that breakthroughs in nanoscale science can be transferred to the marketplace. CHN's goals are to:

1. Understand the fundamentals of synthesis and control at the nanoscale to enable high-rate/high-volume bottom-up, precise directed assembly of nanoelements.
2. Translate the nanoscale science into practical applications in energy, bio/medical applications, electronics, and materials.
3. Develop responsible manufacturing by understanding and managing potential risks of nanotechnology.
4. Educate the current and emerging nanomanufacturing workforce.

**At least 13 of Massachusetts' public and private colleges and universities are hosting research in one or more of the five Clean Tech areas of focus (as well as in other related fields such as transportation, planning, sustainable development, water conservation, and more.**

CHN's research seeks to bridge the gap between scientific research and the creation of commercial products, such as those used in the electronic, medical, and automotive industries, where nanomaterials have the ability to make stronger materials that can use fewer resources and increase energy efficiency, and drug delivery systems that are more targeted to a specific disease. Examples include development of smaller, lighter weight electronics using carbon nanotubes; creating improved antimicrobial medical devices that prevent infections; flexible photovoltaics that allow for wider uses of solar energy; targeted systems that increase the efficiency of drug delivery in patients; improved sensors for cancer detection; and lighter weight materials for aircraft and cars that will help reduce fuel consumption.



RESEARCH HIGHLIGHT:

## Emerging Materials—Biodegradable Polymers

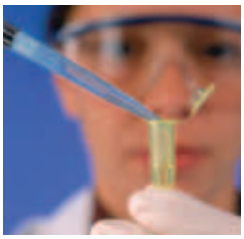
The Biodegradable Polymer Research Center (BPRC) at UMass Lowell is a partnership of industrial scientists, government laboratories and researchers that carries out exploratory and applied

research on biodegradable polymers to support medical and environmental objectives. The BPRC's research includes identification of microorganisms and fermentation methods to make new materials from renewable resources, blending biodegradable components to vary properties and biodegradability, processes to mold these new polymers, characterization of various material properties, and lab simulations of degradation in varying conditions.

Sponsored research funding to date has come from the National Science Foundation, Warner Lambert, Johnson and Johnson, Bristol Meyers Squibb, Eastman, Cargill, Union Carbide, Dow, and currently Metabolix. This research has resulted in patents, as well as spin-off companies here in Massachusetts, including:

1. Massachusetts-based Metabolix and Archer Daniels Midland have formed a joint venture, Telles, headquartered in Lowell. Using a license from a BPRC patent, Telles makes Mirel™, a biodegradable polymer from non-food crops. Mirel™ can be molded in a variety of ways, and can be used in compost bags, agriculture, horticulture, marine and water applications, consumer products, business equipment, and packaging.
2. Anterios (formerly Encapsion) a new Massachusetts company partly owned by UMass Lowell, uses a BPRC patent. It uses biodegradable nanotechnology to create a small-scale delivery system that can administer drugs or cosmetics more efficiently.
3. Adherion, another new company partially owned by UMass Lowell, makes a biodegradable bone adhesive system based on a BPRC patent.

Dow and Cargill have opened plants mass producing biodegradable plastics using BPRC licenses in Germany and Texas.



RESEARCH HIGHLIGHT:

## Green Chemistry

Researchers at UMass Lowell are working on new products, and new ways to make products, using the principles of green chemistry to maximize efficiency of material and energy while avoiding the generation and use of toxic substances. These products include organic photovoltaics, new drugs and drug delivery systems, and flame retardant materials.

The use of flame retardant additives in commercial polymers exceeds 909,000 tons/year globally. Flame retardant additives currently used are often toxic and threaten both air and water ecosystems. Researchers are developing a novel class of flame retardant material based on a naturally occurring waste by-product of cashew nut processing called the Cashew Nut Shell Liquid (CNSL). CNSL contains a phenolic compound known as cardanol. Naturally occurring enzymes (peroxidases from horseradish) are used to polymerize cardanol. This single-step enzymatic polymerization method using a renewable material, starting material, and catalyst yields polymers that show promising flame retardant properties.

Researchers are also using green chemistry to make a new class of cancer fighting drugs. Ironically, current methods of synthesizing anticancer drugs create large amounts of carcinogenic chemicals. UMass researchers have found a way to use green chemistry methods for creating a new family of compounds from green tea. These compounds show anti-tumorigenic promise, without harming healthy cells. This technology has won a number of awards including the P3 (People, Prosperity and Planet) award from the Environmental Protection Agency.

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# How Massachusetts Compares to Other States

The Clean Tech Initiative sent a survey to every state environmental and economic development agency in the country to see how they were promoting clean technology research, development, and application. The 30 states that responded[9] included those known to be taking proactive action in one or more fields below. The number of states with existing or planned policies in each area follows.

| Number of States | Policies addressing specific Clean Tech areas |
|---|---|
| 9 | Green chemistry and safer alternatives to toxic substances |
| 20 | Green buildings |
| 18 | Materials reuse and recycling |
| 10 | Emerging materials |
| 24 | Clean energy |

Of the responding states, seven had existing or proposed policies in all of the five clean technology areas in which Massachusetts has leadership potential. Within each state, some efforts were carried out by environmental agencies, and some by economic development agencies. However, no state has explicitly developed a comprehensive overarching vision that ties together their activities into a coordinated Clean Tech economic development effort.

California, the state most often pointed to as Massachusetts' competitor in environmental policy and clean technologies, promotes its Clean Tech efforts under the umbrella of its Climate Protection Plan. This plan has a goal of 30% greenhouse gas emission reductions by 2020. These efforts include a flagship Green Chemistry Initiative, and zero waste, green building, and nanotechnology programs. Internationally, California is working to develop standards for green chemistry, including labeling for children's toys; development of incentives to reduce carbon; and cross-border initiatives with Mexico to reduce litter and dumping by helping to set up recycling industries.

These activities are overseen by the California Environmental Protection Agency (Cal EPA), along with relevant departments within that agency. While economic development is a factor in promoting clean technology, the driver is to create incentives and requirements for businesses to operate in a more environmentally sustainable manner: businesses remain competitive by operating in an efficient, yet environmental manner, while creating a demand for research and development of green technology.

Ohio has one of the top-ranked economic development programs in the country, called the Third Frontier Project. Third Frontier is looking into developing a Clean Tech strategy, but for now, its programs only target energy-related companies and advanced materials. Third Frontier has funded the Ohio BioProducts Innovation Center (OBIC), run out of the state university. OBIC is a research initiative that integrates academia and industry in the development of renewable specialty chemicals, polymers/plastics, and advanced materials. Ohio's Department of Development focuses on clean energy development, and the governor has assigned an energy czar. The state's environmental protection agency does business outreach and education around sustainability principles as a re-growth opportunity for Ohio businesses.

**However, no state has explicitly developed a comprehensive overarching vision that ties together their activities into a coordinated Clean Tech economic development effort.**

Michigan has separate initiatives promoting recycled materials, green chemistry, biobased products, and green buildings. The drivers of these programs, however, are climate and environmental protection, although the state's Green Chemistry Directive does note the economic development importance of this field. In addition, there is no overarching plan or entity tying these initiatives all together as an economic development strategy,

Closer to home, in 2003 Vermont's lieutenant governor declared Vermont the Green Valley, and created a vision that linked jobs and the environment, supporting environmental goods and services through networking, education, marketing,

and growing and attracting new companies providing environmental goods and services. However, government leadership has waned and the non-profit Vermont Environmental Consortium is carrying out part of that mission, providing a networking and education function for the environmental businesses in that state. The state Department of Environmental Conservation also has a number of individual policies and programs promoting end uses for recycled materials, deconstruction and green building, materials exchange, energy efficiency, and renewable energy.

The lack of coordinated Clean Tech economic vision in the states, combined with Massachusetts' strengths in so many environmental technologies, highlights the opportunity that Massachusetts has to not only lead all the other states, but create partnerships and markets with those states for Massachusetts technologies and products.

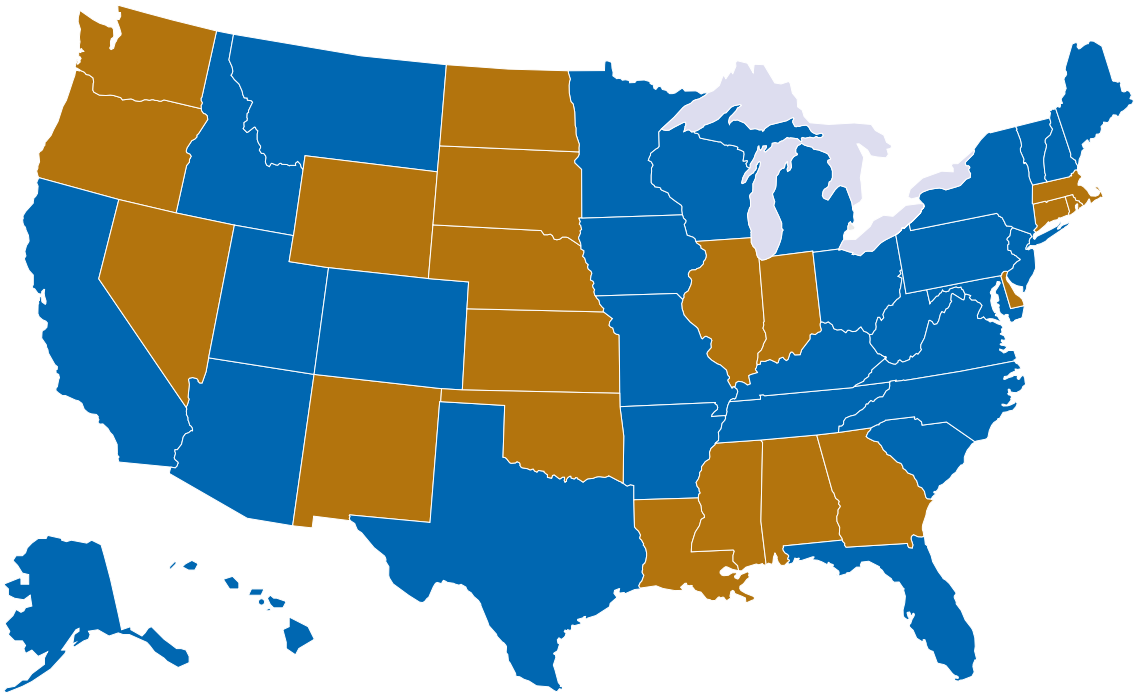
## Respondents to State Clean Tech Policy Survey

**Responding**

Alaska
Arizona
Arkansas
California
Colorado
Florida
Hawaii
Idaho
Iowa
Kentucky
Maine
Maryland
Michigan
Minnesota
Missouri
Montana
New Hampshire
New Jersey
New York
North Carolina
Ohio
Pennsylvania
South Carolina
Tennessee
Texas
Utah
Vermont
Virginia
West Virginia
Wisconsin

**Not Responding**

Alabama
Connecticut
Delaware
Georgia
Illinois
Indiana
Kansas
Louisiana
(Massachusetts)
Mississippi
Nebraska
Nevada
New Mexico
North Dakota
Oklahoma
Oregon
Rhode Island
South Dakota
Washington
Wyoming



# Economic, Environmental, and Social Benefits

The potential for environmental and health regulations to spur innovation has been widely described. But it is difficult to project economic benefits of Clean Tech policies and investments. Such figures have been estimated for many sectors, including clean energy, but not for a whole Clean Tech agenda. Hence, it is important to explore and outline the broad range of benefits that have been documented and that could increase if more investments were made and the right public policies were in place. Future research could explore the economic benefits question for particular sectors in greater detail, understanding that such assessments are mainly projections based on complex models.

A literature review[10] conducted by the Economic Development Research (EDR) Group demonstrated that a range of economic, environmental, and social benefits could be realized through the growth of Clean Tech oriented industries. A key barrier to stimulating private investment is that the social and broader public benefits don't necessarily accrue to an individual firm. Therefore, there is a need for governmental co-investments and/or other action to promote certain markets until they become viable on their own.

While some environmental and social benefits, such as moving towards environmentally preferable products and technologies, *may* have an up front cost, they can lead to economic benefit by avoiding health problems, increasing productivity, reducing the need for future cleanup or remediation, and sustaining the systems on which we need to survive. In addition, while it may be difficult to attach a dollar amount to these environmental and social benefits, these are widely believed to have value to society.

The EDR Group's research shows that:

- **Safer alternatives** have significant societal benefits in terms of reduction in chemical waste and exposure which harm local plants, animals, and people. This technology requires sophisticated skills and equipment that would enable Massachusetts businesses to differentiate themselves further as innovation leaders—the backbone of the Massachusetts economy.

- **Green buildings** generate labor productivity increases through improved shop-floor design efficiency and by improving general morale through creation of a more healthy and pleasant work environment. For Massachusetts, increased construction of green buildings will likely spur technological changes in design as well as equipment manufacturing. It can also attract green-conscious businesses.

- **Recycling** can act as a "gateway activity" by increasing consciousness about resource use and waste disposal, leading to other environmental behaviors. It also has recognized impacts on the Massachusetts economy by reducing costs to local businesses and municipalities, providing a local source of materials for manufacturers and artisans, as well as providing opportunities for innovative goods.

- **Emerging materials** present significant opportunities to create cleaner, safer, and more efficient production processes. This would provide beneficial environmental impacts to the state, and spur innovation in the manufacturing sector. Compatible with Massachusetts' high-skilled labor force and advanced technology industry, development and adoption of advancing emerging materials may also represent job replacement for mature industries on the wane.

- **Investments in clean energy** would diversify energy sources, reduce the adverse environmental and economic vulnerabilities from fossil fuels, and foster innovative, knowledge-based industries by creating demand for *local* energy production built upon efficient technologies. These present opportunities for Massachusetts to provide solar, wind and biofuels that would expedite growth in its innovative economy and provide cleaner energy to businesses and households.

# The Economic Costs of Not Acting

As discussed in the previous section, while there is no way to truly calculate the full economic benefits that will come to the state by investing in a Clean Tech economic platform, there are some direct and indirect costs to businesses and the state of not doing so. Some of the greatest risks may include the losses of:

- key export markets
- government and industrial grants and contracts for research, development, and application
- key industries moving outside of the state for more favorable conditions or for direct incentives from other states
- intellectual capital from university graduates and academic researchers seeking more forward-looking opportunities

Leading edge firms want to be in locales with other innovating firms. Any losses in business or intellectual capital could have a snowballing effect and make Massachusetts lose its competitive edge and ability to track companies, research and investment.

These potential losses are most profound when examining specific sectors and their response to Clean Tech oriented policies from other markets. As a recent example, the Economic Development Research (EDR) Group examined the impacts to the Massachusetts economy if the state's firms did not comply with the 2006 European Union directive for *Reduction of Hazardous Substances* (RoHS).[12]

RoHs promotes safer alternatives to toxic chemicals by restricting the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ethers in the Computer and Electronics sector and in the Electric Equipment, Component, and Appliance manufacturing sector (NAICs 334 and 335). Such measures are underway in other parts of the world. China and Korea have implemented similar regulations; state-mandated changes regarding waste from electrical equipment and electronics have been adopted in California, and Australia; and Canada and Taiwan are in the process of advancing similar regulations. The EU is considering including medical equipment and monitoring/control equipment, as well as additional hazardous substances, in the future.

EDR found that Massachusetts exports annually approximately $2.6 billion of electronic manufactured products to Europe that are covered under the RoHs initiative. These companies directly employ 4,000 people, and indirectly employ an additional 5,450 in their supply chains. These are well paid jobs, averaging $113,250 per worker, including fringe, for the direct employees, as compared to $57,475 for the average Massachusetts worker. These are jobs that would have been lost if these companies did not comply with the RoHs initiative and the companies could not replace these markets. This would have had an impact throughout the supply chain, and on consumer spending.

Product manufacturers and their supply chains have incurred costs and continue to do so to comply with this law, in order to preserve or gain market share. There is no study of the potential lost sales from Massachusetts firms to the EU as a result of RoHs, but a sample of 200 U.S. firms showed that 29% have incurred lost or delayed sales into the EU due to the law—averaging $1.84 million per firm. On the positive side, proactive first-mover firms are citing advantages such as improved supply chain processes (25% of those surveyed), rationalized product lines (20%) and increased market shares (15%).

As new substances are added to ROHS and additional directives come on line elsewhere, companies that are knowledgeable and experienced in switching to less toxic alternatives will have a clear advantage in the marketplace. Firms who track these trends, understand the issues, and comply with international laws will also have a competitive advantage in places where chemical restrictions do not yet exist, as customer demand for safer products increases. If Massachusetts firms don't have the information and tools they need to understand chemical hazards and alternatives and be compliant with these directives, important jobs become at risk in the state's economy.

# Policy Recommendations

What role can Massachusetts play in building a strong economy based on a cleaner, healthier way of doing business? Ten overarching themes and many recommendations specific to each of the five Clean Tech areas emerged in the stakeholder roundtables, Advisory Committee meetings, and individual discussions held for this project. These actions can send a strong signal to the marketplace that will show the state is willing to provide long-term support for clean technologies, and is committed to creating competitive conditions for their development and implementation.

Many of the recommendations are no or low cost. They involve public leadership and coordinating of existing programs and agencies. Others are higher cost but, given market trends, increasingly limited resources, and growing information about the impacts of exposure to toxic substances, climate change, and resource depletion, the economic benefits over the medium to long term should well outweigh the costs.

## Ten Ways to Support a Clean Tech Economy

1. **Create a "Clean Tech Blueprint" for Massachusetts That Establishes a Clear Vision, Goals, Metrics, and Leadership Roles.** By articulating a clear vision, goals (including performance standards such as energy efficiency, recycled content, or toxicity), and desired environmental and public health outcomes, government can set the parameters under which companies in the marketplace develop new technologies, and create conditions for those to thrive. This blueprint would set the stage for innovation in new technologies that meet its vision and outcomes, in addition to setting criteria by which government and investors can evaluate and choose specific technologies. The Blueprint would set the roles for various agencies, and metrics that would be evaluated as part of the Competitiveness Index of the Massachusetts Green Innovation Economy (see #3 below).
   - ***Cost:*** *Low to medium. Could be done in-house or through consulting services. A more public process would increase costs related to coordination.*

2. **Create a Massachusetts Brand or Identity for all Clean Tech Activity.** By creating an identity that promotes Massachusetts as a hub of activity for all types of clean technologies, the state has the potential to emerge as a Clean Tech powerhouse that attracts investment, research, and business activity. Creating this identity would include developing a central web portal that posts state research, patents, funding, resources, products, events, etc; preparing marketing materials that can be used nationally and internationally to attract businesses and investors; creating an outreach program to encourage the purchase of locally manufactured products; and using the bully pulpit of state leaders to promote Clean Tech activities and achievements.
   - ***Cost:*** *Medium. Would involve some initial and ongoing costs of developing and maintaining branding materials and resources*

3. **Track Massachusetts' Competitiveness by Creating an "Index of the Massachusetts Green Innovation Economy."** Similar to the John Adams *Index of the Massachusetts Innovation Economy*, the Green Innovation Index would determine indicators that are important in creating the Clean Tech economy, measure these indicators, and compare our progress in meeting them against other states that are Clean Tech leaders. It would also evaluate Massachusetts' progress in meeting the goals and metrics articulated in the Clean Tech Blueprint, and would be updated every two years. California is already using such an index.[13]
   - ***Cost:*** *Low. Could be done in-house or through consultant.*

4. **Create a State Office of Clean Technology (or Clean Tech Coordinating Council.** The state should institutionalize its Clean Tech Blueprint with the establishment of a governance and support structure to advance the vision. This can be done either through the establishment of a new State Office of Clean Technology or a Clean Tech Coordinating Council comprised of the directors of all key state agencies who would have a role in implementing and updating the Blueprint. The coordinating council would identify programs, services, and policies that would meet the Blueprint goals, drawing on the experiences of previous state environmental technology assistance programs (such as STEP and the Chelsea Center for

Recycling and Economic Development), as well as that of other states and countries.

- ***Cost:*** *Low to medium, depending on whether an entirely new office is created or if a coordinating council is established, Costs could involve coordination or reorganization of existing staff or entirely new staff.*

5. **Create Regional Clean Tech Centers of Excellence.** A network of Regional Centers of Excellence would bring together leading businesses, researchers, labor leaders, environmental and health advocates, and researchers to identify and implement cutting-edge research, create partnerships, apply for funding, and act as a clearinghouse for Clean Tech information. Within Massachusetts, this set of regional centers should extend to all major regions.
   - ***Cost:*** *Low to medium. Could be done through the regional offices of the Massachusetts Office of Business Development, Small Business Development Centers, colleges and universities, or other entities. Could be gradually phased in throughout the state as funds become more available.*

6. **Stimulate Collaboration and Cross-Fertilization of Technologies.** The state should help foster a culture of collaboration, which was reported by businesses and researchers to not now exist, by encouraging cross-fertilization within and among technologies, including industries that have the potential to be "clean" but may not yet be so. This cross-fertilization would help define business, government, environmental and health priorities; spread current best practices; identify public and private needs for assistance; link people with resources; and create industry-education-government partnerships that can be on the forefront of innovation and adoption and help bring in more funding. The roundtable meetings created for this project provide a good model for future efforts, involving the full range of stakeholders.
   - ***Cost:*** *Low to medium. Could be done by existing staff. Might involve costs related to organizing, publicizing and holding events, creating outreach and informational materials, etc.*

7. **Support Manufacturing as a Viable Sector.** Manufacturing is still an important part of the Massachusetts economy, and should be treated as a priority equal to the state's knowledge sector. State officials must market and strengthen the Commonwealth's unique capacity for high-end, first-run, niche manufacturing in all parts of the Clean Tech supply chain, so that it can thrive in the long term. In addition, the state's manufacturers should be assisted in adopting environmental practices to help them stay competitive by saving energy, recycling wastes, and using less toxic substances.
   - ***Cost:*** *Low to medium, depending on level of actions—from marketing in and out of state, to technical assistance.*

8. **Develop a Trained Workforce.** The growing Clean Tech economy will need people of all skill levels to fill positions. To effectively build this workforce, business and labor leaders, community colleges, vocational technology schools, and workforce investment boards, regional employment boards, one-stop career centers and other training agencies should be brought together to identify current and future workforce needs and how to fill them. Green jobs legislation should cover green jobs beyond the energy sector, and training programs should be funded to develop the needed workforce. An annual report should be created on green jobs employment and forecasts, including sectors, skill levels, and training needs.
   - ***Cost:*** *Medium to high, depending on level of training.*

9. **Regulate, Procure, and Invest.** The state needs to show that it will provide long-term support for clean technologies and is committed to creating competitive conditions for their development and implementation. These market signals can help give entrepreneurs the confidence to innovate and spur change. However, any policies or specifications should encourage continuous improvement, not a static solution.
   - ***Cost:*** *Medium to high, depending on level and type of investments.*

10. **Take Risks to Spur Innovations.** Agencies and programs that fund Clean Tech activities should be a little less risk averse when determining projects to fund. Even if a project fails, there is still something to learn and benefits that can be gained. Being less cautious may yield exciting breakthroughs.
    - ***Cost:*** *Unknown, may not mean big changes in funding levels, vs. changing the way things are funded.*

## Five Technology-Specific Recommendations

Many ideas were recommended to grow the five key technology areas and include roles for the public and private sectors. These are detailed in Appendix I. The recommendations below incorporate or support many of those ideas, focusing on public sector actions.

### 1. Safer Alternatives to Toxic Chemicals

**Pass key policies on Safer Chemicals and Products**

The Governor should issue A *Green Chemistry Executive Order* that would define green chemistry, establish state policy, and provide funding and other incentives to encourage the research and use of safer, less toxic, or non-toxic chemical alternatives to hazardous substances in Massachusetts. An executive order of this kind should include defining the scope and priorities of a Green Chemistry Program, building a resource clearinghouse of Green Chemistry activities in the state, building support and commitments from key stakeholders to advance Green Chemistry in Massachusetts, developing education and outreach opportunities, recognizing and rewarding green chemistry achievements, and advancing long-term Green Chemistry directions by building on Massachusetts' existing capacity. Alternatively, this action could be accomplished through legislation. Either option would involve the Legislature in funding the program.

Ultimately a Green Chemistry center housed either in the state Office of Technical Assistance or a university would provide a "home" to highlight Massachusetts' research and accomplishments as well as to train existing and new leaders in the field. A recently established Executive Directive for Green Chemistry Research and Development in Michigan and subsequent action plan could serve as the foundation for a Massachusetts model.

The Legislature should pass the *Safer Alternatives* bill, which establishes a policy framework that builds on the state's successful toxics use reduction model. It would focus on tools, regulations, and incentives that promote the transition towards alternative, less toxic materials and products and protect Massachusetts' workers, residents, and eco-systems.

- ***Cost:*** *medium to high. Could be paid in whole or part from filing fees from the Toxics Use Reduction Act. Costs to businesses should be offset by savings in toxic chemical use and retention or increase in market share.*

### 2. Green Building

**Create an implementation plan for the recommendations of the governor's Zero Net Energy Building Task Force, prioritizing data collection and dissemination, and energy rating and certification.**

In Massachusetts, the most recent available data (from 2005) indicate that residential and commercial buildings account for 56 percent of the state's annual energy consumption and 35 percent of the state's carbon dioxide emissions. As a result, Governor Patrick called for the creation of a Zero Net Energy Building Task Force that would put the state in the forefront of creating buildings that will eventually generate at least as much energy as they use.

The Task Force's recommendations[14] cover performance standards, measurement, incentives, workforce development, and continuous improvement in public, commercial, and residential buildings.

These are far-reaching recommendations that, when implemented, will not only reduce the energy demand of these buildings, but incubate a market for technologies and services that can meet similar needs around the world.

These recommendations should be adopted and a plan developed to move forward on their implementation, with a priority on 1) developing a system for collecting and tracking information on energy use in buildings, and 2) creating an annual energy rating standard and building certification that would be available to tenants and property buyers.

- ***Cost:*** *costs will be highest for the private sector, but should be offset by savings in energy use and increased demand for more energy efficient buildings*

### 3. Materials Reuse and Recycling

**Reestablish a stable funding mechanism adequate to double the State's recycling and waste reduction rates.**

Recycling not only reduces environmental impacts and greenhouse gas generation associating with mining, processing, and transportation of raw materials, it can help local communities reduce the costs of waste disposal, provide inputs for local manufacturers to make new products, and create many more jobs in collection, processing, and reuse than does garbage disposal. For example, approximately one third of garbage is comprised of food and yard waste and other organic materials. These can be composted and returned to the soil where they add nutrients and increase the soil's ability

to capture carbon, but new systems must be put in place to do this. In order to significantly increase the state's recycling rate, and realize the associated economic and environmental benefits, investments are needed in education, enforcement of bans on disposal of certain waste materials, next-generation collection and processing infrastructure, development of programs that encourage waste reduction and design for recyclability, research to develop and test new ways to use secondary materials, and in technical and business assistance and incentives to increase the use of recyclable materials by Massachusetts manufacturers.

In the past, the state recycling programs were funded through the Clean Environment Fund (CEF), which was comprised of unredeemed deposits from the bottle bill. Additional funding for recycling market development was provided from 1995 through 2003 by the former STrategic Envirotechnology Partnership, STEP.

Unredeemed deposits—from bottles that were recycled in curbside and drop-off programs without redeeming the deposit, or thrown away—generated close to $40 million in state revenues in 2008. This money now goes into the general fund, rather than to support recycling, and the state's recycling budget has plummeted. Not surprisingly, its recycling rate also leveled off. The Clean Environment Fund should be reinstated for its original purpose; 100% of the unredeemed deposits from the proposed Expanded Bottle Bill, if it passes, put to use supporting recycling and waste reduction programs; a surcharge levied on the disposal of solid waste as 35 other states do; and/or some other mechanism found to support a transition from a wasting to a recycling economy.

- ***Cost:*** *high, but will be paid for by consumers through waste disposal surcharges or unredeemed bottle deposits, and will be offset through savings in garbage disposal and increased economic activity in recycling.*

## 4. Emerging Materials

### Biobased Materials

***Adopt the Sustainable Biomaterials Collaborative guidelines as criteria for state purchasing and research and development investment***

A "biomaterial" is any material made from annually renewable plant matter (as opposed to non-renewable prehistoric plant material, fossil fuels), including agricultural crops and residues, and trees. Sustainable biomaterials are those that are (1) sourced from sustainably grown and harvested crop-land or forests, (2) manufactured without hazardous inputs and impacts, (3) healthy and safe for the environment during use, and (4) designed to be reutilized at the end of their intended use such as via recycling or composting.

While biomaterials have the potential to reap environmental benefits, they can also be developed in ways that do not allow this to happen, including competing for food crops, using unsustainable agricultural practices, and creating products that contaminate recycling streams. The Sustainable Biomaterials Collaborative worked with businesses, recycling professionals, and academics, as well as advocates focused on environmental

### Sustainable Biomaterials Principles

As endorsed by the Sustainable Biomaterials Collaborative, *www.sustainablebiomaterials.org*

- Reduce the amount of material, product and packaging used
- Eliminate single-use products that can be neither recycled nor composted
- Avoid fossil-fuel-based materials in favor of materials and products derived from renewable feedstocks
- Address sustainability across the life cycle of the material: the growing of the feedstock, manufacturing of the biomaterial and final product, using the product and reclaiming the material at the end of its original use
- Define sustainability to include issues of environment, health, and social and economic justice
- Design and use products that are reusable, recyclable or compostable
- Encourage agricultural systems that are sustainable for farmers, the environment, farm workers and communities
- Support small- to mid-sized family-owned and -operated farms
- Do not use genetically modified organisms in agricultural feedstock production
- Use chemicals that meet the 12 Principles of Green Chemistry
- Avoid engineered nanomaterials and chemicals that have not been tested for environmental and public health effects across the lifecycle
- Decentralize production and buy local to reduce the environmental footprint of production, transportation, and consumption.

health, environmental justice, and rural communities, to develop principles and guidelines that help guide the development of biomaterials that are better for the environment. These guidelines cover feedstocks, life-cycle issues, genetically modified organisms, chemicals, and production systems.

These guidelines should be adopted by the state through executive order or legislation, and used as requirements for funding research and development, as well as for procuring products with state funds. This will encourage researchers and entrepreneurs to create products and technologies that genuinely are better for the environment throughout their life cycles.

- ***Cost:*** *Neutral, although there may be higher costs initially of purchasing biomaterials that meet the Sustainable Bio-materials Collaborative guidelines.*

### Nanomaterials

***Advocate that more federal funding be dedicated to assessing health and safety aspects of nanomaterials, and strive to double the Massachusetts share of federal research funds, matched with increasing state funding, in this area to create a Signature Research Center Initiative.***

Nanoparticles have tremendous potential to reap environmental benefits, but real concerns exist about their environmental, health and safety risks as well. The federal research budget for nanotechnology risk for Fiscal Year 2010 is about 5.5% of the overall federal nanotechnology budget. To help ensure that risks from nanoparticles in manufacturing and commercial use are minimized, this amount must be increased.

Congress has passed the National Nanotechnology Initiative Amendments Act of 2009 (H.R. 554), which highlights the growing need to learn more about the possible dangers posed by some nanoscale materials.

Massachusetts should encourage its two senators to support the bill when it comes to a vote in the Senate, and work with the state's nanotechnology research centers to double the amount of federal funding coming into the state. These funds would go towards the establishment of a *Sustainable Nanomaterials Signature Research Program.*

This program, started with federal and dedicated state funds, would provide research grants to establish at least two to three Signature Research Centers for Sustainable Nanomaterials, housed at universities in the state. A model for such investment is the Signature Research Center Initiatives program, established by the state Economic and Community Development Division in Oregon. These establish investments in three Signature Research Centers committed to accelerating the commercialization of cutting-edge research and facilitating public-private partnerships that anchor next-generation industries in Oregon: Nanoscience and Microtechnologies Institute; Translational Research and Drug Development Institute; and Built Environment and Sustainable Technology. Massachusetts can link its research centers to key industries such as solar energy, life sciences, and pharmaceuticals.

- ***Cost:*** *Low, and could bring research dollars into the state*

## 5. Clean Energy:

### Define what clean energy is

Good definitions and guidelines can spur innovation in the desired direction. Despite all of the activity to promote the development and use of clean energy, the state has not developed principles or criteria that define what clean energy is, leaving the door open for promotion of technologies that might not actually meet the state's interest in developing clean energy sources.

The state should adopt a strong and clear definition of what constitutes clean energy, perhaps even having categories of "clean, cleaner, cleanest." An ideal definition would at a minimum include the following elements: the energy should be from natural and renewable resources that replenish themselves in a certain period of time and don't degrade the environment by their extraction or use; it should be locally produced, and not cause the buildup of global warming gasses or toxins in the atmosphere or produce waste; it should only create a certain amount of greenhouse gasses per BTU; or, it should avoid the generation of energy altogether, such as conservation or efficiency measures.

Legislation, funding for research and development, and other incentives should reflect this definition, and technologies would then be nurtured and used that move towards and meet these criteria. This would send a clear message to the marketplace that would lead to innovation and adoption of technologies that are truly clean.

- ***Cost:*** *Low*

# Implementation

Achieving broad and comprehensive transition to a Clean Tech economy will require effort on the part of many public and private entities, including the governor, legislature, Secretariats of Environmental and Economic Affairs, colleges and universities, businesses, labor, and environmental groups.

**The Governor.** Provide leadership on articulating a vision, using the bully pulpit to send signals to the marketplace, create executive orders, develop the Clean Tech Blueprint, introduce relevant legislation, set priorities for and coordinate his executive offices, and advocate for federal policies that support Clean Tech research and development;

**The Legislature.** Support legislation such as the Safer Alternatives and Expanded Bottle Bills and other policies that support a Clean Tech marketplace, appropriate funding for research and for the state's recycling programs, create regional Centers of Excellence, and create tax and other incentives for Clean Tech;

**The Executive Office of Environmental Affairs.** Host an Office of Clean Tech, coordinate task forces and roundtables, set benchmarks for environmental achievement, streamline permitting hurdles, administer grants, provide technical assistance and guidance, and refine the definition of clean energy;

**The Executive Office of Housing and Economic Development.** Assign an industry expert to work with all Clean Tech businesses, convene stakeholders to work together to de-fragment industries and create partnerships, help businesses transition to Clean Tech, create a Clean Tech brand or identity, retain and attract new Clean Tech businesses, coordinate federal funding applications;

**The Executive Office of Labor and Workforce Development.** Define, track and forecast green jobs and provide training for green jobs of the future;

**Public and Private Colleges and Universities.** Conduct research on all aspects of clean technologies, cultivate and license new technology breakthroughs and create spin-off businesses, develop curricula, and lead centers of excellence;

**Trade Unions, Vocational Schools, Workforce Investment Boards, Regional Employment Boards, Community-based Workforce Development Organizations, and Community Colleges.** Help train workers for Clean Tech jobs;

**The John Adams Innovation Institute.** Develop, track, and report on indictors of the Green Innovation Economy;

**The Massachusetts Office of International Trade and Investment and the Massachusetts Export Center.** Help develop international markets for Massachusetts companies, track exports, and attract investments;

**Private Sector Entrepreneurs and Financiers.** Develop and invest in Clean Tech businesses in this state and encourage others to do the same, help spread the word that Massachusetts is an inviting place for Clean Tech, provide products and services, and advocate for responsible policies; and

**Environmental Groups.** Advocate for cutting-edge policies that push the envelope for environmental protection, promote the most environmentally sound solutions and technologies, and educate the public on the benefits for health, jobs, and the economy of cleaner products and processes.

# Clean Tech—A Competitive Differentiator For Massachusetts

Clean technologies encompass a wide range of activities and products that are better for people, our economy, and our environment. Massachusetts has ready expertise in the five technology areas identified in this report and in many others. The need is growing worldwide for other clean technologies that Massachusetts' knowledge, innovation, and skill can help fill, such as water conservation and infrastructure, wastewater treatment, sustainability measures, and organic agriculture.

Our Governor and legislative leaders can bring together government, business, academic, finance, and NGO professionals to identify, advocate for, and pass local and national legislation that encourages Clean Tech activity, nurtures research, encourages partnerships among and between technologies, and take other steps outlined in this report to create an environment that makes Massachusetts the center of knowledge and activity on Clean Tech.

**Whether and how we achieve this vision in the future will depend on the policies and programs that we put in place today. Massachusetts has an unprecedented opportunity to turn environmental protection into a vibrant and long-term, sustainable economy.**

A Clean Tech initiative in Massachusetts can bring together the well-respected strengths of Massachusetts businesses and institutions to lead the transition to safer technologies that serve the local as well as global marketplace. Massachusetts has an opportunity right now to start taking steps to make it *the* place where:

- Companies compete actively to make the safest, most environmentally benign and most effective products and processes for local and global markets;
- Regular new breakthroughs in technologies that are less toxic, polluting, and/or wasteful are creating safer products and services to meet world demands;
- Significant federal dollars and private investments support our cutting-edge research into next-generation clean technologies;
- Our energy demands are greatly reduced through investment in conservation and efficiency techniques, and our remaining energy needs are met through renewable resources, such as wind, solar, and biomass;
- Our air, water, and land are cleaner because our wastes are turned back into new products rather than buried or burned;
- Our population is healthier because our homes, workplaces, and the products we use do not poison the air we breathe, the ground or waters where our food grows, or the water we drink;
- Our firms provide good, secure jobs, from entry-level to executive, in safe and healthy workplaces;
- Entrepreneurs and individuals are clamoring to come to Massachusetts and take advantage of the healthy environment, good jobs, and wealth of intellectual and physical resources we have in clean technologies; and
- Our tax base is growing, allowing us to have a truly healthy economy in all senses of the phrase.

Whether and how we achieve this vision in the future will depend on the policies and programs that we put in place today. Massachusetts has an unprecedented opportunity to turn environmental protection into a vibrant and long-term, sustainable economy. This means building a Clean Tech economy that is broader than the current focus on clean energy alone. Recognizing and supporting the full existing and emerging Clean Tech industry is critical to that vision.

# Appendix I
## Additional Ways to Build the Massachusetts Clean Tech Sector

Many ideas were suggested to move each of the five clean technology sectors forward in the interviews, research, and eight stakeholder Roundtables conducted as part of this project. They are captured below. Some are applicable to the private sector, others to government. The recommendations in the body of this report drew from these ideas.

### Green Building

- Sponsor research on costs and benefits of green building measures.
- Encourage measurement and monitoring of energy use and indoor environmental quality through systems. controls, software, and monitoring technologies, and begin training people for related jobs.
- Market Massachusetts sustainably harvested wood as a brand.
- Create financial incentives to encourage investment in green buildings, and broad adoption of green building practices and products, such as carbon tax, differential insurance rates, property tax reductions.
- Standardize quality control by creating or supporting training and certification programs for green-building contractors, including electricians, builders, plumbers, etc.
- Develop ways to more affordably retrofit older, existing building stock, and publicize best practices.
- Make the voluntary "stretch" energy efficiency code mandatory.
- Identify buildings products that can be manufactured locally to receive LEED™ points, and brand them as being Made in Massachusetts.
- Facilitate aggregated purchase of green building materials for public and private developers.
- Encourage local governments to enact planning codes that are more stringent than state building codes
- Identify future job and training needs.
- Look at more opportunities for deconstruction and building materials reuse.
- Create a green building tax credit.
- Create an energy efficiency rating standard for buildings, and require owners to disclose it to tenants and buyers.

**The Capuano Early Childhood Center in Somerville was envisioned as a model high-performance facility, able to teach sustainability by example. It is the first Massachusetts public school to register with the LEED program.**

- Require an accounting of carbon footprints, including those related to transportation and products, along with a mitigation and reduction plan, as part of the building permit process for MEPA, cities, and towns.
- Mandate data tracking for building performance, prioritizing energy consumption, to measure performance over time and encourage reductions towards measured goals.
- Encourage local governments to create sustainability master plans or overlay districts that take into account, at a minimum, energy, water, habitat, and transportation.
- Tie metrics to state and local energy and Greenhouse Gas Reduction Plan goals.
- Create funding mechanism that will help push demand for green buildings.

## Emerging Materials

- Lead the national discussion on defining what is "clean" or "cleaner," and define areas for such development.
- Fund research into identifying environmental and health benefits, hazards, and risks throughout lifecycle and in different environments.
- Develop guidance on how and where to adopt advanced materials.
- Provide guidelines and training on how to manage environmental and health safety risks.
- Continue research and adoption on manufacturing these materials in a more environmentally benign way.
- Develop local and state ordinances that give companies clear direction on managing nanoparticles.
- Support development of monitoring technologies for nanoparticles.
- Promote collaboration with related sectors to find new applications.

## Clean Energy

- Help early-stage companies test and adopt their technologies locally.
- Update the Commonwealth's Renewable Portfolio Standard (RPS) to require a higher fraction of generation to be renewable.
- Cultivate culture of experimentation by encouraging more university investment in research.
- Expand well-planned public transportation opportunities.
- Use more peer review to choose state-funded projects.
- Develop collaborations with other states.
- Find ways to shorten the payback of energy conservation efforts.

## Materials Reuse

- Reinstate the Clean Environment Fund, or significantly increase recycling funding through another mechanism.
- Support research into new uses for scrap materials.
- Assist industries in incorporating recycled feedstocks.
- Increase diversion of paper from waste stream.
- Set standards and require certification of recycled content for state's EPP program.
- Ensure that waste-to-energy technologies don't compete with the recycling industry.
- Adopt zero waste goals and develop programs to reach them.
- Work with farms in the state to host compost operations for urban and suburban generators.
- Create new ways to recycle construction and demolition materials.
- Work through agricultural extension agencies to promote more composting and compost application.
- Work with MassHighway to utilize more recycled products.
- Create a standing committee comprised of DEP and DOER to focus on understanding and quantifying energy conservation benefits of materials reuse.

## Safer Alternatives

- Pass Safer Alternatives Bill.
- Educate all sectors about importance of safer alternatives.
- Develop specifications and regulations to help spur research, procurement, innovation, and technology adoption.
- Create program to underwrite costs of testing to help companies bring products to market.
- Assist companies in identifying safer alternatives to meet their specific needs.
- Expand Toxics Use Reduction model to other chemicals, businesses, and products.
- Engage Massachusetts companies that face European environmental regulations and help them with supply chain management, information technology, and more.

# Appendix II:
## Participants in Clean Teach Discussions

**The Clean Tech Initiative would like to thank all the people who participated in the Roundtable discussions and interviews:**

- Brian Ahern, Next Generation Energy Corp, Boxboro
- Carol Alon, LEED Inc., Great Barrington
- Joseph April, MassBay Community College, Wellesley Hills
- Moneer Azzamm, SolarOne Solutions, Framingham
- Jack Bailey, Bose Corporation, Framingham
- John Bantjes, Texon USA, Russell
- Wayne Bates, Capaccio Environmental Engineering, Inc. Marlboro
- Dolly Batra, TIAX, LLC, Cambridge
- Jeffrey Beam, Masters of City Planning and Real Estate Development Candidate, Department of Urban Studies and Planning, MIT Cambridge
- Jon Beekman, SEA Consulting, Framingham
- Linda Benevides, Executive Office of Energy and Environmental Affairs, Boston
- Jeff Bentley, CellTech Power ,Westborough
- Bonnie Biocchi, Mass Office of Business Development, Devens
- Rich Bizzozero, Office of Technical Assistance for Pollution Prevention Boston
- June Black, Office of Congresswoman Niki Tsongas, Lawrence
- Natalie Blais, Office of Congressman John Olver, Holyoke
- Daniel Bosley, Joint Committee on Economic Development and Emerging Technologies, First Berkshire and parts of Franklin Counties
- Heather Boulger, Regional Employment Board Pittsfield
- Donald (Brad) Bradshaw, Jr. , Massachusetts Hydrogen Coalition, Beverly
- Robert Brandt ,Office of Chairman Daniel Bosley, Boston
- Ron Brumback, CertaLogic, Inc., Sudbury
- Jamie Cahillane, Center for Ecological Technology, Pittsfield
- George Camougis
- Amy Cannon, Beyond Benign, Woburn
- Norman Chagnon, Third Frontier Project, Ohio
- Noah Chesmin, Green Roundtable, Boston
- Steven Clarke, Massachusetts Executive Office of Energy and Environmental Affairs, Boston
- Ed Connelly, New Ecology, Cambridge
- Paul Cronin, Axcelus, Andover
- Patricia Crosby, Franklin Hampshire Regional Employment Board, Greenfield
- Mary Cuticchia, Merrimack Valley Economic Development Council, Lawrence
- Elise Dauksevicz, Alpha Chemical Services Inc., Stoughton
- James Devol, Gilbane Building Company, Providence
- Matt Dindio ,Office of Mayor James Ruberto, Pittsfield
- Patty Dillon
- Benjamin B. Downing, State Senator, Pittsfield
- Bob Dvorchik, Western Mass Electric Co., Pittsfield
- Carolyn Dykema, Representative-Elect, 8th Middlesex District
- Jamie Eldridge, Senator-Elect Middlesex and Worcester
- Pam Eliason, Toxics Use Reduction Institute, University of Massachusetts Lowell
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- Jenny Hersch, Housatonic River Museum, Pittsfield
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- Pam Richardson, Representative Boston
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- Gary Sidell, Bell Tower Square Management, LLC Lawrence
- Ron Smith, Ohio Environmental Protection Agency, Ohio
- Madeline Snow, UMass Lowell
- Karen Spilka, Senator, 2nd Middlesex and Norfolk District, Boston
- Andy St.Pierre, Crane and Co., Dalton
- Eduardo Suarez, El Mercado, Holyoke
- Adam Sugarman, Solar Sugar, Pittsfield
- Maggie Super-Church, Union Crossing, Lawrence
- Mike Supranowicz, Berkshires Chamber of Commerce, Pittsfield
- Brian Sutton, Berkshire Green Builders, Great Barrington
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- Dave Turcotte, UMass Lowell Center for Family Work and Community
- Frank Urro, The Tsunami Green Project, Billerica
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- William Weber, MACTECH, Portland
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- Ted Welte, MetroWest Chamber of Commerce, Framingham
- George Wilkish, Prime Consulting, Holden
- Robert Wilson, TIAX, Cambridge
- Anita Worden, Solectria Renewables, Lawrence

# Endnotes

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# CLEAN TECH
## An Agenda for a Healthy Economy

By re-orienting our economy to one built on clean technologies, Massachusetts could emerge as an international magnet for the innovation and adoption of technologies that generate jobs and attract funding as well as restore our health and environment. With input from the Clean Tech Advisory Committee and roundtable discussions, this initial report identifies five areas where Massachusetts already has leadership, and increased leadership potential.

### SAFER ALTERNATIVES
The design of products and processes that use or create less toxic substances.

### GREEN BUILDINGS
Encompassing products and services that reduce the health and environmental impacts of constructing, renovating, and operating building structures.

### EMERGING MATERIALS
Biobased and nanomaterials that have the potential to yield tremendous environmental benefits through energy and materials use reduction.

### CLEAN ENERGY
The use of cleaner sources and generation methods of energy production that create less pollution—from mining through generation.

### MATERIALS REUSE
Returning products and materials back into the economic mainstream through reuse, remanu-facturing, and recycling.

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