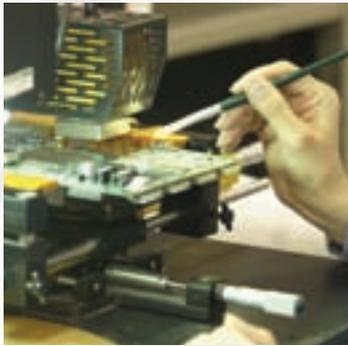


CLEAN TECH

An Agenda for a Healthy Economy



**How Massachusetts can be the center of
clean technology innovations that serve the world**

December 2007
Clean Tech Initial Report



**Lowell Center for
Sustainable Production**



**University of
Massachusetts
UMASS Lowell**

OPPORTUNITY ABOUNDS IN MASSACHUSETTS

Last December, when I was a member of Congress, I hosted a town hall meeting at UMass Lowell on solutions to global warming. It was just a week before the holidays, yet more than 1,000 people waited in line outside Durgin Hall.

This is a telling message. Members of the public are deeply concerned about their health, their environment and the legacy they're leaving to their children. People have told me that they want safer and more efficient products, along with a strong economy that generates well-paid, skilled jobs.

That is why I am pleased to present UMass Lowell's "Clean Tech" project report that takes on all of these issues. Massachusetts has the talent, the technology and the passion to foster development in clean technologies and emerge as a worldwide leader in shaping a new, truly sustainable economy.

The great news is that Massachusetts already has strengths in many clean technology areas. What this project sets out to do—define an agenda for a Clean Tech economy for Massachusetts—will help us unify our strategy to harness the opportunity before us.

The Clean Tech project brings together a diverse group—higher education, business, government, unions and advocacy groups—to generate ideas. I am proud of the role that UMass Lowell has played in coordinating this effort. I am committed to the University also educating a new generation of leaders in environmentally sustainable technologies and economic development. By building bridges with companies and communities, we are able to turn university research into real-world solutions.

I congratulate and thank all of the project participants who have defined practical steps toward a more sustainable world – one that's good for the environment, our economy and the next generation.

Sincerely,



Marty Meehan

Chancellor, University of Massachusetts Lowell



TABLE OF CONTENTS

- 4 Executive Summary**
- 7 The Clean Tech Opportunity**
- 9 Massachusetts Strengths**
- 14 10 Ways to Support a Clean Tech Economy**
- 16 Building on 5 Areas of Leadership**
 - 16 Safer Alternatives**
 - 18 Green Buildings**
 - 21 Emerging Materials**
 - 24 Clean Energy**
 - 26 Materials Reuse**
- 28 A Vision for a New Economy**
- 30 Endnotes**
- 31 Acknowledgements**



EXECUTIVE SUMMARY

Massachusetts can be a leader in the global shift to a clean tech economy. While clean technology activity is robust in many parts of the world, the only country that has developed an overall plan to reorient its economy and economic competitiveness towards clean technologies is Germany. No U.S. state to date has developed a similar plan. But Massachusetts has the strengths and leadership to be the first in the nation based on initial findings of *Clean Tech: An Agenda for a Healthy Economy*, a project spearheaded by the Lowell Center for Sustainable Production at the University of Massachusetts Lowell.

The purpose of the Clean Tech project is 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. The ultimate goal is to create an identity for Massachusetts that makes it an international magnet for the innovation and adoption of technologies that minimize harms and help restore our health and our environment.

This initial report reflects input from the project's diverse Advisory Committee, listed on page 31, as well as from five roundtable discussions that brought together representatives from business, labor, the investment community, public health, environment, and academia. It also incorporates information from interviews and reports that have already been prepared on the Massachusetts economy and clean technologies.

The intent of providing this initial information now is to ramp up the statewide dialogue with policymakers, businesses, community representatives, and other stakeholders on the Clean Tech vision and opportunities.



5 AREAS OF LEADERSHIP

There are any number of technologies that can be considered “clean”: renewable energy generation, energy efficiency, water conservation and purification, emissions controls, toxics and pesticide reduction, and more. While Massachusetts has activity in virtually all these areas, the Clean Tech Project identified five areas where Massachusetts already has significant strengths and leadership potential:



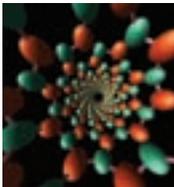
Safer Alternatives

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



Green Buildings

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 fuel extraction to energy generation.



Materials Reuse

Returning products and materials back into the economic mainstream through reuse, remanufacturing, and recycling.

Recommendations for building on existing strengths in these areas start on page 16.



10 WAYS TO SUPPORT A CLEAN TECH ECONOMY

Through research and stakeholder interviews, 10 recommendations emerged for how Massachusetts policymakers can support a strong economy based on clean technologies.

- 1. Create a clear vision and goals**
- 2. Send a strong signal to the marketplace**
- 3. Stimulate collaboration**
- 4. Create a State Office of Clean Technology**
- 5. Develop a trained workforce**
- 6. Create a Massachusetts Clean Tech “brand” or identity**
- 7. Regulate, procure, and invest**
- 8. Don’t be afraid to take risks**
- 9. Promote all clean technologies in the state**
- 10. Encourage cross-fertilization of technologies**

These recommendations are described in more detail on page 14. The Advisory Committee for the Clean Tech project will continue working together to further define the opportunities, understand business needs, and identify clear recommendations for policymakers.

For more information or to get involved with the Clean Tech project, please contact Cathy Crumbley, Program Director of the Lowell Center for Sustainable Production at the University of Massachusetts Lowell, Cathy_Crumbley@uml.edu, 978-934-2980.

The **CLEAN** TECH *Opportunity*

Massachusetts is known throughout the world as a center of innovation in high tech, life sciences, and information technology. Now Massachusetts has a unique opportunity to also become a hub of activity in developing a new generation of clean technologies—products, services, and processes that greatly reduce or eliminate environmental impacts throughout a product’s lifecycle, including mining, manufacturing, product use, and disposal. These clean technologies can serve the world and, in so doing, improve our quality of life, the health of the planet, and our economy.

The current way of doing business has led to climate change, resource depletion, habitat destruction, and increasing rates of cancer and other diseases. Growing recognition of these consequences by health professionals, researchers, investors, entrepreneurs, workers, retailers, policy makers, and consumers is creating an opportunity to change current patterns of business and chart a new course.



An estimated \$208 billion market exists in the U.S. for goods and services focused on health, the environment, social justice, personal development, and sustainable living.¹ In the past year, almost half of the population purchased “environmentally friendly” products.²

Clean Tech activity is robust in many parts of the world. The European Union has created policies to significantly reduce the use of toxic chemicals and emissions of greenhouse gases; Japan is leading in the commercialization of hybrid auto technologies; and U.S. states are creating policies to support individual technologies such as biobased materials, materials recycling, green chemistry, and renewable energy. Germany is the only country that has developed a comprehensive plan to reorient its economy and economic competitiveness towards clean technologies. But no state in the U.S. has yet developed a similar comprehensive strategy.

Our richness of researchers, investors, educated public and workers, core technologies, and entrepreneurs, combined with the increasing awareness of environmental issues, provide Massachusetts a tremendous and timely opportunity to invest in our clean technology infrastructure.



THE GERMAN MODEL

The German Government has developed a strategy to reorient Germany's economic competitiveness around clean technologies. The effort is currently a major priority for the German government at all levels. They believe that their efforts to advance Clean Tech will be much more successful when there is an understanding and commitment to Clean Tech in the United States. Through its Ministry of Environment, the German Government has already built a partnership with the University of Massachusetts Lowell in green chemistry.

They would like to build on this relationship to develop a high-level transatlantic collaboration with Massachusetts that supports the jobs, innovation, and environment agenda.

Massachusetts **STRENGTHS**

Massachusetts has important and well-recognized strengths that make it poised to be a leader in the innovation (research, patents, and licenses) and/or adoption (manufacture or use) of cleaner products, services, and technologies:

A STRONG MANUFACTURING BASE

The Massachusetts manufacturing base is a specialized and educated one, with skills and strengths in precision machining and control of complex processes,³ as well as in making products requiring software-hardware integration and close collaboration with research and development. While manufacturing jobs have been decreasing in the state and the country, manufacturing still accounts for close to \$80 billion, or over one quarter, of the Massachusetts economy.⁴ Manufacturing is a continual source of productivity growth in the state's economy.

A HISTORY OF TOXICS USE REDUCTION

Massachusetts manufacturers know how to make their products while minimizing the use of toxic substances. Through its Toxic Use Reduction Act, Massachusetts has been leading in promoting the use of less toxic materials in products and services. The state's Office of Technical Assistance and University of Massachusetts Lowell's Toxics Use Reduction Institute have been working with industries as diverse as plastics, wire and cable, textiles, electronics, and printing to profitably substitute their use of toxins such as lead and chlorinated solvents with safer alternatives.

A STRONG INNOVATION ECONOMY

Massachusetts, with its concentration of leading colleges and universities, and the entrepreneurs they have fostered, has a strong history of technological innovation. Universities fuel research that turns into new business ventures, and companies locate here to take advantage of our



knowledge base and highly trained workforce. The economy is adept at attracting research funds, in patenting and licensing activity, in venture capital funding, and in incorporating new business.⁵ The technologies and expertise developed in Massachusetts are diffused around the world.

STRONG CORE TECHNOLOGIES

The long history of manufacturing in Massachusetts has created a base of knowledge about complex product systems and an ability to respond to market shifts. In addition to the companies working directly in clean technologies, there are many more with the capability to move into this area. Massachusetts has the technological base that can be reconfigured to a Clean Tech market.⁶

KEY INDUSTRY CLUSTERS

Most, if not all, of the ten industry clusters key to the Massachusetts economy⁷ are also key to Clean Tech industries, or can benefit from them: green buildings need instrumentation as well as communications hardware and software to enhance performance; the pharmaceutical industry is moving towards using green chemistry methods to make their medicines; scientific and technical services, business services and financial services underpin any new industry; the defense industry needs mobile sources of energy and less energy-demanding equipment; and post-secondary education is key to creating a workforce that can help us compete in a global economy. Innovations in clean technology can create growth opportunities in all ten industry clusters.





STRONG EXPORT TIES

Massachusetts' geographic proximity to Europe provides a unique opportunity to promote its clean technologies to a receptive market. Many countries in Europe have recognized both the need and opportunity for clean technologies and have been moving forward with extensive regulatory reforms to reduce the use of toxic materials in their countries, require producers to take back products at the end of their life, and develop cleaner and more efficient sources of energy. In 2005, Massachusetts' exports topped over \$22 billion. Countries in Europe and Asia accounted for 5 of the top 6 export markets for Massachusetts, with more than 42% of Massachusetts exports going to Europe—higher than any other state as a percentage of total imports.⁸

STRONG INSTITUTIONAL SUPPORT FOR ENVIRONMENTAL TECHNOLOGIES AND BEHAVIORS

Organizations such as the Toxics Use Reduction Institute, the Massachusetts Office of Technical Assistance, the Massachusetts Renewable Energy Trust, and non-governmental entities such as the Green Roundtable all work to support the development of cleaner products, processes, and environmental services. The Massachusetts Office of Business Development has successfully worked to expand renewable energy related business activity. The John Adams Innovation Institute, the Massachusetts Technology Transfer Center, the Massachusetts Manufacturing Partnership, MIT Enterprise Forum, and others help spur innovation and commercialization of platform technologies and specialized products throughout Massachusetts businesses.



A STRONG TRACK RECORD IN ATTRACTING PUBLIC AND PRIVATE INVESTMENT

As noted, Massachusetts is adept at attracting research funds, in patenting activity, in venture capital funding, and in new business incorporations.⁹ Its strong track record in attracting private and public funds can be built on to attract investments in Clean Tech. In fact, it already has, with the awarding of a high-profile grant for a wind-blade testing facility from the Department of Energy, and a five-year grant from the National Science Foundation for a three-campus center for high-rate nanomanufacturing. And, according to the Clean Tech Venture Network, Massachusetts placed second, behind Silicon Valley, in attracting Clean Tech venture investment in 2006.¹⁰

A SUPPORTIVE REGULATORY ENVIRONMENT

The state has been working to create a regulatory environment that promotes the development and utilization of clean technologies. The “systems benefit charge” from utility restructuring helps fund the adoption of renewable energy through grants from the Renewable Energy Trust; the Toxics Use Reduction Act encourages and facilitates the development of alternatives to toxic substances, helping companies reduce their use of toxics by over 40% since the Act’s inception in 1989; proactive environmentally preferable purchasing policies have created a market for safer products; and the Regional Greenhouse Gas Initiative will encourage less polluting energy generation and major reductions in carbon dioxide emissions.

STRONG PUBLIC AWARENESS OF ISSUES

Industry leaders have reported that the high awareness of Massachusetts consumers about environmental issues creates a positive environment for their businesses and products.¹¹

HIGH QUALITY COLLEGE AND UNIVERSITY RESEARCH

Researchers from internationally recognized institutions of higher education such as MIT, the University of Massachusetts, Northeastern University, Boston University, Harvard University, Worcester Polytechnic Institute, and others have been developing breakthroughs in energy generation and storage, materials reuse, biodegradable polymers, green buildings, advanced materials, and green chemistry. These innovations have led to patents, licenses, and new businesses. Many of these research institutions work closely with the business community to develop innovations that can be easily commercialized and adopted in Massachusetts industry and diffused around the world.



A WELL-EDUCATED WORKFORCE

Massachusetts has a well-educated workforce in both blue and white collar jobs. In 2005, more than two out of every five workers had earned at least a bachelor's degree.¹² In addition, it is a workforce that is educated about environmental issues and opportunities. Labor unions have shown a strong interest in clean technologies as evidenced by their participation in non-profit organizations that support renewable energy and safer alternatives to toxic chemicals, such as the Alliance for a Healthy Tomorrow and the Apollo Alliance. Sheet metal and electrical workers unions in the state have instituted training programs for apprentices in solar and wind energy. And, the International Brotherhood of Electrical Workers has built a windmill at their offices in Boston, which is highly visible from Route 93.

A STRONG ADVOCACY COMMUNITY

Massachusetts has strong and forward-looking environmental and health organizations—Clean Water Action, Massachusetts Public Health Association, Environment Massachusetts, and others—that are educating the public and advocating for policies to support safer technologies.

10 WAYS

to Support a Clean Tech Economy

What role can Massachusetts play in building a strong economy that treads more lightly on the environment? Ten overarching, consistent themes have emerged from discussions with the Clean Tech Advisory Committee and five sector-specific roundtables.

1. **CREATE A CLEAR VISION AND GOALS:** Government should not pick and choose technology winners and losers. By articulating a clear vision, performance standards, and desired environmental and public health outcomes, it can set the parameters under which companies in the marketplace can develop new technologies. Massachusetts can take a national leadership role in creating these visions and goals, and guiding the research and development of cleaner technologies.
2. **SEND A STRONG SIGNAL TO THE MARKETPLACE:** Through efforts described below as well as through the “bully pulpit,” the state can show that it will provide long-term support for clean technologies, and is committed to creating competitive conditions for their development and implementation.
3. **STIMULATE COLLABORATION:** The state should help foster a culture of collaboration which does not now exist, by encouraging cross-fertilization, defining environmental and health priorities, linking people with resources, and creating 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 a model for future efforts, involving the full range of stakeholders.
4. **CREATE A STATE OFFICE OF CLEAN TECHNOLOGY:** The work of two former state programs—the Chelsea Center for Recycling and Economic Development and the Strategic Envirotechnology Partnership (STEP)—were cited as examples of how Massachusetts had helped support Clean Tech businesses and research through product testing, partnership building, new materials development, demonstration projects, opening new markets in and out of state, and more. This type of support should be resurrected in some form, and incorporate the state’s successful toxics use reduction research, training, networking, and demonstration activities.
5. **DEVELOP A TRAINED WORKFORCE:** Bring together business leaders and academia to identify technical and non-technical, entry-level through management workforce needs and how to fill them—from training teachers to educating kindergarten through post-graduate students and continuing professional education.

6. **CREATE A MASSACHUSETTS CLEAN TECH “BRAND” OR IDENTITY:**
A strong Clean Tech identity can help draw in investment, research, and business activity, and encourage Massachusetts businesses and residents to buy locally produced products. A Massachusetts Clean Tech web site that posts state research, patents, funding, resources, products, etc., would help create this identity, develop markets, and foster partnerships.
7. **REGULATE, PROCURE, AND INVEST:** These actions can help give entrepreneurs the confidence to innovate and spur change. However, any policies or specifications should encourage continuous improvement, not a static solution.
8. **DON'T BE AFRAID TO TAKE RISKS WITH PUBLIC FUNDS:** Even if a project fails, there is still something to learn. Being less cautious could yield exciting breakthroughs.
9. **PROMOTE ALL CLEAN TECHNOLOGIES IN THE STATE:** Government leaders should speak out and promote all clean technologies in the state. While clean energy is a major focus of the state, Massachusetts has the potential to emerge as a Clean Tech powerhouse by broadening our view to also include safer alternatives, green building, emerging materials, and materials reuse.
10. **ENCOURAGE CROSS-FERTILIZATION OF TECHNOLOGIES:** Each of the clean technology areas identified can be adopted to varying degrees by each other, as well as by “conventional” industries. Through information sharing, demonstration projects, and other means, help Massachusetts businesses not only make cleaner products, but also adopt other clean ways of doing business.

“Many of us practicing in the Cleaner Technology field have been working to develop lead-free soldering for electronics since the early 1990s. After more than a decade, we seemed little closer than when we started. Then, the European Union RoHS [Reduction of Hazardous Substances] Directive was passed and in less than three years, we have lead-free electronics. While our preceding efforts allowed us to meet the RoHS Directive’s deadlines successfully, it’s hard to discount the role that the regulatory requirement played in finally bringing lead-free products to market.”

— **Raymond Lizotte**, Product Environmental Compliance Engineer,
American Power Conversion Corporation, North Billerica, MA.

Building on **5 AREAS** OF LEADERSHIP

Within each area—safer alternatives, green buildings, emerging materials, clean energy, and materials reuse—the Clean Tech project identified specific opportunities to build on Massachusetts’ leadership.

SAFER ALTERNATIVES

Historically, products and processes have been designed with little regard to toxic constituents and their impacts. The fields of Green Chemistry and Green Engineering provide an approach for scientists and engineers to use when designing new materials, products, processes, and systems. The 12 Principles of Green Chemistry and of Green Engineering are frameworks that incorporate consideration of human health and the environment into design, yielding creative, innovative, safer alternatives with increased performance, value, and benefits.¹³

Massachusetts is home to world-renowned experts in the policy and science of replacing toxic substances with safer alternatives. Massachusetts researchers have been tapped for national and international advisory boards, as well as advisors to other states, in setting up or overseeing their toxics reduction and green chemistry initiatives. The University of Massachusetts hosts the only Green Chemistry PhD program in the U.S. Hundreds of companies, including two key industries—wire and cable and electronics—in addition to local governments and community groups, have been helped by the 1989 Massachusetts Toxics Use Reduction Program. They have identified cost-effective ways to eliminate millions of tons of dangerous chemicals, while also improving the environmental quality of the state and the competitiveness of firms.

The Lowell Center for Sustainable Production at UMass Lowell has brought together both large and small forward-acting companies throughout the country to form the Green Chemistry and Commerce Council (GC3). The GC3 works to identify and overcome barriers to implementing green chemistry and design for the environment, including identifying safer alternatives, and supporting federal policies and funding.

A weakness is the lack of technicians and mid-level chemists and engineers to fill demands from companies for workers knowledgeable in green chemistry and implementation of safer alternatives. In addition, while research is happening here, the commercialization and adoption of safer alternative breakthroughs may not be staying in the state.



Opportunities to make Massachusetts a leader in safer alternatives include:

- Educating the public sector, entrepreneurs, and institutions about safer alternatives and why they are important.
- Developing specifications and regulations to help spur research, procurement, innovation, and technology adoption. European laws are critical drivers right now.
- Creating a program to help underwrite the costs of testing that will help companies bring their products to market. Testing may include validation of company claims and obtaining third party certifications.
- Assisting companies in identifying safer alternatives for their needs, as well as the costs and benefits of those alternatives.
- Expanding the state's successful toxic use reduction model to other chemicals and businesses as well as consumer product uses.

**NEW GREEN CHEMISTRY INSTITUTE SPURS INDUSTRIES TODAY,
WORKFORCE FOR THE FUTURE**

THE WARNER BABCOCK INSTITUTE FOR GREEN CHEMISTRY, a unique, new, private laboratory research organization based in Woburn partners with industry to co-develop green chemistry solutions, as well as to perform independent research, development and patent creation. **BEYOND BENIGN** is an affiliated foundation that develops curricula locally, nationally and internationally, working with K-12, colleges, communities, and industry to train a future workforce skilled in the principles of green chemistry. Both organizations are founded by Dr. John Warner, who is also one of the founding leaders of the field of green chemistry.



GREEN BUILDING

Buildings are a major contributor to greenhouse gas generation, waste, and other environmental and health problems. The U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ is the nationally accepted benchmark for the design, construction, and operation of high-performance green buildings. LEED promotes a whole-building approach and focuses on building performance in five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.

More than one third of the total energy consumed in the U.S. is used in the building sector, and the high cost of energy in the state is just one driver of green building activity here.

Massachusetts has a high concentration of architects, designers, engineers, and builders promoting all aspects of green building. Boston's U.S. Green Building Council (USGBC) affiliate, the Green Roundtable, has over 3,000 members, and a new affiliate is forming in the Berkshires. There are 45 projects in Massachusetts that have received some level of LEED certification from the USGBC, and over 200 have been registered (not all projects that meet LEED standards are registered with the USGBC).





WHY MASSACHUSETTS? *Healthy, Hip, Affordable Green Homes*

“Massachusetts’ innovation-driven business climate, high concentration of architects and designers that understand environmental issues, existing policies to support renewable energy, and wealth of resources in renewable energy, energy efficiency, environmental health, and green building materials, made it a logical place to conceive of and start our business.”

— **Quincy Vale**, *Founder and President, PowerHouse Enterprises, Lawrence, MA*

POWERHOUSE ENTERPRISES works with developers, builders, and homeowners to create homes that are healthier, less polluting, and less expensive to own and operate than conventional construction. The PowerHouse process combines advanced factory construction techniques with site-responsive and neighborhood appropriate solar designs. PowerHouse homes use sustainably harvested natural building materials, low VOC paints and adhesives, and formaldehyde-free insulation. They are energy and water efficient, create less waste in construction, and can be designed with additional environmental features such as reused building materials and green roofs. Homes created through the PowerHouse process are routinely capable of certification at the highest levels of LEED.

Massachusetts’ educational institutions and private companies are leaders in both innovation and adoption of green building practices and materials. MIT’s Building Technology Program is an interdisciplinary program jointly sponsored by the Departments of Architecture, Civil and Environmental Engineering, and Mechanical Engineering, to look at opportunities for innovation in materials, manufacturing, and other areas for more efficient operation of existing and new buildings. Massachusetts companies also have established expertise in controls and software that can be applied to help reduce the environmental impacts of buildings. Over the past decade, a significant fraction of the state’s building contractors have become knowledgeable about green building technology and its benefits.

The Massachusetts State Building Code and Residential and Commercial and Energy Codes are not strong enough in certain aspects of green design and construction. As a result, some municipalities, such as Boston, are revising their zoning codes to require buildings to meet or exceed LEED standards. Unfortunately, the rapid advance in green building technology and materials has not always been matched by updated building regulations—environmental, safety, historic preservation—which often conflict when it comes to green building interests.



Massachusetts has the opportunity to lead in green building practices and technology by:

- Sponsoring research and development on costs, benefits, and actual vs. perceived risks of new practices and products to spur new product innovation.
- Encouraging the development of systems controls, software, and monitoring technologies for energy conservation and indoor air quality.
- Creating and marketing a “brand” for Massachusetts sustainably harvested wood and other Massachusetts manufactured green building products.
- Creating additional financial incentives to encourage green building investment and the broad adoption of green building practices and products, such as a carbon tax, differential insurance rates, and property tax rebates or reductions.
- Developing a training and certification program for green building contractors.
- Developing ways to affordably retrofit older, existing building stock, such as that found in Massachusetts.

EMERGING MATERIALS

Two types of materials are emerging that have the potential to yield tremendous environmental benefits. Biobased materials from plants can be turned into plastics that can reduce our demand for fossil fuels, and can return nutrients back to the earth through composting rather than being landfilled. Nanotechnology—manipulating matter at the molecular level at sizes approaching one billionth of a meter—provides opportunities for advances in manufacturing, materials science, and curing diseases. However, while the potential exists for tremendous environmental benefits from these materials, there is also the potential for risk if environmental health and safety are not taken into consideration early in the development process.

UMass Lowell's Biodegradable Polymer Research Center is leveraging the research capacity of university researchers, government laboratories, and global companies such as 3M, Dow, Monsanto, BASF and others to lead in the development of the next generation of biodegradable polymers, such as polylactic acid (PLA) and polyhydroxyalkanoate (PHA). Both PLA and PHA are biodegradable materials made from plants that are being used to replace fossil-fuel based, non-biodegradable plastics in many applications. Biobased plastics can be made from a range of plant sources—those planted specifically to be turned into plastics, as well as those that are otherwise unusable. For example, the state of Maine is researching turning unusable potatoes from their harvests into plastics. The Massachusetts research company, Metabolix, has been a leader in developing PHA plastics. In 2006, Metabolix formed Telles™, a 50-50 joint venture with Archer Daniels Midland (ADM), to commercialize the production of Mirel™ natural plastics. In addition to plastics, the Biomufacturing Center at UMass Lowell has been working on ways to create new fuels, pharmaceuticals, and other products using biological processes. Nonetheless, there are social as well as environmental issues—for example competing land

CREATING A CLEAR VISION AND GOAL: *Sustainable Biobased Materials*

The Lowell Center for Sustainable Production at the University of Massachusetts is a member of the steering committee of the **SUSTAINABLE BIOMATERIAL COLLABORATIVE**, a coalition of environmental NGOs, businesses, and academics working together to define criteria for sustainable biobased plastics—from the growth of the plant material to its transformation into a product to what happens to that product after its intended use. This definition will provide a framework in which researchers and entrepreneurs can innovate to create feedstocks, processes, and products that are widely agreed to be better for the environment, and will give them confidence that there will be a market for these materials.

demands for food or open space, and genetic manipulation of some plants used to make plastics—that should be identified and solved before these technologies develop.

According to the National Science Foundation (NSF), by 2015 the global market for products with key components based on nanotechnology is estimated to reach \$1 trillion, generating more than two million jobs.¹⁴ The most recent report on micro- and nanotechnology from SmallTimes magazine shows Massachusetts ranked in the top three states in the nation in each of its four categories: venture capital, industry, research, and innovation. A May 2007 study by the Project on Emerging Technologies of the Woodrow Wilson International Center for Scholars found that two of the top five “nano metros” in the U.S.—defined by the density and volume of universities, businesses and other organizations involved in nanotechnology—are in Massachusetts: one clustered in Boston and the other in the Middlesex-Essex Counties and MetroWest region. The other three are in California.¹⁵ Industries important to the Commonwealth that can benefit from nanotechnology include medical devices, pharmaceuticals, biomedical applications, electronics, polymers, and materials.¹⁶

Massachusetts has been adept at attracting venture and federal funding for its nanotechnology work. It ranked second after California in attracting venture funding (over \$8 billion) in 2005, twice as much as third-ranked Texas.¹⁷ And Massachusetts receives billions of dollars in funding from the National Science Foundation, Department of Defense, and National Institutes of Health. Federally funded centers exist at Northeastern University, UMass Lowell and Amherst, Boston University, Harvard University, and MIT to research manufacturing techniques, nanomaterials in devices, polymers, societal impacts of nanotechnologies, cancer treatment, and to develop educational materials.

Private companies working with nanotechnologies have varying degrees of awareness that there may be unintentional environmental and health consequences of their use, but many, especially small and medium sized companies, do not have enough information on what impacts there might be and how to control them.¹⁸

Opportunities for Massachusetts to lead in clean, emerging bio- and nanomaterial technologies include:

- Lead the national discussion and definition of what is “clean” or “cleaner” in these processes and materials, identifying areas for safer materials development, and creating appropriate incentives for their development and use.



- Fund research into identifying environmental and health benefits, hazards, and risks of emerging materials throughout their life cycles and in different environments.
- Develop guidance on how to adopt advanced materials—how and where using them would make a product cleaner, and what should be considered when comparing materials.
- Provide guidelines and training to researchers and businesses on the environmental health and safety risks and how to manage them.
- Continue research and adoption on manufacturing these materials in a more environmentally benign way.
- Develop ordinances, such as those being considered by the City of Cambridge, that give companies and researchers clear guidelines on how to manage nanoparticles and help allay public concerns that may discourage companies from locating in the state.
- Support the development of technologies to monitoring the impacts—intended and unintended—of adoption of nano- and biobased materials.
- Promote collaboration with related sectors to find new applications—energy, green chemistry, green buildings etc.

CLEAN ENERGY

Renewable and plentiful energy sources (wind, solar, microbes, biomass, and hydrogen), conservation, energy storage, and monitoring and control devices can help reduce energy use and ensure that the energy that is created and used reduces greenhouse gasses, other forms of pollution, and mining impacts. The clean energy sector in Massachusetts employs an estimated 14,400 people, making it close to becoming one of the State's top-ten industries, and has experienced a 26% annual growth rate. Massachusetts is home to at least 566 clean energy companies working in renewable energy, energy efficiency/demand response, consulting and support, and university centers researching a range of energy generation, storage, and monitoring technologies. Industry executives project an annual job growth rate of 20 percent.

- Massachusetts is an incubator for clean energy start-ups, with 116 companies founded since 2001. Nearly half of clean energy companies have less than five employees; 68 percent of firms have less than \$10 million in annual revenues, 41 percent below \$1 million.
- Energy efficiency and demand response companies are currently the largest employers, with 6,300 jobs, or 44 percent of total employment in the sector.
- Renewable energy companies are the youngest and fastest growing firms, with executives projecting 30 percent job growth in the coming year.
- In both companies and jobs, the clean energy sector has significant presence in several areas of the state, inside Interstate 495 but also in the Pioneer Valley and the Berkshires.¹⁹

KONARKA TECHNOLOGIES, LOWELL, MA: *Using Nanomaterials to Generate Energy From the Sun*

Konarka develops and builds light-activated power plastic that converts light to energy. This technology allows devices to generate their own electricity anywhere, without connecting to a distant energy source. The "power plastic" material is made from conducting polymers and nano-engineered materials that can be coated or printed onto a surface similar to the way photographic film is made. It is inexpensive, lightweight, and flexible and can make low-cost sources of renewable power affordable and universally available all over the world.





Massachusetts has been taking action to support its clean energy industry through joining the Regional Greenhouse Gas Initiative, expanding the Secretariat of Environmental Affairs to include energy, passing the “Leading by Example—Clean Energy and Efficient Buildings” Executive Order that sets goals for energy efficiency and renewable energy use by state agencies, and exploring policies to provide incentives for utilities to promote energy efficiency. In addition, the state helped Evergreen Solar locate its first solar panel manufacturing plant in the U.S. here in Massachusetts, and coordinated a winning application for a major U.S. Department of Energy wind blade testing facility to be located in Charlestown.

Massachusetts can become even more of a leader in Clean Energy by:

- Helping early stage companies test and adopt their technologies locally to better prepare them to be global players.
- Updating the state’s Renewable Portfolio Standards to require a higher fraction of the state’s electricity generation to come from renewable sources.
- Cultivating a culture of experimentation by encouraging more university investment in research.
- Expanding well-planned public transportation opportunities.
- Expanding the John Adams Innovation Institute.
- Using more peer review to choose state-funded projects.
- Developing collaborations with other states, such as the Regional Greenhouse Gas Initiative, RGGI.

MATERIALS REUSE

The products that we use in our every day lives at some point started as natural resources—trees, minerals, petroleum. Many of these resources are dwindling, require large amounts of energy and/or water to extract, and cause varying degrees of environmental impacts to mine, turn into new products, and transport and distribute. They create further environmental impacts at the end of their life when they are disposed. Treating these products and materials as resources, rather than waste, creates opportunities through reuse, remanufacture, or recycling. This reaps a range of benefits including avoided mining impacts, less energy used in transportation and manufacturing, reduced use of water, fewer toxic emissions, and, in many cases, enhanced product and materials properties.

Sorting and processing recyclables provides 10 times more jobs than if the same materials were thrown away. More than 3 percent of the Massachusetts workforce works in recycling-related fields. Recycling employs as many people in Massachusetts as child care services, the accounting and bookkeeping sector, or the electric utilities industry. Employment in the Massachusetts recycling industry ranks higher per capita than California, New York, and Florida.²⁰

Massachusetts manufacturers already turn about 4 million tons of textiles, plastics, tires, paper, glass, organic materials, and other materials into high-value products, products used for civil engineering purposes in highways and construction, building materials, works of art, packaging, and more.²¹ With its goal to reduce 70% of all solid waste generated in the state, Massachusetts will need to find a home for close to 9 million tons of recyclable materials in the coming years.

A HISTORY AND FUTURE FOR MATERIALS REUSE

The Newark Group, with facilities in New England since 1917, is an integrated global producer of 100% recycled paperboard and paperboard products. They are the largest open-market sellers of recycled paperboard in North America. They collect and sort recycled paper, as well as convert it into new products. Their paperboard mills produce over 2.5 million tons of 100% recycled paperboard annually, more than 5% of all paper collected for recycling in the US. They have four facilities in Massachusetts—Haverhill, Fitchburg, Webster, and Salem. Two of these facilities manufacture paperboard, and two sort paper to supply these and their nine other paper mills.

Roxbury Technology Corporation is a \$11.5 million African American woman-owned business founded in Roxbury in 1994. Roxbury Technology takes empty toner cartridges from printer and fax machines, inspects them, and refills them so that they can be reused rather than discarded. Roxbury Technology was recognized by *Inc. Magazine* as one of the fastest growing inner-city companies in the country.



Massachusetts colleges and universities host a range of materials reuse research and patent activity in plastics, tires, textiles, electronics, remanufacturing, civil engineering, industrial by-products, and organics.

Competition from cheaper Chinese products claiming to contain recycled content, poor enforcement of bans on recyclable materials at state disposal facilities, and the diversion of unredeemed bottle deposits from support of recycling activities have limited the growth of materials reuse activity in the state.

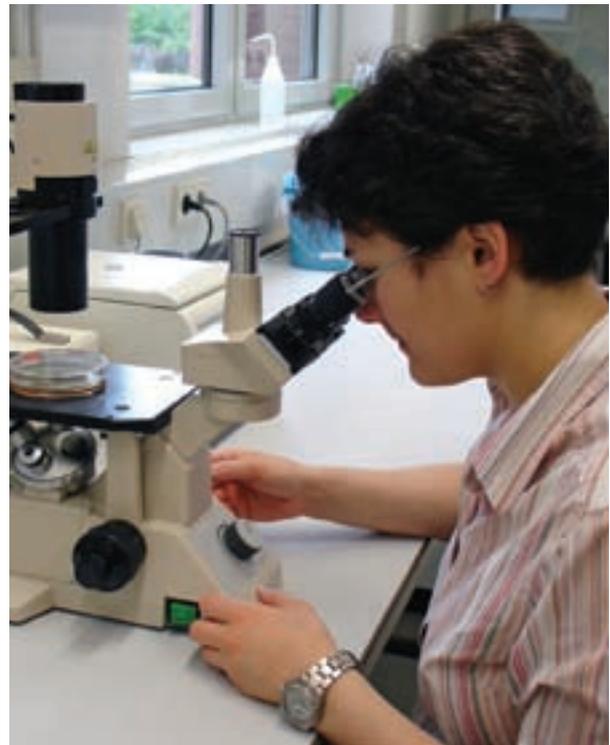
Opportunities for Massachusetts to lead in Materials Reuse:

- Support research into new uses for old tires, textiles, plastics (engineering grades and low grades), glass, and other high-volume materials.
- Assist the State’s plastics industry in identifying opportunities to use recycled feedstocks and overcoming any technical barriers.
- Increase diversion of paper from the waste stream. An estimated 1.5 million tons of paper,²² with a value of more than \$100 million,²³ is thrown away each year by Massachusetts residents and businesses. This can instead be profitably used in Massachusetts paper mills.
- Set standards and require certification of recycled content for products purchased by the state under its Environmentally Preferable Products (EPP) program.
- Assist recycled product manufacturers in buying more energy-efficient equipment through investment tax credits or other methods.

A Vision for **A NEW** ECONOMY

A Clean Technology 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;
- Federal dollars and private investments come in to 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 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.

Clean Tech: An Agenda for a Healthy Economy will continue over the next months to further define the Clean Tech sector in the state and its unique strengths, gain an understanding of the market potential and business needs to support growth and innovation in key Clean Tech industries, and identify opportunities and tools for growth, such as policies, partnerships, investments, research, business support, and education initiatives. The outcome will be an Agenda for an economy where cleaner technology research, manufacturing, and services can thrive.



ENDNOTES

- 1 Lifestyles of Health and Sustainability (LOHAS), <http://www.lohas.com/about.htm>
- 2 2007 Cone Consumer Environmental Survey, <http://www.coneinc.com/content69.html>
- 3 “Choosing to Lead: The Race for National R&D Leadership and New Economy Jobs,” Battelle and Mass Insight, 2004
- 4 Jack Healy, Director, Massachusetts Manufacturing Advancement Center
- 5 John Adams Innovation Institute, *10 Year Index of the Massachusetts Innovation Economy*, 2006
- 6 Michael Best, Co-Director, Center for Industrial Competitiveness, UMASS Lowell
- 7 John Adams Innovation Institute, *10 Year Index of the Massachusetts Innovation Economy*, 2006
Key industries: computer and communications hardware, defense manufacturing & instrumentation, healthcare technology, scientific, technical and management services, software and communications services, post-secondary education, diversified industrial support, financial services, business services, and textiles and apparel.
- 8 Massachusetts Alliance for International Business (MAIB)
- 9 John Adams Innovation Institute, *Index of the Massachusetts Innovation Economy*, 2006
- 10 *The Economist*, May 24, 2007, “Venture Capitals”
- 11 Clean Tech project roundtable discussions and business interviews, summer, 2007
- 12 Massachusetts Budget and Policy Center, “State of Working Massachusetts,” 2006
- 13 American Chemical Society’s Green Chemistry Institute, <http://www.chemistry.org/portal/a/c/s/1/acdisplay.html?DOC=greenchemistryinstitute/index.html>
- 14 Mihail C. Roco, “National Nanotechnology Initiative: Overview,” in ASME Workshop (2004)
- 15 David M. Smith and Christopher J. Bosso, *Realizing the Potential of the Massachusetts Nanotechnology Sector: Recommendations for the Commonwealth*, Northeastern University, August 2007
- 16 *Ibid*
- 17 *Ibid*
- 18 John E. Lindberg and Margaret M. Quinn, “A Survey of EHS Risk Information Needs and Practices Among Nanotechnology Firms in the Massachusetts Region,” Woodrow Wilson Center for Scholars, Lowell Center for Sustainable Production, to be published December 2007.
- 19 *Massachusetts Clean Energy Industry Census August 2007*, Massachusetts Technology Collaborative Renewable Energy Trust, Prepared by Global Insight Inc.
- 20 Massachusetts Department of Environmental Protection, *Fact Sheet: The Massachusetts Recycling Economy*, July 2004
- 21 Chelsea Center for Recycling and Economic Development, *Recycled Product Manufacturers Survey*, 1999
- 22 Tellus Institute, *Waste Reduction Program Assessment and Analysis for Massachusetts*, December 2002.
- 23 “It’s Time to Be Proactive: Let’s Use Our Regional Strengths,” presentation by Pete Grogan, Weyerhaeuser, NERC Fall Conference, October 27, 2004.

ACKNOWLEDGEMENTS

Thank you to the following members of the Clean Tech Advisory Committee for providing insightful guidance and feedback to this project and report.

Steve Andrade, Program Manager, Battelle Technology Partnership Practice

Barbra Batshalom, Executive Director, Green Roundtable

Michael Best, Co-Director, Center for Industrial Competitiveness,
University of Massachusetts Lowell

Tom Burton, Chair, Energy and Clean Technology Practice Group, Mintz,
Levin, Cohn, Ferris, Glovsky and Popeo P.C.

Tom Chmura, Vice President for Economic Development, University of
Massachusetts Office of the President

Ed Collins, International Representative of the International Brotherhood of
Electrical Workers and Executive Vice President of the Massachusetts AFL/CIO

Nick d'Arbeloff, Co-Director, New England Clean Energy Council

Paul Epstein, Associate Director, Center for Health and the Global Environment,
Harvard University

Kathleen J. Freeman, Partner, Bowditch and Dewey

Michael Goodman, Director, Economic and Policy Research,
University of Massachusetts Donahue Institute

Jill Griffin, Assistant Director of Economic Initiatives,
Boston Redevelopment Authority

Bill Guenther, President, Mass Insight Corporation

Berl Hartman, New England Co-Founder, Environmental Entrepreneurs (E2)

Jack Healy, Director, Massachusetts Manufacturing Extension Partnership;
CEO, Manufacturing Advancement Center

James Hoyte, Assistant to the President and Associate Vice President,
Harvard University

Lee Ketelsen, New England Regional Director, Clean Water Action

Judith Kurland, Chief of Staff to the Mayor, City of Boston

David Levy, Professor of Management, University of Massachusetts Boston

Wyndham Lewis, Vice President, Massachusetts High Tech Council

Chuck McDermott, General Partner, RockPort Capital Partners

Daniel K. Moon, Executive Director, Environmental Business Council

Lisa Petraglia, Director of Economic Research, Economic Development
Research Group

Senator Pam Resor, Co-Chair, Joint Committee on Environment,
Natural Resources and Agriculture, Commonwealth of Massachusetts

Andrea Silbert, President, Eos Foundation

Representative Frank Smizik, Co-Chair, Joint Committee on Environment,
Natural Resources and Agriculture, Commonwealth of Massachusetts

Hemant Taneja, Principal, General Catalyst Partners

Thank you also to the industry, academic, labor, and environmental representatives that participated in the Clean Tech Roundtables, to the Tellus Institute for their assistance and input on the project, and to Amy Perlmutter for her leadership in implementing this project.



Lowell Center for
Sustainable Production

University of Massachusetts Lowell

The Lowell Center for Sustainable Production gratefully acknowledges the John Merck Fund for support of this project.

**The Lowell Center
for Sustainable Production
University of Massachusetts Lowell
www.sustainableproduction.org**

The Lowell Center for Sustainable Production uses rigorous science, collaborative research, and innovative strategies to promote communities, workplaces, and products that are healthy, humane, and respectful of natural systems. The Center is composed of faculty, staff, and graduate students at the University of Massachusetts Lowell who work collaboratively with citizen groups, workers, businesses, institutions, and government agencies to build healthy work environments, thriving communities, and viable businesses that support a more sustainable world.





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.

The goals of the ***Clean Tech, An Agenda for a Healthy Economy*** project are:

- To identify Clean Tech industries in which Massachusetts is positioned to be a national and international leader
- To identify and create a Massachusetts Clean Tech Cluster and identity around those industries that will help attract a range of R&D, investment, jobs and other economic activity
- To create an Agenda to make Massachusetts a clean tech leader through policies, investments, partnership building, market development, and other measures
- To characterize the environmental, health, economic and job benefits (qualitative and/or quantitative) that could be realized through Clean Tech leadership
- To develop a broad base of partnerships and support for building a clean tech economy

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, remanufacturing, and recycling.



LOWELL CENTER FOR SUSTAINABLE PRODUCTION

University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854

978-934-2980 • cleantech@uml.edu • www.sustainableproduction.org