Clean Tech: An Opportunity for Technology-based Economic Development in Maine

A White Paper

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I. Executive Summary

Clean Tech, a term that describes a number of technologies that are addressing the combined environmental, climate change and energy challenges, is an economic development opportunity for Maine to create research, development, and manufacturing jobs in Maine. This is a segment that is growing exponentially in terms of market growth and investment, and is being viewed by some as the next industrial revolution following computers, the Internet and biotechnology.

The technologies include bioenergy and biomaterials, wind power, solar energy, green buildings, personal transportation, the smart grid, mobile applications and water filtration. The global market for Clean Tech is already $284 billion and expected to reach $1.3 trillion within a decade.

This paper describes the various technology segments and notes the research and entrepreneurial assets we have in Maine already working on these technologies. This is evidence that Maine can be a player in Clean Tech.

Our recommendations are:

- Make a major R&D investment in Clean Tech technologies in the form of a multi-institution, multi-disciplinary research center;
- Support the technology transfer mechanisms that move the resultant inventions into enterprises that will commercialize them,
- Provide mentoring, management and financial assistance for the early stage enterprises to bring the innovations to market, and
- Secure debt and equity financing to bring the technologies to scale and deployment for the benefit of Mainers.

These innovation and economic development policies, when combined with the more traditional energy policies, will allow Maine to take even greater advantage of the situation than either alone.

II. Introduction

There is no doubt that fundamental changes are coming to the energy markets in this country. As noted in *The Clean Tech Revolution,*[1] the drivers of these changes include not only the costs of energy, but more fundamental changes such as the growth of energy consumption in emerging markets such as China, changes in consumer attitudes towards environmental protection, and concerns about climate change. People are now focused on the life cycle costs of energy sources and their total carbon footprint. This makes the imperative to respond to calls for energy efficiency and renewable energy unavoidable for states.

The response from Maine's Office of Energy Independence and Security and other state agencies has been completely in line with (and sometimes ahead of) the policies being implemented throughout the country. Their focus has been on energy efficiency and conservation, combined with the use of renewable portfolio standards, financing mechanisms for energy efficiency, and energy use by governments and large employers. This approach is also consistent with current federal policy with regards to the states' role in energy.

However, we have been deluged in recent months with out-of-state developers wanting to tap into our natural resources for renewable energy projects, especially wind and biomass. These developers promise more alternative energy for Maine, and jobs in construction and maintenance. In most cases, the energy generated will go directly to the grid, and may or may not assist Mainers through lower electricity prices or through less impact on the climate.

This paper describes a broader opportunity for Maine called Clean Tech, which has the potential to create more economic development for the state than simply acting on the projects that have been proposed. We discuss the various technology segments that are included in this umbrella term, and identify research and entrepreneurial assets in Maine for each. Finally, we make recommendations for policies and programs to support the economic development opportunity the lies ahead of us.

III. Clean Tech Opportunity Defined

Clean Tech is a relatively new term being used in the investment community to describe cutting edge technologies that address the world's environmental problems. These technologies include bioenergy and biomaterials, wind power, solar energy, green buildings, personal transportation, the smart grid, mobile applications and water filtration. The global market for Clean Tech is already $284 billion and expected to reach $1.3 trillion within a decade.

The venture capital community is jumping on this opportunity. Since 2001, the Clean Tech investment category has expanded an average of 49.6% annually, with a 76% increase in the first half of 2008 over 2007: 125 deals for $1.8 billion![2] If you include the European Union, Clean Tech investments totaled over $5.18 billion in 2007 alone. [3]

Many are viewing Clean Tech as the next technology revolution, following computers, the Internet, and biotechnology. Maine did not play a significant role in any of the previous technology waves, but we are poised to participate in this opportunity if we act now. The remainder of this paper discusses the various technologies included under Clean Tech and describes the research and entrepreneurial assets that we already have in Maine for each.

As we respond to the current energy crisis, as well as implement responses to climate change and work to reduce our environmental impact, we should be aware that Maine could realize significant economic development impacts, potentially in rural areas, if we support the development of a Clean Tech industry in Maine, where the management, research and development, manufacturing and deployment of new and emerging technologies all happen here. If we rely solely on outside developers to come in to harness our wind power and burn our wood, we will miss out on the economic development impacts that would result from an indigenous, sustainable industry that makes wind turbine parts or builds a forest biorefineries.

In many ways, the current push to alternative or renewable energy sources is like the gold rush. During the gold rush, many prospectors came from away to search for and mine the gold that was discovered. In most cases, they took the gold away and eventually left ghost towns when the natural resource was depleted. Some places did better, however, because they developed industries that supported the prospectors – Levis Strauss built a company based on rugged clothes for them, for instance – and grew sustainable companies (and places).

The Economic Policy Institute recently published a discussion paper, "Energizing Prosperity: Renewable Energy and Re-Industrialization," that argues: "federal energy policy must go beyond providing incentives for renewable energy deployment and provide for the development of a domestic renewable energy industry."[4] The paper goes on to assert the importance of combining energy policy and economic development.

The second important point is that Clean Tech is much broader than just renewable energy. Based on our review of Maine's research and entrepreneurial assets, we have an opportunity to be a player in most of the technology segments. So, it is also critical to create policies that are broad enough to support economic development potential in as many of the segments as possible, and let the market decide which are ultimately viable.

IV. Bioenergy

The Department of Energy defines bioenergy as the use of renewable biomass resources to produce energy products including electricity, liquid, solid and gaseous fuels, and heat, among others. Biomass is any plant matter such as trees, grasses, agricultural crops, aquatic plants and other living plant material. The wastes from the harvesting and processing of these plants and other residues are also potential sources of biomass as are some municipal and animal wastes. [5] In fact, it appears that the most economical forms of biomass for generating electricity are residues, the organic by-products of food, fiber, and forest production such as sawdust, rice husks, wheat straw, con stalks, and bagasse (the residue remaining after juice has been extracted from sugar cane).

Biomass-fueled furnaces or boilers are reasonably available and offer an attractive alternative for many situations, especially where the source of biomass is located close by, especially at a paper mill, sawmill or sugar mill.[6]

The use of biomass for biofuels, i.e., ethanol and biodiesel, is emerging. Over the past few years, the use of corn to make ethanol has exploded enough to cause a backlash and debate over the relative value of using it for fuel or for food. [7] This debate is also accelerating research into alternatives to corn for the production of ethanol and alternatives for biodiesel as well.

Cellulosic Ethanol

Cellulosic ethanol refers to any biofuel derived from lignocellulose, a structural material that comprises much of the mass of plants. Lignocellulose is composed mainly of cellulose, hemicellulose and lignin. Corn stover (residues from corn harvesting), switchgrass, miscanthus and woodchips are some of the more popular cellulosic materials for ethanol production. While lignocellulose is more abundant compared to corn or cane sugar, it requires a greater amount of processing to make the sugars required to produce ethanol by fermentation. There are two types of processing being studied: biochemical and thermochemical.

Biochemical processing tasks include several steps. First is pretreatment to separate the cellulose from the hemicellulose and lignin. Then, the cellulose is broken down into its components, primarily sugars. This process, called hydroylsis, requires enzymes. Unfortunately, the process also produces acetic acids which are toxic to the fungi and bacteria need to ferment the sugars into ethanol. So, special yeasts are being developed which can thrive and effectively create ethanol.

Thermochemical processes for creating ethanol are most suited to feedstocks such as forest products and mill residues. In this process, heat and chemicals are used to break the biomass into syngas which can then be converted into ethanol. This is an important process because about one-third of the biomass is lignin-rich and cannot be converted using the biochemical process. [8]

Maine researchers are very active in the cellulosic ethanol arena. Forest Bioproducts Research Institute's (FBRI) research aims to develop ways to convert woody biomass from sustainable forests into cellulose-based products such as ethanol, while maintaining the ability to produce paper and building products.[9]

In 2006, University of Maine researchers at FBRI won a $3.6 million award under the National Science Foundation EPSCoR program to study alternative uses for forest products, including for biofuels. The ultimate goal is to build a forest bioproducts refinery in Maine. The initial award has been followed by a 2007 award for $1.5 million from the Department of Energy for follow-on work on the project.

In 2008, a partnership involving University of Maine, Red Shield Environmental (RSE) and American Process Incorporated (API) was awarded a grant of up to $30 million from the US Department of Energy to design, build and operate a small scale commercial biorefinery. This biorefinery will produce ethanol, acetic acid and other by-products along with market pulp in the RSE Pulp & Chemical's existing mill located in Old Town, Maine. Construction is expected to begin in 2009 and a fully integrated biorefinery will be operation in 2011.

Finally, FBRI was the recipient of a $4.8 million award from the Maine Technology Asset Fund for a development and commercialization facility, also planned for the Red Shield location.

V. Algae: Biofuel of the Future

Certain algae make oil naturally. It can be processed to make an equivalent of crude oil and refined to make gasoline, biodiesel, jet fuel and feedstocks for plastics and drugs. Biodiesel is only 2 percent less fuel efficient than petroleum-based diesel (whereas ethanol is 2/3 as efficient), so this is one reason why people think that it should be seriously considered as a substitute.

The chief feedstock for biodiesel is plant oil, such as rapeseed oil, for instance. However, many believe that huge acreages of any plant feedstock would be required to make reasonable amount of biodiesel. This has been linked with higher food prices because of the corn ethanol experience, and so alternatives are being explored. One of the technologies that was heavily researched in the 1970s has made a resurgence: the use of algae to produce biodiesel. National Renewable Energy Laboratory (NREL) researchers think enough of the potential for this technology to restart their research program which had been terminated in 1996.[10]

Algae is widely recognized as having great potential in this area because certain algae yield oil as a byproduct of photosynthesis. The main selling points[11] are:

- Yields are orders of magnitude higher than from traditional oil seeds (*see Table V.1*),
- Algae has a very high growth rate
- Algae is grown in water or on marginal land and therefore doesn't compete with land used for food, and
- Some algae can be grown in sewage and smokestacks, potentially digesting pollutants and harmful emissions as well.

There is concern about the level of hype around this technology. Most agree that fuel can be produced from algae.[12] The question is whether it can be done cheaply or at scale.[13] Researchers who have worked on the problem have tended to think in terms of growing algae in simple open ponds and therefore have expressed concerns about the acreage required to replace all petroleum usage. Another issue is the alcohol required to mix with the oil to form biodiesel.[14] In general, most argue that we should build pilot scale facilities to get an accurate idea of the challenges involved.[15]

At any rate, microalgae biofuels is still a long-term R&D goal. At present, NREL in combination with large firms like Chevron and many smaller companies are trying to grow scalable amounts of the right type of algae and how to process it efficiently.

DARPA is working with Honeywell, General Electric and University of North Dakota to develop jet fuel from plants, including algae.[16]

Table V.1. Relative Oil Yield from Various Feedstocks

Crop	***Oil Yield Gallons/Acre***
Corn	18
Cotton	35
Soybean	48
Mustard Seed	61
Sunflower	102
Rapeseed/Canola	127
Jatropha	202
Oil Palm	635
Algae (10 g/m^2/day at 15% TAG)	1,200
Algae (50 g/m^2/day at 50% TAG)	10,000

Note: g/m^2/day is the harvest rate of the algae and % TAG is the percentage of triglycerides.
Source: Hodge, Nick. 2008. "Investing in Algae Biofuel." http://www.greenchipstocks.com, accessed September 16, 2008.

The US Department of Energy Joint Genome Institute is using genetics to accelerate research into converting plant biomass into biofuel. Specifically, they want to identify enzymes suitable for industrial scale biofuel production. In Nature, the Director of the Institute discusses potential feedstocks, including oil-producing algae.[17]

Several Maine researchers are working in this field. Professor Ira Levine of the University of Southern Maine has done extensive work is on the bioremediation potential of algae, and cultivation of commercial algae.[18]

The Bigelow Laboratory in Boothbay Harbor is the world's largest repository of living phytoplankton strains, and is therefore uniquely positioned to test and develop algal biofuel production technology. Scientists at Bigelow are actively involved in studying the microbiology of trace gas emissions, the population structure of marine microbial communities in the open ocean, the role of microbes in utilizing iron as an energy source and contributing to the iron cycle, the evolution and systematics of microorganisms, and understanding the interplay of viruses and microbes in controlling microbial population dynamics in the ocean, and affecting the health of fish and other marine organisms utilized in aquaculture. [19]

Finally, the Center for Cooperative Aquaculture Research[20] is working with University of Maine, School of Marine Science researchers on various algae cultivation techniques, including the development of integrated aquaculture where algae are part of a system involving multiple species.[21]

VI. Biomaterials

Biomaterials is a broad category of materials including biochemicals, biopolymers and bioplastics, bioenzymes and some composites. Biomaterials are being developed to use renewable resources in industry, decreasing pollution, reducing petroleum and energy usage, reducing waste and increasing efficiency. The growth in the biomaterials market is partially in reaction to European Union requirements that manufactured equipment be completely recyclable or reusable, as well as climate change and energy concerns.

Biochemicals

Biochemicals are chemicals produced from biomass, any living matter that can be regularly and naturally replenished, such as crops, residues and wastes, aquatic plants, animals, and animal wastes. Biochemicals are also sometimes called green chemicals.

To date, most biochemicals are made from corn. Chemicals like ethyl lactate, succinic acid, and polylactic acid (PLA) are made from corn components, such as corn starch, and are used to make a variety of products, such as plastics, solvents, clothing fibers, paints, and food additives.

The process is similar to the beginning of the process to make ethanol: first sugars are extracted from the feedstock, and then the sugars are fermented. Finally, the fermented sugars are purified and made into various products such as plastics and solids.

Biopolymers and Bioplastics

Biopolymers are polymers which are present in or can be made from living organisms. Bioplastics are made from biopolymers and are, by definition, biodegradable. Examples of biopolymers are cellulose (present in corn, wood, wheat and other crops), soy protein, starch (corn, potatoes, etc.) and some polyesters found in bacteria. Polylactic acid (PLA) is one plastic that can be made from these biopolymers. Creating efficiency in the production of PLA and other bioplastics is the major area of research at this time.

SRI International predicts that the widespread use of bio-based materials and biofuels will occur in the relatively short term:

- 2010—Cellulosic-ethanol–production technology could become economically viable on a commercial scale, enabling the spread of energy-efficient biofuels production facilities based on abundant lignocellulosic biomass feedstocks that do not compete with food or feed needs.
- 2010 to 2015—Algae-derived biofuels technology could become cost competitive, allowing high-volume biofuels production on marginal land or water or, for example, in closed photo-bioreactors that capture CO_2 emitted from power plants during the day.
- 2012—Successful commercial-scale demonstrations of integrated biorefinery technology could enable the large-scale and economical coproduction of biofuels,

chemicals, bioplastics, power, and other high-value products from lignocellulosic feedstock.

- 2012 to 2020—"Custom-designed" biofuels emerge, enabled by highly engineered microbes that can convert biomass to synthetic hydrocarbons products, such as high-performance jet fuel, low-sulfur gasoline, advanced diesel, and specialty biochemicals. Such hydrocarbon products will be wholly consistent with existing fuel infrastructures and vehicle engines.
- 2025—U.S. biofuels consumption could displace 25% or more of petroleum-based fuels, with similar reductions in CO_2 emissions. Petrochemical products may also see a major transition to bio-based feedstocks.[22]

Maine has researchers who are working in this area as well. The potato-to-plastics project is probably the best known. With support from Maine Technology Institute, a group now known as the Sustainable Bioplastics Consortium, which includes the Alliance for a Clean and Healthy Maine, the Environmental Health Strategy Center and Interface FABRIC (now True, Inc.) have been working on the viability of Maine potatoes as a source for polylactic acid. A report by the Margaret Chase Smith Policy Center at the University of Maine concluded that it is economically feasible for Maine potato growers to plant and harvest potatoes specifically for the purpose of providing a source of starch to manufacture PLA. The group recently embarked on its second MTI funded project to pursue both the technology and business challenges of the initiative.[23]

Also at the University of Maine, the Forest Bioproducts Research Institute (FBRI) is working on an integrated forest products biorefinery. The biorefinery would have a large number of outputs from sugar feedstocks, synfuels, and ethanol to oriented strand board and pulp. The refinery would extract hemicellulose from wood which can have a number of chemicals and could also be used in composite materials. It would also provide a base for biopolymers.[24]

In addition, a number of companies are active in this area, particularly using existing paper production capacity to produce biomaterials. Sappi N.A., for instance, recently was awarded an MTI MTAF grant to explore the development of bioceramics from paper.

VII. Wind

Wind power is the technology adding the most new, zero-emissions electricity to the U.S. supply today. According to the American Wind Energy Association, the U.S. wind power industry grew 45 percent in 2007 with over 5,200 megawatts installed. Wind power accounts for about 30% of al new power generating capacity added in 2007.[25]

Wind power development creates both construction and manufacturing jobs. The new and announced facilities created over 6,000 jobs in the last two years, including new companies that manufacture blades, turbines, and towers.[26] [None to date are in Maine, but many are composite manufacturers that previously served other industry segments such as vehicle manufacturing.]

Wind power has a number of advantages, the main one being its ability to generate zero-emissions electricity at a relatively affordable cost. In addition, wind projects do not use any fuels for operations. The wind resource does not create any radioactive or hazardous wastes, and doesn't rely on water for steam of cooling.

A study conducted for the Department of Energy and the National Renewable Energy Laboratory (NREL) concluded, "Wind power can play a major role in meeting America's increasing demand for electricity." Under the scenario developed in this report, 46 states would experience significant wind power development and the U.S. wind industry could support an annual average of more than 150,000 workers directly in the industry and hundred of thousands more in associated industries by 2030. This scenario also predicts a 25% reduction in the CO_2 emissions from power generation facilities.[27]

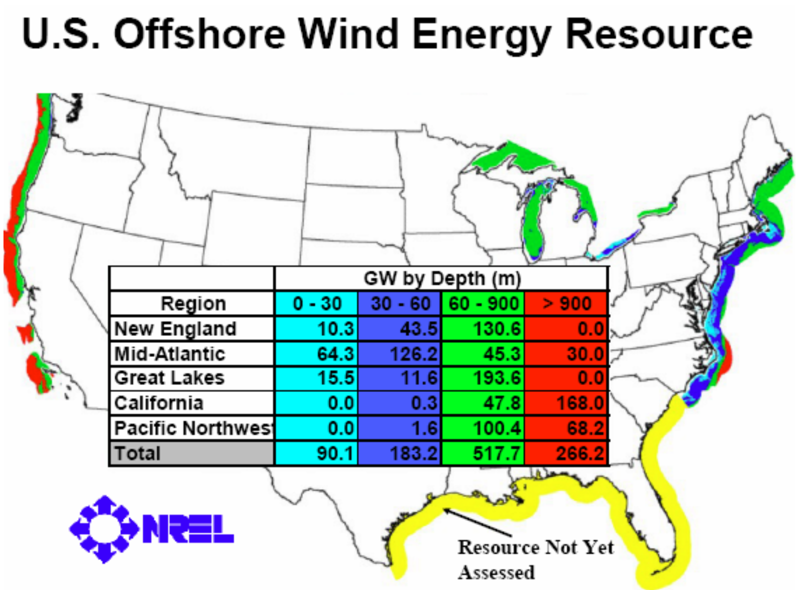
Much of the current projects under development are for onshore wind, including substantial numbers of turbines being installed in Texas, California and other states in the center of the country. However, offshore wind is gaining ground as a companion to this type of development. There are two reasons for this change:

1. Much of the electricity demand in the U.S. is on the two coasts, too far from the onshore wind resources in the center of the country.
2. The onshore wind resources cannot generate enough power to meet the renewable energy goals. The better wind resources are offshore.

The interest in offshore wind is good for Maine because more than one-half of the nation's identified offshore wind potential is off New England and the mid-Atlantic coasts.[28] Further, the Maine wind potential is very high in deep water, i.e., greater than 60 meters. A study by AWS Truewind for the Department of Energy found that there is 100,000 megawatts of potential wind energy that could be tapped in the Gulf of Maine. A significant advantage to deep water offshore wind is that it can mitigate the issue of visual impact by being beyond the horizon.

The far offshore potential brings technological challenges, however. To date, monopole and other fixed designs adapted from onshore installations have been installed in the shallow waters off northern Europe. But, to fully harness the Maine opportunity, new technologies will have to be developed for larger turbines, higher speed rotors, towers, underwater transmission cables as well as lower shipping and erection constraints. In addition, work in the storage of wind power would greatly improve the economics and reliability of this energy source.

Most of the research is focused on floating offshore wind foundations, similar to oil drilling platforms.[29] These are appropriate to depths of greater than 60 meters such as are contemplated in the Gulf of Maine. The Framework for Offshore Wind Energy Development in the United States provides a detailed list of the work to be done.[30] With these types of new technologies, including very large blades, high hub heights and more reliability, offshore wind costs are expected to be as low as 5 cents/kWh by 2014. [31]



Region	GW by Depth (m) 0 - 30	30 - 60	60 - 900	> 900
New England	10.3	43.5	130.6	0.0
Mid-Atlantic	64.3	126.2	45.3	30.0
Great Lakes	15.5	11.6	193.6	0.0
California	0.0	0.3	47.8	168.0
Pacific Northwes	0.0	1.6	100.4	68.2
Total	90.1	183.2	517.7	266.2

Source: http://ocsenergy.anl.gov/documents/docs/NREL_Scoping_6_06_2006_web.pdf, Accessed September 23, 2008.

Maine's competitive advantage lies not only in the resource, but in technology. The key to many of the technology hurdles being faced by deep water offshore wind energy is lighter materials – composites. Habib Dagher, Director of the Advanced Engineered Wood Composites Center (AEWC) at the University of Maine recently testified to Congress that his center is working on developing experimental wind turbines. They are now testing the durability of composite turbine blades at Orono (and recently received a MTAF grant to expand their testing facilities to accommodate much larger wind blades.) Furthermore, they are working with industry leaders such as Cianbro who has extensive experience with offshore platforms. The stated goals of the Center's R&D effort in windblades are to:

1. Improve performance and durability of composite wind blades and nacelles.
2. Reduce blade costs through the development of improved manufacturing technology.
3. Create jobs in Maine's Composite Manufacturing sector by creating opportunities for existing Maine composites companies to manufacture wind energy components, and by attracting new manufacturers to Maine.[32]

One new start-up company in Bath that is working with AEWC is US Windblades. Others involved in the offshore wind power project are Ocean Energy Institute, Independence Wind, and Harbor Technologies.

VIII. Tidal

Tidal power or tidal energy involves harnessing the power of the tides to produce electricity or other useful forms of power. The stronger the tide, either in water level heights or current velocities, the greater the potential for power generation.

One technology that can be used is the tidal barrage which harnesses the cyclical rise and fall of the water. These are essentially barriers across a large area with high tides. The movement of the tides moves the barrier up and down, causing a turbine to produce electricity. There has been a barrage operating in Brittany since 1966, producing 240 mW of power. There are a number of other sites worldwide where this technology would be possible because of the power of the tides and physical characteristics of the sites, including the Bay of Fundy. However, like dams, barrages inhibit the movement of marine life and are a barrier to shipping, fishing and other maritime interests. Both barrages and dams would be very problematic to permit, as well.

Another technology is the use of tidal current to run turbines which in turn generate electricity. Tidal stream turbines are most effective in areas where there is a high velocity such as entrances to harbors and bays, or between land masses. The technical issues relate to the design of the turbines, how they should be anchored, and how to minimize their impact on marine life and other uses of the waterways.

Maine’s coastline with its high tides is well suited to tidal applications. A 2006 study by the Electric Power Research Institute (EPRI) funded by the Maine Technology Institute evaluated ten sites in Maine and concluded the several merited further exploration. The study found that some of the most promising sites are off the coast of Maine in the Western Passage and Cobscook Bay. According to study project leader Roger Bedard, Maine's "world-class tidal resource," with its enormous range of 9 feet to 30 feet, is capable of producing electricity at a cost of 4.2 cents to 6.5 cents per kilowatt hour.[33]

So, even though this technology is in its infancy, and is dogged by concerns about scalability, there are several projects moving forward here.

Ocean Renewable Power Company’s (ORPC) projects in Western Passage and Cobscook Bay have made the most progress. With funding from the Maine Technology Institute and various venture and individual investors, ORPC’s proprietary turbine technology was recently tested in the water in Cobscook Bay and its technical feasibility proven.[34] ORPC is collaborating with the University of Maine on a number of fronts: with Dr. Bob Lindyberg at AEWC to explore the possibility of incorporating composite materials into the design of their turbine blades, with Dr. Mick Peterson and his students to design computer models of the turbines themselves and with Dr. Huijie Xue to model the current flows in Cobscook Bay.

Maine Tidal Energy Company was issued a preliminary permit for a project in the Kennebec River. This company is a wholly-owned subsidiary of Oceana Energy Company, a renewable energy and site development company with headquarters in

Washington, DC. This company is also developing proprietary technology which it hopes to deploy in a number of locations including Maine.[35]

Tidewater Associates, a Trenton, Maine engineering company, has applied for a permit for a project off Cutler in Little Machias Bay. And the Passamaquoddy Tribe has a permit for the Western Passage and Cobscook Bay as well.

Maine Maritime Academy has also been active in tidal energy. They received a preliminary permit in October 2008 from the Federal Energy Regulation Commission (FERC) for a Tidal Energy Device Evaluation Center. The Center has proposed two testing sites: Bagaduce River and Castine Harbor.

IX. Other Technologies

There are a number of other technologies that are included in Clean Tech. These include solar power, green buildings, personal transportation, water filtration, and mobile applications. Maine has a limited role to play at present in these technologies, but our deep environmental engineering experience as noted in *Maine's Technology Sectors and Clusters: Status and Strategy,*[36] could lead to a bigger opportunity. A brief description of each area follows.

Solar Power

Solar technologies use the sun's energy to provide heat, light, hot water, electricity and even cooling. The major technologies are photovoltaic (solar cells), concentrating solar systems, passive solar heating, and solar hot water.

Maine's location on the earth means that photovoltaic flat panel solar cells can be a useful resource here, but concentrating collectors will be marginal.[37] It appears that little research is being done in Maine on solar cells except by small companies. Notable is Ascendant Energy in Rockland which has developed a photovoltaic co-generator that produces electricity and hot water heat from the same solar unit. Ascendant has developed this technology with three Seed Grants and a Development Award from the Maine Technology Institute. The company also installs systems made by other manufacturers. [38]

Mobile Applications

This category includes portable energy devices that are safe, clean and reliable such as lithium-ion batteries, embedded, thin-film solar cells and mobile power stations. The applications include consumer electronic devices, military and national security, disaster recovery and relief, and off-grid power in rural and developing areas.[39]

Maine's angle on this technology may emerge either from the composite structures being developed at the University of Maine at AEWC and/or the shipbuilding cluster where marine applications are driving related developments. The Power Consol Deployable

Power Unit, a turn-key solution for providing power in remote or disasters situations, for instance, a project recently completed at Lyman Morse using Maine Technology Institute funding, is finding an unexpected market in the Department of Homeland Security.[40]

Green Buildings

New and refurbished commercial and residential buildings are increasingly being built with attention to operational and energy efficiency as well as the use of materials that are sustainable. Maine's role in this sector includes the potato-to-plastics project which is planned to result in a fabric that is used in building interiors, wood composite and extruded building materials being developed at AEWC and design and architectural specialists in LEED certified building. Also, research at AEWC on composite dimension lumber, extruded composites and panels could have applications in green buildings.

Water Filtration

Turning oceans, wastewater and other sources into pure water, especially in remote areas of the world, is a major opportunity in Clean Tech. According to the World Health Organization, cleaning up rural water supplies could eradicate a majority of the diseases that kill millions of people in the developing world.[41] Technology-based opportunities exist in nano-based membranes, desalination plants powered by renewable energy, extraction of water from air, and other infrastructure improvements.

University of Maine start-up Zeomatrix has just been awarded a $102,000 SBIR Phase I grant from the National Institutes of Health to develop a new water purification technology. Their technology targets the removal of industrial cleaning solutions from water.[42] The company uses zeolite catalysts provide remediation of air pollution, odor control at sanitary landfills and composting facilities, and recycling of contaminated wash water. Zeolites are safe-to-handle, non-toxic powders used through-out environmental technology to clean radioactive waste, control odor, and as non-toxic detergents.

Seldon Technologies, a Vermont start-up that is moving its production operation to Maine is being funded by an MTAF award to work closely with Red Shield Environmental to produce specialized filters for its portable water filtration system. Their nanotechnology-based products clean water, air and oil.[43]

Personal Transportation

Ultra-efficient, low-emissions, high-performance vehicles are the goal of companies and researchers in the personal transportation segment of the Clean Tech market. Although carbon composite materials such as AEWC and Hodgdon Yachts are using on the Navy's Mark V.1 small combatant craft are also a critical component of the personal transportation opportunity, Maine's lack of experience in automobile manufacturing may hamper our ability to play a significant role in this sector. Another wild card could be fuel-cell vehicle or hydrogen-fueled cars. There is a significant interest in hydrogen, notably at Chewonki Foundation which has done research in this area funded by the

Maine Technology Institute. That project resulted in a hydrogen energy system that provides back-up power for one building at the Foundation's campus.[44]

Smart Grid

One vision of the future of our energy distribution system involves a nano-enabled electricity grid, with storage systems distributed around the country so that both centralized and distributed renewable energy sources could feed into a national system. Some discuss this as an electric grid that more closely resembles the Internet in that it would be extremely distributed with intelligence embedded throughout. [45] New enabling technologies include smart appliances, grid monitoring, superconductors, and quantum wires.

To our knowledge, no Maine companies or researchers are active in this sector. However, Commissioner Sharon Reishus of Maine's Public Utilities Commission is a member of the joint federal-State Smart Grid Collaborative organized by the National Association of Regulatory Utility Commissioners.

X. Recommendations

In order to secure Maine's position in the Clean Tech field, we need to be proactive and make a concerted R&D investment. We believe that the investment should be for Clean Tech technologies generally and that the state should not be deciding that one technology is more worthy than another. There is 30 years of experience at the Department of Energy that shows that even the most thorough analysis is most often wrong when choosing one technology over another. Many of the technologies long supported by DOE have turned out not to be cost effective, while others that were not supported are now viable.

In order to ensure that our research and development investments are commercialized, we need the same as for our other technology sectors:

- support for the technology transfer mechanisms that move the resultant inventions into enterprises that will commercialize them,
- mentoring, management and financial assistance for the early stage enterprises to bring the innovations to market, and
- debt and equity financing to bring the technologies to scale and deployment for the benefit of Mainers.

These innovation and economic development policies, when combined with the more traditional energy policies, will allow Maine to take even greater advantage of the situation than either alone.

Endnotes

[1] Pernick, Ron and Wilder, Clint, *The Clean Tech Revolution*, www.cleantechrevolution.com)
[2] National Venture Capital Association and Thomson Research, http://www.nvca.org
[3] http://cleantech.com, accessed October 1, 2008.
[4] Sterzinger, "Energizing Prosperity: Renewable Energy and Re-Industrialization." Economic Policy Institute, March 3, 2008, Briefing Paper #205. http://www.epi.org.
[5] http://www.doe.org, http://apps1.eere.energy.gov/states/alternatives/biomass.cfm?print, accessed September 14, 2008.
[6] Ibid.
[7] See for instance, http://www.ncga.com/Ethanol/main/economics.htm, http://www.reuters.com/article/reutersEdge/idUSN1042557020071210, and http://www.ces.purdue.edu/extmedia/ID/ID-339.pdf for different views on the matter. Accessed September 25, 2008.
[8] An overview of the research being done on both methods of producing cellulosic ethanol is available on http://www.nrel.gov/biomass/pdfs/40742.pdf, accessed September 25, 2008.
[9] http://www.forestbioproducts.umaine.edu/, accessed September 25, 2008.
[10] Bullis, Kevin. 2007. "Algae-Based Fuels Set to Bloom." *Technology Review*, Massachusetts Institute of Technology. http://www.technologyreview.com
[11] http://media.cleantech.com/1224/algae-biofuel-of-the-future, accessed September 12, 2008.
[12] Ibid.
[13] Scheider, David. 2006. "Grow Your Own." *American Scientist*. http://www.americanscientist.org/issues/pub/grow-your-own, accessed September 12, 2008.
[14] Briggs, Michael. 2004. "Widespread Biodiesel Production from Algae." University of New Hampshire Biodiesel Group. http://www.unh.edu/p2/biodiesel/article_algae.html, accessed September 16, 2008.
[15] Fox, Michael R. 2007. "Algae to Biodiesel? You Jest." http://www.hawaiireporter.com, accessed September 16, 2008.
[16] Karnowski, Steve. 2007. "Algae Fueling Renewable Energy Research Boom." Associated Press, December 1, 2007. http://www.panatagraph.com/articles/2007/12/01, accessed September 16, 2008.
[17] http:/www.nature.com, August 14, 2008, referenced in http://jgi.doe.gov/News/news_8_13_08.html.
[18] http://www.usm.maine.edu/lac/directory/profiles/levine.html, accessed September 16, 2008.
[19] http://www.bigelow.org.
[20] http://www.ccar.um.maine.edu/, accessed October 1, 2008.
[21] http://www.umaine.edu/marine/research/clusters-marine-aquaculture.php, accessed October 1, 2008.
[22] SRI Consulting Business Intelligence, 2008. Conference Report to National Intelligence Council, "Disruptive Civil Technologies: Six Technologies with Potential Impacts on US Business Interests to 2025," http://www.dni.gov/nic/PDF_GIF_confreports/disruptivetech/appendix_C.pdf, accessed September 28, 2008.
[23] http://www.masshightech.com/stories/2008/06/02/weekly13-Maine-group-hopes-to-cook-up-plastics-from-potatoes.html, accessed September 28, 2008.
[24] http://teamdean08.com/mediafiles/pdfs/Pendse_FBRP_UMaine_June_2006.pdf, accessed September 28, 2008.
[25] American Wind Energy Association, Wind Power Outlook 2008, www.awea.org. Accessed September 23, 2008.
[26] http://www.awea.org/pubs/documents/Outlook_2008.pdf, accessed September 23, 2008.
[27] U.S. Department of Energy, "20% Wind Energy by 2030: Increasing Wind Energy's Contributions to U.S. Electricity Supply, May 2008. www.eere.energy.gov/windandhydro, www.20percentwind.org. Accessed September 23, 2008.
[28] Massachusetts Technology Collaborative, U.S. Department of Energy and General Electric. 2005. "A Framework for Offshore Wind Energy Development in the U.S." http://www.offshorewind.net.

[29] Minerals Management Service, U.S. Department of the Interior, 2006. "Technology White Paper on Wind Energy Potential on the U.S. Outer Continental Shelf." http://ocsenergy.anl.gov. , accessed September 23, 2008.
[30] Op. cit.
[31] Robinson, Mike and Musial, Walt, 2006. "Offshore Wind Technology Overview." National Wind Technology Center, National renewable Energy Laboratory. NREL/PR-500-40462, http://www.nrel.gov/wind/pubs_technologies.html#offshore, accessed September 23, 2008.
[32]http://maine.gov/doc/mfs/windpower/meeting_summaries/010908_summary_files/composite_wind_blade_development.doc, accessed September 23, 2008.
[33] Hagerman. George and Bedard, Roger, 2006. "Maine Tidal In-Stream Energy Conversion: Survey and Characterization of Potential Project Sites," Electric Power Research Institute, http://oceanenergy.epri.com/attachments/streamenergy/reports/Tidal_003_ME_Site_Survey_Report_Rev_1.pdf, accessed September 28, 2008.
[34] http://www.oceanrenewablepower.com/home.htm, accessed September 25, 2008.
[35] http://www.oceanaenergy.com/index.htm, accessed September 25, 2008.
[36] Colgan, C. et al., 2008. Maine's Technology Sectors and Clusters: Status and Strategy. www.maineinnovation.org.
[37] http://apps1.eere.energy.gov/states/alternatives/resources_me.cfm, accessed September 14, 2008.
[38] www.ascendantenergy.com.
[39] Pernick, Ron and Wilder, Clint. 2008. The Clean Tech Revolution, Harper Collins.
[40] http://www.lymanmorse.com, accessed September 28, 2008.
[41] Op cit, Pernick and Wilder, p. 219.
[42] http://www.zmtrx.com/, accessed September 28, 2008.
[43] http://www.seldontechnologies.com/, accessed October 1, 2008.
[44] http://www.chewonki.org/pathways/default.asp, accessed September 28, 2008.
[45] Op cit, Pernick and Wilder, pp. 171-175.