SITING OF RENEWABLE ENERGY FACILITIES

WITHIN THE

MONTACHUSETT AND NORTHERN MIDDLESEX REGIONS

Funded by:

EDA
U.S. ECONOMIC DEVELOPMENT ADMINISTRATION

Prepared by the Montachusett Regional Planning Commission (MRPC) and the Northern Middlesex Council of Governments (NMCOG)

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EXECUTIVE SUMMARY

Expenditures for conventional energy and fuel costs provide little direct economic benefit for our regional economies. Utilization of renewable energy and improvements to energy efficiency has the ability to keep more of those dollars in our local communities and regional economy. This involves siting and promoting renewable energy facilities in appropriate locations, increasing reliance on renewable energy sources, and making these energy sources more practical and affordable. Renewables are not subject to fossil fuel price volatility, enabling residents to more efficiently deal with temperature extremes. Energy prices in a region with both high efficiency and renewable energy are likely to see less volatility and lower average power prices because price spikes will be reduced. However, at this time, there are insufficient siting standards for renewables. As a result, developers of renewable energy do not know what criteria they need to meet in order to develop wind, solar, geothermal, hydropower and other facilities.

Renewable energy facilities also provide complementary economic development benefits by generating investment and employment in different sectors of the economy, which expands the total economic stimulus effect. Renewable energy also has a high job growth rate, reflected in efforts at Fitchburg State College, Mount Wachusett Community College, and University of Massachusetts - Lowell to educate and train people in the skill areas necessary to fuel the clean energy transition. This report was developed, in part, to serve as a template for other Regional Planning Agencies (RPAs) throughout the Commonwealth to promote renewable energy and enhance economic development in their regions.

Many of the communities in the area affected by this EDA grant meet the definition of a "traditional New England" manufacturing city or town. The reality today, given the migration of employers away from this region in the past 10 years, is communities have large amounts of vacant industrial space. In fact, the vacancy rate of modern industrial space in the Fitchburg-Leominster area alone has ranged from a low of 1.60% in 1995 to the current high of 16.8% in 2010. The City of Lowell and other communities within the NMCOG region have seen similar trends. By having the opportunity to site renewable energy across our region, MRPC and NMCOG have a great opportunity to utilize these rooftops and vacant spaces for renewable energy production, allowing for cheaper utility rates for interested business while helping to meet the statewide goals established under the Global Warming Solutions Act (GWSA).

The research conducted in support of the study found that the Montachusett and Northern Middlesex regions have the infrastructure and the overall capability to employ an effective mix of renewable energies to begin to reduce reliance on finite fuel sources. These regions are well suited to photovoltaic solar power, ground source heat pumps, biomass power and hydropower. With our regional history of manufacturing, our future still lies in manufacturing, but the difference moving forward will be to shift from consumer goods and furniture to green energy components, helping to turn the regions back into the economic powerhouse they once were.

Energy Advisory Committee Meetings

The Montachusett Region Energy Advisory Committee (EAC) was formed in January 2010 prior to this grant award and it will remain intact indefinitely. The Greater Lowell Energy Advisory Committee met for the first time on December 13th and was briefed on the components of this study and the role that the committee would have throughout the duration of this project. A complete listing of those serving on the Montachusett Energy Advisory Committee and the Greater Lowell Energy Advisory Committee can be found in Appendices A.1 and A.2.

Since the beginning of this particular project, the Montachusett Energy Advisory Committee met a total of 10 times while the Greater Lowell Energy Advisory Committee met 8 times to provide oversight of grant activities. During these meetings, significant contributions and accomplishments were made concerning the siting of renewable facilities, and commenting on the final draft report. In short, all meetings were well attended and significant input and contribution towards the project were realized. Meeting agendas can be found in Appendices B. 1 and B.2.

It should also be noted that as part of this project, MRPC staff collaborated with Worcester Polytechnic Institute to form a team of four students. Supervised by Derren Rossbach, Assistant Teaching Professor at WPI, the team of WPI students researched, reported and presented at a Montachusett Energy Advisory Committee meeting held on February 21, 2014 on promoting economic development in the Montachusett region by enhancing solar adoption and the siting of renewable energy on brownfields. Boreal Renewable Energy Development located in Concord, MA was also hired as a consultant to assist with overseeing student activities. The reports have been posted on the WPI library site and are now publicly available: http://www.wpi.edu/Pubs/E-project/Available/E-project-030714-003608/ & http://www.wpi.edu/Pubs/E-project/Available/E-project-031914-142902/

Regional Workshops

A total of six (6) educational workshops were held as part of this project. All six workshops were well advertised and open to the general public - anyone interested was highly encouraged to attend including citizens, local and state officials, students, the regional business community and others. (Workshop Notices have been attached in appendices B.3 and B.4 but materials distributed at workshops are not included in this final report due to their magnitude. However, these materials are available upon request by contacting either the Montachusett Regional Planning Commission or the Northern Middlesex Council of Governments.)

Wind Energy

MRPC was the agency assigned to lead the first community workshop on Wind Energy held on February 12th, 2013 at MRPC Offices in Fitchburg. Workshop Topics included *Collaboration and Public Engagement in Wind Energy Siting* presented by Stacie Smith, Consensus Building Institute; *Wind Energy Bylaw Process*, presented by Stephen Wallace, Westminster Town Planner, and; an *Energy Issues Legislative Update*, presented by Representative Stephen DiNatale.

Solar Energy

The second community workshop, led by NMCOG, was about Solar Energy. The workshop was held on April 23, 2013 at Middlesex Community College Federal Building, 50 Kearney Square, Lowell. Workshop topics included the *Westford Solar Park* presented by Jim Goldenberg, Co-Founder Cathartes Investments; *Solar Energy Market* presented by John Langton, Vice President American Capital Energy;

and *Workforce Development Issues* presented by Gail Brown, PMP, Senior Project Manager Greater Lowell Workforce Investment Board.

Hydropower

MRPC worked to organize/facilitate a workshop on Hydropower. It was held at Pepperell Town Hall and included a tour of the Pepperell Hydroelectric Plant. Topics presented at this workshop, held on November 7th 2013 included an *Energy Issues Legislative Update* by Representative Stephen DiNatale; an *Overview of Hydroelectric Power Generation* by Celeste Fay, Project Engineer, Alden Research Laboratory, Inc., and an *Overview of Pepperell Hydroelectric Plant* by Davis Hobbs, Principal Pepperell Hydro, LLC. The workshop concluded with a guided tour of the Pepperell Hydro Company.

Renewable Energy in Historic Buildings

NMCOG took the lead to organize the fourth community workshop about Renewable Energy in Historic Buildings at Middlesex Community College in Lowell on November 18, 2013. Presenters for this workshop were Tom Heslin from the City of Lowell Department of Planning and Development, Ken Koornneef from Nobis Engineering, Inc. and Gregg Croteau from the United Teen Equality Center (UTEC).

New Construction and Renewable Energy

This workshop took place in the Montachusett Region within the community of Devens at the Vicksburg Square Conference room at 33 Andrews Parkway on April 10 at 6PM. Specific topics/speakers included *Net Zero Energy Housing*, presented by Carter Scott, Transformations, Inc.; *Roof Mounted Solar*, presented by Jonathan Abe, Blacksmith Solar Design, Engineering, and; *Implementation of Renewable Energy for New Construction*, presented by Steven J. Strong, President, Solar Design Associates, LLC, Harvard, MA.

Renewable Energy Incentives

The sixth and final educational workshop took place at the UMass Lowell Inn and Conference Center, 50 Warren Street, Lowell, MA. It featured five speakers. Sean Robertson, Director of Bostonia Partners talked about *Renewable Energy Financing and Economics*. This was followed by a presentation by Rebecca Sullivan, Senior Vice President of Institutional Finance, Massachusetts Development Finance Agency on *MassDevelopment Lending Programs*. Bram Claeys, Deputy Director, Renewables Division, Massachusetts Department of Energy Resources (DOER) then spoke about *Renewable Heating and Cooling Alternatives*, followed by speaker Dinesh Patel, Principal Engineer, National Grid on *Combined Heat and Power (CHP) Incentives*. To conclude, David Gaudet, Senior Energy Engineer from National Grid, presented on *Thermal Heat Recovery Solutions and Sustainable Gas Efficiency Measures.*

Recommendations

Recommendations that can be found at the conclusion of this document include:

- Clarifying Goals and Priorities Related to Solar Energy Use
- Clarifying Standards and Permitting Procedure for Solar Energy
- Hiring an Energy Manager
- Promoting Community Solar Applications

- Establishing Wind Energy Facility Overlay Districts
- Including Wind Energy in Comprehensive Plans
- Creating Zoning Bylaws to Permit Wind Turbines
- Developing Binary Cycle Geothermal Facilities
- Promoting Geothermal Heating and Cooling
- Developing Bylaws to Permit Geothermal Heating
- Evaluating the Potential of Existing Dams to Increase Hydropower
- Evaluate Existing Landfills for Potential Biomass Industry
- Conducting an Inventory of Industrial Sites for Renewable Energy Manufacturing
- Conducting a “Cluster Analysis” of Region’s Energy Industries
- Educate Manufacturers and Suppliers about energy manufacturing opportunities
- Working with the Greater Lowell and Montachusett Investment Boards

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WIND

History

For centuries, whether it was used to turn a grind stone at a mill, push a boat across oceans or pump water, wind has been harnessed for the benefit of human kind. The first windmill for electricity was built in the summer of 1887 by Professor James Blyth of Anderson College in Glasgow, Scotland. It was used to store electricity in accumulators (early batteries with large storage) to power his country home. The design was simple, consisting of eight cloth sails, turning a vertical drive shaft with a sprocket connected to a generator. While he was able to produce surplus power, the local towns did not want electricity, claiming it was the work of the devil. It was not until 1941 that the world's first megawatt scale wind turbine was built in Vermont. Despite failing in high winds, it was the first indication that wind as a means of commercial production of electricity was on its way to becoming a reality.

Today, commercial wind turbines are capable of producing over 7.5MW of energy per turbine, with an 8MW turbine soon to be released, and 10MW turbines on the drawing board. To put this into perspective, according to the Department of Energy (DoE), 1 MW is the equivalent of power for 250 average American homes. Massachusetts currently produces about 100MW, essentially powering 25,000 homes. With new turbine designs that number could increase substantially.

Capacity and Efficiency

Capacity is the percentage of electricity produced versus the rating of the turbine. Reports of capacity range from 20-45%, comparable to fossil fuels at 75-85% (or fossil fuel stations designed as dispatchable sources, as low as 10% when not needed). This means that a wind turbine will produce 20-45% of the nameplate value over a year. While this may seem to be disappointing, one must realize that the wind does not blow 100% of the time and its velocity varies over time. Therefore, it cannot reach as high of a capacity as a fuel which stores 100% of its energy in a readily available, tangible form.

However, capacity is not to be confused with its efficiency, which is the ratio of energy input versus the amount of energy output as a conversion rate. Right now, wind is the second most efficient source of power, as it converts 45-50% of the kinetic energy that passes through the blades into electrical energy. Compared to coal production, which exchanges the energy stored in coal to electricity, at only 29-37% or gas production at 32-50%, wind is clearly an efficient form of energy generation. The main

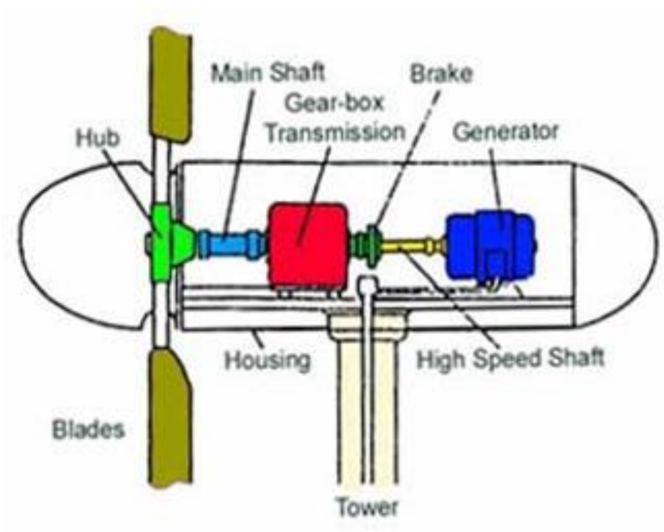
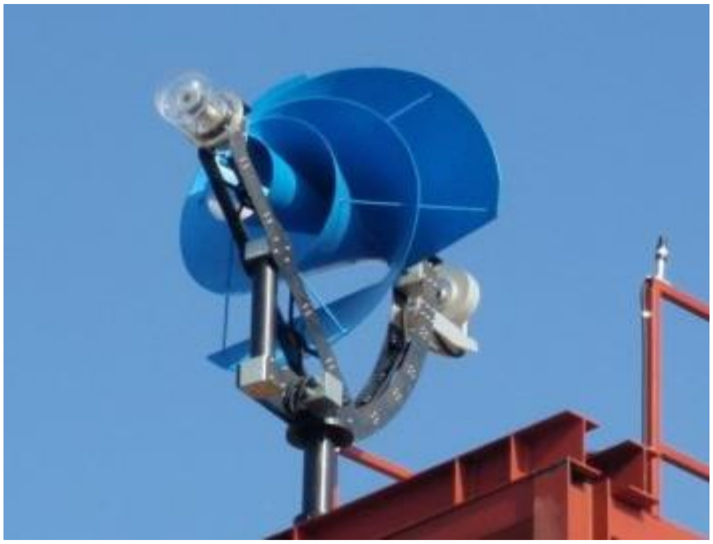


Figure 1: Cut-away image of a wind turbine

source of inefficiency in a wind turbine is its gearbox (similar to the transmission in a car[1]), where energy from the blades is transferred to the driveshaft of the turbine. The turbine requires a gearbox to maintain the most efficient speed on the drive shaft of the generator, and prevents damage caused by the blades moving too fast. There are dozens of companies and research institutes working to make gearboxes more efficient.

Figure 2: Liam F1 Wind Turbine



Recently a wind turbine has been developed that is capable of reaching 80% efficiency. Its Nautilus shell shape is a total of 165 pounds and spans 5 feet wide. This turbine has been designed for urban and residential use with an estimated capacity to generate half the electricity needed by a home. The Liam F1, featured in Figure 2[2], automatically points into the direction of the wind because of its shape and does not have the sound problems traditional wind turbines have. According to The Archimedes, the firm that developed the Liam F1, the turbine "generates an average of 1,500 kilowatt-hours of energy [per year] at a wind-speed of 5 m/s [16.4 ft/s], which resembles half of the power consumption of a common household".

"Dispatchable" power sources are capable of being powered up on short notice, dispatching additional electricity to the grid to supplement peak loads or accommodate sudden increases in the demand on the grid. These sources help balance supply and demand on the grid, which lacks storage capability. A wind turbine falls in to a hybrid category. Wind is erratic, so wind power cannot be truly dispatchable, nor is it reliable as a base load. At times when the wind is capable of sustaining power, it can be used as a base load, but when the wind dies, it must be quickly replaced by other sources. This means that wind turbines function as a surplus producer of energy. The challenge to wind turbines which makes them environmentally ambiguous is that when they are functioning, non-renewable energy can be scaled back, thus lowering emissions, but when the wind stops, they must be replaced with alternative non-renewable sourced energy.

Currently in the Montachusett Region

The following table identifies existing wind projects within the Northern Middlesex and Montachusett Regions (Mass DOER) (Mass.gov). The Northern Middlesex region does not have any wind projects. There should be additional narrative with this table that talks about the feasibility study in Winchendon and the additional consideration by the City of Gardner in additional wind turbines.

[1] http://www.teachengineering.org/collection/cub_/lessons/cub_images/cub_earth_lesson04_activity2_figure1.jpg
[2] http://images.gizmag.com/inline/liamf1urbanwindturbine-1.jpg

Table 1: Wind Turbines Installed in the MRPC/NMCOG Region

Advocate	City/Town	Capacity (kw)	Number of Turbines	Year Built
Mount Wachusett Community College	Gardner	3300	2	2011
Narragansett Regional Middle-High School	Templeton	1650	1	2010
North Central Correctional Center	Gardner	3300	2	2010

**Note: This chart shows only Montachusett Facilities since there are no currently in the Northern Middlesex Region.*

The Center for Wind Energy at UMass Lowell has unique expertise and capabilities to conduct research in the advancement of wind turbine science and systems. The group consists of many interdisciplinary faculty members whose research focuses on wind turbine manufacturing, reliability, energy storage, and design. The team is actively pursuing research supported by the National Science Foundation (NSF) through the I/UCRC and SEP research programs and the Massachusetts Clean Energy Center (Mass CEC) and has recently completed several projects supported by the Department of Energy, NSF, National Collegiate Inventors and Innovators Alliance (NCIIA), National Grid, Massachusetts Technology Collaborative, and UMass President's Office. The Center for Wind Energy has established collaborations and partnerships with several industrial partners, national laboratories and academic partners. These collaborations include TPI Composites Inc., the Wind Technology Testing Center, National Renewable Energy Laboratory (NREL), Sandia National Laboratories, Iowa State University, UT Dallas, and Texas A&M University. The mission of the UMass Lowell Center for Wind Energy is to conduct scientific research and perform education that will help to advance wind energy harvesting, making its use globally widespread.[3]

Regional Potential

According to the National Renewable Energy Laboratory, wind power in Massachusetts has an on-land potential of 3.3 terawatts, over the space of 205.6 km2. This means that the State can produce 3.3 terawatts if all 205.6 km2 are developed based on a 30% efficient turbine. Wind in Massachusetts is the strongest in the Berkshires and offshore at Cape Cod. Within the Montachusett and Northern Middlesex regions, there is greater potential for wind projects in the Montachusett region. Wind energy represents a promising future technology that can be applied within our region. There is still much work to be done on the capacity of turbines in order to make utility scale turbines more feasible in our region, where our wind speeds are only just above the cut-in speeds required by utility scale turbines. There is, however, greater potential for industrial or mid-sized turbines, as well as residential turbines, to be applied to the grid in order to lower costs and increase clean energy generation by replacing other fuel sources. Inventive wind energy technologies are also being developed, such as the shrouded wind

[3] http://www.uml.edu/Research/Centers/Wind-Energy/About-Us.aspx

turbine design being commercialized by Waltham, Massachusetts based Ogin, Inc.[4] These designs may advance the wind energy industry and will result in more efficient turbines with reduced environmental impact.

Wind Speed

There are detailed wind maps available for the Montachusett and Northern Middlesex regions, provided as Appendices C.1.a through C.1.f (also available at the MRPC web site: http://www.mrpc.org/resources/pages/mrpc-regional-wind-maps and the NMCOG site: http://www.nmcog.org/RegionalStrategicPlan/Maps/Map9_WindEnergyResources.pdf). Wind speeds are measured in meters per second at 3 different levels, 30 meters, 50 meters, and 70 meters. Wind turbines have been designed around these elevations, small and micro wind at 30 meters, industrial at 50 meters and utility scale at 70 meters. Each category is capable of producing different amounts of electricity: residential ranging from 400W to 10kW, utility scale turbines generally produce 0.5MW to the current record holder at 8MW, industrial scale generally fills the gap between residential and utility.

Surveys of wind speed in the area indicate 70-80m winds range from 5.0 meters per second to 8.1 meters per second (m/s). Some utility scale turbines are capable of operating at lower wind speeds such as this, rated between 1.0 and 2.6 MW. The wind speeds in the region do not allow these turbines to run at their full capacity. Within this wind speed range, more turbines are needed to achieve any meaningful generation. The more turbines able to fit in these areas, the more electricity can be produced. There are few locations that could sustain these turbines however. These locations are primarily on the range of hills and mountains surrounding Mt. Wachusett (the highlands in Gardner and Westminster) and the highlands around Ashby and Ashburnham (areas highlighted in deep brown and red on the map, see Appendices C.1.b and C.1.c). Based on the maps in Appendices C.1.d through C.1.f the NMCOG region does not have locations that are capable of sustaining medium or utility scale wind turbines.

Due to of the lack of wind speed in the range needed to produce utility scale wind power at a useful capacity; it is much more feasible to run small scale industrial use turbines. These would support individual industrial parks, rather than support the overall grid, while at the same time producing tax revenue. Surplus electricity produced by these installations could be sold into the grid, reducing the cost for residents. At the same time taxes generated by the installation could lower taxes for residents in the area. Based on GIS mapping, industrial scale turbines would do well in all locations where utility scale is possible.

Similarly, homes that are on the sides of the hills could benefit from residential scale turbines. Turbines in this category have a nameplate capacity ranging from 400W to 100kW, and are only about 30 meters (98 feet) tall. In a residential situation, wind power and solar power tend to complement each other quite well. If the wind is blowing, it doesn't matter if it is nighttime, electricity is generated. On sunny days that are hot, humid and without wind, a solar generator can produce ancillary or even surplus supply. Residential turbines generally have a low cut-in speed, and therefore can be profitable

[4] www.oginenergy.com [formerly FloDesign Wind Turbine Corporation]

almost anywhere in the region. The amount of time required to cover initial cost would vary with the cost, maintenance agreements and wind speeds of each specific site.

Planning and Zoning

Planning a location

A detailed study of the wind resource in the planned location of the windmill is necessary to ensure the proper siting, height and type of turbine to be installed. This generally requires the placement of a temporary structure called a Meteorological Tower or “Met Tower,” which measures the wind speed and direction at a given height with an anemometer (wind speed measuring device) and vane (instrument for measuring wind direction). The Met Tower is generally in place for at least a year to three years. Along with a met tower, some developers will incorporate the use of a Sonic Detection and Ranging device (SODAR). This device is capable of determining wind shear at different levels and allows for more detailed data, ensuring that when the turbine is built it can be configured to maximize the collection of wind energy. These SODARs tend to be extremely expensive, so they are generally used for short periods of time to minimize costs.

Once the wind resource is mapped out, decisions can be made on the make and model of the turbine in order to make the most efficient use of the resource. Turbines come in many different shapes and sizes based on the need of the location. The conventional horizontal axis wind turbine (HAWT) is visually similar to a giant fan with two or more blades. A vertical axis wind turbine (VAWT) often looks similar to an egg beater, and works by running the wind over a wing shaped surface, similar to how a sailboat tacks into the wind. The force that would normally be associated with lift is angled in such a way to push the turbine along the horizontal axis. A HAWT is more durable but its capacities require higher wind speeds, while a VAWT runs at lower wind speeds, but is less durable.

The developer must also consider the cut-in (the speed at which a wind turbine begins to produce electricity) and cut-out (the speed at which the wind is blowing too hard to efficiently turn the turbine) speeds. If the cut-in speed of the turbine is too high, the wind in the area may not be able to turn the turbine enough to actually produce electricity. Similarly if the cut out speed is too low, there is a risk of the turbine both not producing efficiently, and being destroyed by the high wind.

Finally, the developer must consider the height of the turbine, in order to mitigate the effects of sound and flicker. Flicker is the visual effect caused by the shadow of the turbine blades moving across the sun. Simple mathematical equations based on the angle of the sun during various times of the year can be used to predict areas subject to the effect of flicker. By minimizing flicker, the developer stands a higher chance of getting approval for their project because there will be fewer complaints from the general public. A noise study should also be completed to minimize complaints from neighbors, as well as ensure the turbine is within the legal limits set by Noise Control Policy regulations (310 CMR 7.10).

Drawbacks and Barriers

Wind turbine technology, despite being one of the most promising clean energy sources for the future, does have some drawbacks, ranging from aesthetic, to comfort, to scientific, to preservation.

Wind turbines generate two kinds of noise, audible and infra-sound. The current debate is that the infra-sound created is potentially harmful to humans. The wind industry maintains that there are no harmful effects of infra-sound on humans, while opponents claim that it can cause nausea, headaches, fatigue and irritability among other symptoms. Another issue is the audible sound - a wind turbine creates a "wooshing" sound, which some people find offensive, while others find it soothing. There are no standards for the setback from residences to minimize noise. However, in Massachusetts wind turbines and associated equipment must conform with the provisions of the Department of Environmental Protection's Division of Air Quality Noise Regulations (310 CMR 7.10).

Another potential health issue associated with windmills is the flicker that the blades create as they pass in front of the sun. Some people claim that the flickering effect can be severely detrimental to their health in similar ways as infra-sound. Experts confirm that while flicker is annoying it is not a confirmed health issue, except for those normally affected by strobe lights. Local Wind Turbine Bylaws attempt to address the minimizing of shadowing or flicker impacts. For a detailed study, please see the report from the State of Massachusetts Department of Environmental Protection entitled *Wind Turbine Health Impact Study, January 2012*.[5]

Another major issue with the perception of wind technology is that wind turbines are considered to be unattractive. Many people feel that wind energy should be out of sight and out of mind. The sound and visual objections often are veils to hide the fact that homeowners are fearful that a wind turbine in the immediate area of their property will cause their property values to fall. There is not enough data currently to verify the decrease in property value.

Barriers to wind development include the absence of lands that are not capable of being developed due to existing environmental constraints such as protected lands, property boundaries, low wind-speeds, and cost.

Involving the General Public

Wind Turbines are highly controversial and hotly contested in some areas. Wind developers must do everything possible to answer any and all questions. When it comes to zoning, most towns will hold a town meeting. At these meetings the facility siting/zoning process must be inclusive and transparent in order to gain acceptance for the project. By maintaining a positive and open stance, the developer is more likely to avoid permitting issues.

Additionally, as part of this project, an educational workshop on Wind Energy was held on February 12, 2003 at the MRPC offices. The workshop was geared toward both the private and public sector. One guest speaker was a representative from the Consensus Building Institute (Stacie Smith), who presented on Collaboration and Public Engagement in Wind Energy Siting.[6]

[5] http://www.mass.gov/eea/docs/dep/energy/wind/turbine-impact-study.pdf

[6] For more information, please contact the MRPC for a copy of this presentation.

Zoning

Some communities in the MRPC and NMCOG regions have approved zoning bylaws or ordinances for wind turbines. The majority of these zoning laws revolve around the placement of the turbine in regards to setbacks from property lines and buildings, and the height requirements of the turbine. Setbacks generally range from at least 25 feet for small turbines, to three times the height of the turbine from base to highest wing arc, resulting in setbacks of more than 1,300 feet. Several communities have decided to opt for the engineered fall zone (the distance from the base of a turbine which an engineer has deemed to be where a critically damaged turbine could fall) instead of basing the setback on the height of the tower alone.

A wind overlay district can be a major factor in the ease of installation and planning of a wind turbine. The Town of Ashby has established a Wind Energy Facility Zoning Overlay District, where wind turbines are permissible through a special permit (http://www.ci.ashby.ma.us/document/planbd/Wind%20Energy%20Facility%20Zoning%20Overlay%20District%20Map.pdf). The overlay district basically covers the entire town with the exception of the downtown area and the area around Mount Watatic (see Appendix C.2). Establishment of an overlay district similar to this would make the zoning and siting of turbines more transparent, rather than limit their development to a specific parcel list or individual districts. An overlay district also reduces the conflicts between the developers and the general population simply because of its visual quality (because it is easily seen on a map rather than a complex list of directions and descriptions bounding the land area).

A wind energy bylaw can also provide additional benefit to communities. At the previously mentioned Wind Energy workshop (see "Involving the General Public" above), guest speaker Stephen Wallace (Westminster Town Planner) talked specifically about his experience crafting a wind energy conversion system bylaw for Westminster.

A list and comparison of zoning bylaws and ordinances is attached in Appendix C.9. Local communities that have approved wind turbine bylaws or ordinances include Ashby, Ashburnham, Athol, Fitchburg, Gardner, Groton, Leominster, Lowell, Pepperell, Sterling, Westminster and Winchendon. When proposing and designing a bylaw or ordinance, local municipalities must be careful not to over-regulate, and make it too cumbersome to the average individual who may want to build an individual resource for their own property. Making laws too complicated it can be very discouraging to developers. As part of this project, MRPC worked with the Townsend Planning Board to draft a local wind energy conversion system that was brought to the Fall 2013 Town Meeting and adopted (it is included as Appendix C.3).

Attached are the model wind bylaw from the Massachusetts Department of Energy Resources (DOER) and two examples of bylaws (Appendices C.3. and C.4), which differ from each other in their restrictions. Appendix C.5 provides a listing of the links to the local Wind Bylaws and Ordinances in the two regions.

Siting

Wind turbines are subject to various siting requirements and restrictions both due to their height and mechanical nature. For example, structures over 200 feet tall are governed by the Federal Aviation Authority (FAA), which is then responsible for notifying other agencies, such as the Department of Defense (DoD) and the National Oceanographic and Atmospheric Agency (NOAA). The mechanical nature of the wind turbines also has an impact on birds, which comes under the review of the U.S. Fish and Wildlife Service (FWS). Furthermore, considerations must be made for the comfort of residents who live near the installation. There are numerous accounts of individuals claiming that the wind turbines cause various health impacts due to shadow flickering and harmonic interference, despite studies indicating that there is no evidence of these health impacts. The NREL and EPA Wind Power Decision Tree for the sighting of wind turbines can be located by following the link in Appendix C.10.

Wind Turbine Sound and Human Health

In December 2009 the American Wind Energy Association (AWEA) and the Canadian Wind Energy Association (CanWEA) released a white paper developed by a panel of medical doctors, audiologists, and acoustical professionals. The panel reviewed current literature about wind turbines and their perceived health effects on people living nearby. The white paper concluded that there was no evidence that the audible or sub audible sounds from wind turbines created health issues for humans.

The Massachusetts Department of Environmental Protection (MasDEP) released a *Wind Turbine Health Impacts Study* in 2012[7], which provided recommendations on changing wind turbine regulations. In July 2013, MassDEP released the *MassDEP Discussion Document: Potential Revisions to MassDEP Noise Regulations and Policy to Address Wind Turbine Noise.* The paper discusses potential revisions to the Noise Regulations and Policy, technical issues associated with implementation of the proposed regulations, as well as pre-construction permitting.

Wind Energy and Wildlife

According to wind energy proponents, wind turbines pose minimal risk to wildlife and their habitats, primarily due to the lack of emissions and small footprint installation. However, there is evidence that birds, bats and turbines are not capable of coexisting without at least some damage to one population or another. When siting a turbine, careful consideration of migration patterns and nesting areas is a requirement, both to prevent damage to indigenous bird and bat populations and to prevent damage to turbines. The wind industry is actively researching ways to mitigate the effect turbines have on birds and bats. The Department of Fish and Wildlife can provide assistance in identifying a safe location for the turbine.

"I want to make sure Audubon is doing everything we can to promote both conservation and wind energy." Flicker summed up the Audubon perspective with stark directness. "When you look at a wind turbine, you can find the bird carcasses and count them," he said. "With a coal-fired power plant, you can't count the carcasses, but it's going to kill a lot more birds."

[7] http://www.cbuilding.org/sites/default/files/WNTAG MassDEP Discussion Document 3.pdf

The U.S. Audubon Society has gone to Congress to promote wind turbine siting and technology that is safe for birds and other wildlife. The Mass Audubon Society worked with the U.S. Department of Fish and Wildlife to develop a set of guidelines for land based wind projects as well. The Mass Audubon Society supports sustainable wind development that follows guidelines for proper wildlife conservation.[8,9]

U.S. Fish & Wildlife Service (FWS)

The United States Fish and Wildlife Service (FWS) is located within the U.S. Department of the Interior (DoI) and is primarily responsible for the protection of wildlife. However, FWS is also responsible for promoting and regulating renewable energy projects on public land. Their policies and regulations can also have an impact on the development of private wind technology. It is prudent for wind project developers to consult with FWS early in the process.

The Federal Aviation Administration (FAA)

The FAA has jurisdiction on any construction higher than 200 feet. This means that utility scale turbines, which are generally over 400 feet, and most other turbine, are subject to permitting. Small planes are required to fly above 10,000 feet, while commercial aircraft are regulated to 60,000 feet. Apart from crop dusters (low flying airplanes which spray crops with chemicals), a collision is not the concern; rather it is the interference with ground radar, and location in relation to airstrips. The FAA will conduct an analysis for each turbine and determine if the installation causes clutter on radar, preventing the FAA from safely tracking air traffic.

The FAA is not the only agency that employs radar technology. The DoD extensively uses radar to guide its aircraft in training exercises and to protect its pilots from collisions. The DoD has embraced wind technology on several of its bases, including air bases, in order to provide surplus power, without adverse effects to the radar and flight of its crews.

The National Oceanic and Atmospheric Administration (NOAA) also operates radar installations across the United States in order to track weather patterns. Wind Farms can produce a radar signature (a blip on a radar screen), but if NOAA is aware of the location, they can compensate for the signature and continue to provide vital weather information. The FAA will notify the DoD, NOAA and any other government agency that relies on radar and air transportation about potential installations. Each agency will have a chance to raise concerns about the location of the installation. If specific concerns are identified, the project developer will need to work with the federal agencies to remedy the concerns, possibly through relocation.

As part of the new technology available, Holographic Radar looks at objects in three dimensions instead of current radar systems that only look at objects in the horizontal dimension. This means that radar systems can more readily distinguish between the signature of a spinning turbine blade and the

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[8] http://www.massaudubon.org/our-conservation-work/climate-change/climate-change-policy/wind/position-statement

[9] http://www.renewableenergyworld.com/rea/news/article/2006/12/for-the-birds-audubon-society-stands-up-in-support-of-wind-energy-46840

signature of an aircraft. If this technology comes to fruition, it will mean that large tracts of land around airports can safely be used for wind turbines and even wind farms.

Furthermore the FAA regulates the lighting of tall structures (see the lighting law link in Appendix C.6). Depending on the location and height of the turbine, it must be marked with a visual beacon (a signal for guidance) in order to prevent collisions with aircraft. Turbines cannot breach the angle of approach and other invisible surfaces of an airport, so as not to be a danger to navigation. A detailed map of the invisible surfaces from the Washington State Department of Transportation is available in Appendix C.7 (Washington State DOT provides best visual representation available)[10]. Any tall object sited near the invisible surfaces is strictly regulated with regard to coloration and lighting in order to keep aircraft safe from collision.

U.S. Forest Service (USFS)

The Forest Service, a section of the Department of the Interior (DoI), has a framework in place to allow wind energy projects to be placed on Forest Service lands. These special use permits are governed by a set of USFS draft directives.

AWEA Siting Handbook

The AWEA Siting Committee has developed a handbook for developers to guide the process of siting a wind turbine. The handbook highlights environmental issues and explains the specific roles of government agencies and the permitting needed from these agencies. The handbook is available on the AWEA website at http://www.awea.org/.

For more information regarding siting and regulation agencies please see Appendix C.8.

MRPC and NMCOG GIS Mapping

The Montachusett Regional Planning Commission (MRPC) and Northern Middlesex Council of Governments (NMCOG) have extensive Geographic Information Systems (GIS) mapping of the region's wind resources. Combining the wind map layer with other layers of interest, such as brownfields, abandoned properties, and industrial zones, can provide useful information in order to site wind turbines. The mapping capabilities can be found at the MRPC website: http://www.mrpc.org/resources/pages/maps or is available through the MRPC. Wind resource information and other GIS information for the Northern Middlesex region may be requested by contacting gis@nmcog.org or by calling 978-454-8012, extension 115.

Permitting and Regulations

Permitting and regulations in each community vary with its bylaws and ordinances. Generally, most communities have sound and flicker laws, and liability insurance requirements. Some communities, like Lowell and Westminster, have specific historical district regulations as well. A financial surety or other form of financial insurance for the community, to be used in the event of turbine abandonment, is required by many communities. The surety generally covers about 125% of the cost of removal, based on a recommendation by the State's DOER model bylaw.

[10] http://www.wsdot.wa.gov/aviation/Planning/CivAPImagSurfBig.htm

Developers must be aware that most towns and cities have a time limit on the permits, ranging from six months to two years. This means that if a turbine is not built within the permitted time period, the permit will expire and the process must be restarted. Furthermore, some towns have a permit that will expire on the actual use of the turbine, generally on the order of 15-25 years. The permit can be renewed or extended to fit the lifetime of the turbine.

See Appendix C.8 for a detailed table showing Local, State, and Federal permitting laws and regulations. The document containing the table was published by UMass Amherst's Renewable Energy Research Laboratory. The full document which Appendix C.8 is derived from also has a detailed listing of each community's permitting boards broken down by scale of the turbine, generally the Planning Board or Building Commissioner.

Recommendations

Going forward, the MRPC and NMCOG should assist each community to develop a Wind Energy Facility Zoning Overlay District. This will aid in the streamlining of future projects. Continuing to encourage municipalities to consider wind energy development in their comprehensive plans, including identifying locations where the municipality encourages wind energy systems to be located or not, will provide a basis for the growth of wind energy in Massachusetts and our regions. Encouraging use of small wind turbines on municipal buildings will aid in the lowering of municipal costs, freeing money for other projects, or mitigation of the effects of climate change. The MRPC and NMCOG should aid communities in changing permitting of small wind turbine systems to a "by right" process in some or all districts, particularly industrial zones. By treating small wind turbines as improvements to a property, not as commercial or industrial projects, could help bring more investors, residents and developers to a community while reducing or waiving permit fees will encourage the installation of wind energy systems. Communities should be encouraged to "lead by example" and introduce small wind turbines, and/or new wind technologies on municipal buildings.

PHOTOVOLTAICS

Overview of Solar Power

As one of the most abundant renewable energy sources currently being developed across the United States, solar photovoltaic cells (PV) convert sunlight directly into electricity by using photons from the sun's rays. In Massachusetts solar power is becoming more and more common due to a better understanding of the environmental benefits, as well as the economic incentives offered at the state and federal level.

This section provides a brief history of solar power technology, describes Massachusetts' regulatory framework, and discusses incentives, initiatives and planning and permitting requirements related to solar. It also highlights existing solar power facilities in the Northern Middlesex and Montachusett regions and discusses the potential for solar power to enable a reliable, affordable and environmentally sound future for the Northern Middlesex and Montachusett regions.

History

Solar power technology dates back to the mid-1800s when solar energy plants were developed to heat water that created steam to drive machinery. In 1839 Alexandre Edmond Becquerel described how "shining light on an electrode submerged in a conductive solution would create an electric current" and in 1876, William Grylls Adams and Richard Day discovered that selenium produced electricity when exposed to light.[11] In 1922 Albert Einstein received the Nobel Prize for his work on the photo electric effect, the basis of photovoltaic technology. Later, in 1954 Calvin Fuller, Gerald Pearson, and Daryl Chapin collaborated to produce the first modern PV cell, which produced electricity and was efficient enough to run small electrical devices. The *New York Times* stated that this discovery was "the beginning of a new era, leading eventually to the realization of harnessing the almost limitless energy of the sun for the uses of civilization".

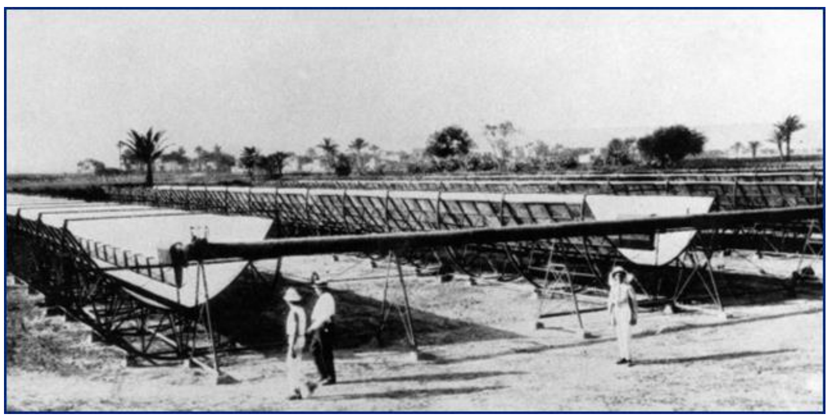


Image 1: Workers Inspect the First Commercial Solar Power Plant (National Geographic)

In 1956 the first solar cells became available commercially, although the cost exceeded the reach of most people. In the early 1970s the price of solar decreased from $100 per watt to around $20 per watt, resulting in a large increase in the use of solar cells into the 1990s. Recent new technology has

[11] http://www.energymatters.com.au/renewable-energy/solar-power/solar-panels.php

created screen printed solar cells, solar fabric that can be used to side a house, and even solar shingles that can be installed on roofs.[12]

Solar Technology

Solar photovoltaic (solar PV) systems convert sunlight into electrical energy using panels that connect to a building's electrical system and/or the electrical grid. Solar installations can be roof-mounted or ground-mounted and consist of solar cells, an inverter, racking, electrical equipment and meters. All of the components work together to produce electricity: solar cells produce direct current (DC), while the inverter converts DC current from the solar modules into household AC current. Mounting and racking fasten the solar panel to the rooftop or to the ground, and wiring and electrical equipment connects the panels to electric meters and to the grid. For residential installations, one meter shows consumption from the utility company's electric grid, while the second meter tracks the electricity produced by the solar array.[13] When connected to the power grid, the excess electricity feeds into the grid and is credited to the customer's electricity account. When the sun is not shining and the system cannot produce electricity, the grid supplies back-up electricity, as necessary.

Figure 3: Residential Grid Connected PV System

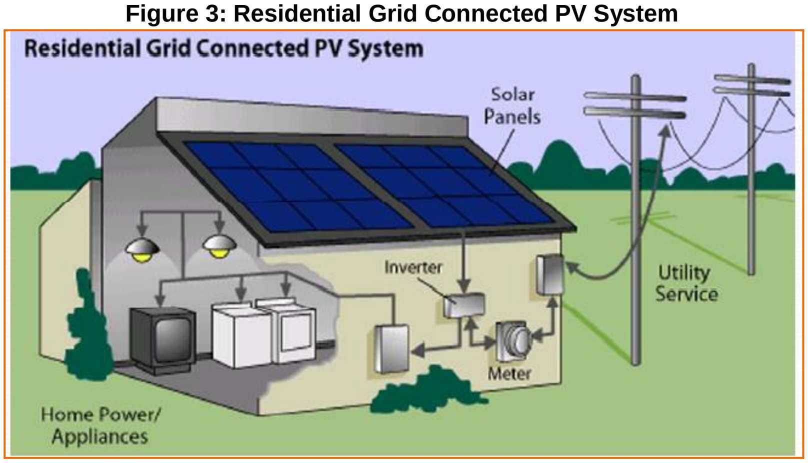


Image Credit: MassCEC

In order to place a solar panel on a residential property, there must be adequate roof space and the roof must be generally south facing. While south is the best angle to mount the panels, they can be mounted less economically to the west, east or north sides of the roof as well. However, this often requires the panels to be mounted on brackets that tilt them toward the south, which can be considered unfavorable aesthetically, and can become a barrier to installation. In addition, a penetration-free and shade-free portion of the roof is needed. For many residents, these building design and layout requirements can be a barrier to the installation of solar panels altogether – even if they have the financial resources. About 80 percent of ratepayers in Massachusetts cannot install solar panels on their roof, either because they have a roof that is not suitable for the panels or no roof at all, as in the case of

[12] www.experience.com/alumnus/article?channel_id=energy_utilities&source_page=additional_articles&article_id=article_1130427780670

[13] http://www.harmonyenergyworks.com/solar-101/basic-solar-components/

renters or condos.[14] For example, an analysis of 6,400 homes in Westford found that approximately 20% had the potential for solar. The remaining homes were unsuitable due to shading, incorrect orientation or other site factors.[15]

One way in which communities are striving to overcome this barrier is to install local community solar farms. Community solar (a.k.a. solar farms, solar gardens) refers to any solar project that has multiple participants where each person finances a small portion of the total project cost and shares proportionally in the project's benefits. Community shared solar is often a good alternative for those whose property may not be conducive to solar panels. In the Montachusett region, the Town of Harvard recently installed a solar garden, which is located on a tract of land in Harvard. Local residents in the correct utility zone can purchase a share of solar power, and benefit from decreases in electricity costs through a credit on their National Grid electric bill. The Harvard Solar Garden held their opening ceremony on June 27, 2014. As of May 2014, almost 300kW had been installed of the total anticipated capacity of 500kW.[16]

PV System Size and Cost and Placement

There are three typical sizes of solar PV systems. The Residential System size is about 5kW, and costs about $20,000 to install ($4 per watt). A small commercial system is about 300kW and costs about $1,000,000 to install ($3.33 per watt), and a larger commercial system is sized at about 10,000W or 1 MW and costs about $3,000,000 to install $3.00 per watt.

Image 2: Residential, small commercial and large commercial solar installations

From left to right: Typical residential solar, small commercial and large commercial installation at Westford Solar Park. (Source: MassCEC and Cathartes Investments).

Installation of solar panels can be relatively expensive when compared to conventional power sources, and as a result, upfront cost can be one of the major barriers to installing solar panels. Fortunately, as the PV market has matured, the price of PV has decreased – over the last 10 years the installed cost for solar PV has dropped by 30%. In addition, over the past few years, solar projects have become more economical due to the numerous incentives available at both the state and federal level.[17] Power purchase agreements (PPA) and leases are one way to overcome the cost barrier. PPAs are

[14] http://www.enterprisenews.com/article/20140526/News/140527216
[15] http://www.sustainablewestford.org/2013/06/09/solar-challenge/
[16] http://www.harvardsolar.org/
[17] DOER Solar PV Financial Webinar for Massachusetts Financial Institutions

particularly attractive for municipalities and have become more common as a way to purchase renewable energy at the municipal level. A PPA is a contract that allows a consumer to purchase energy produced by a renewable energy facility owned by a third party. The energy can be used either for a specific purpose or delivered into the electric distribution grid, or both.

Today many solar companies are working directly with municipalities as well as residents to assist with project financing through leases and PPA agreements. For example, the City of Lowell recently joined in a PPA with Ameresco, Inc. to improve defunct and aging equipment, increase monetary savings, and develop environmentally sustainable infrastructure. [18] Ameresco secured financing for the project, and the City of Lowell pays Ameresco an expected 20-year discounted electricity rate as compared to anticipated National Grid rates plus the commodity cost of electricity. The agreement impacts 47 buildings with a total of 2,864,730 square feet, and will result in an estimated annual energy savings of $1,522,679. The project is also expected to save the equivalent of 6,158 tons of carbon dioxide emissions per year. To date five rooftop-mounted solar PV systems, located at three elementary schools, a middle school, and the Lowell Memorial Auditorium have been installed. Ameresco did face several challenges during the design and installation phase including constraints of the existing roof systems, the age of the roof structure, obstructions on roofs and shade from existing buildings and/or trees. [19]

Installation and Maintenance

In general, solar panels are relatively low maintenance because they have no moving parts, the inverter turns on and off automatically, and rain keeps the panels clean. Snow slides off the panels, and is not typically an issue in Massachusetts. For smaller systems, annual inspections are recommended, while for larger systems, performance should be continuously monitored remotely. An installer warranty covers parts and labor and typically lasts 1 to 5 years. The manufacturer warranty typically lasts 25 years for the solar panels and 5 to 10 years for the inverters.[20] DOER recommends installation by a licensed Massachusetts electrical contractor with North American Board of Certified Energy Practitioners (NABCEP) certification.

Today, hundreds of thousands of houses and buildings around the world have solar PV systems on their roofs.[21] In 2013 there were 140,000 new solar installations in the U.S., bringing the total to over 445,000 PV systems producing over 13,000 MW of cumulative solar electric capacity, which is enough to power more than 2.2 million average American homes.[22] In Massachusetts the solar installations

[18] Ameresco, Inc. is an independent provider of energy efficiency and renewable energy solutions for facilities throughout North America.
[19] http://www.lowellsun.com/todaysheadlines/ci_24852844/lowell-turns-former-landfill-into-lucrative-solar-venture#ixzz35Bue0IPD
[20] DOER Solar PV Financial Webinar for Massachusetts Financial Institutions
[21] U.S. Energy Information Administration
[22] http://www.seia.org/research-resources/solar-industry-data

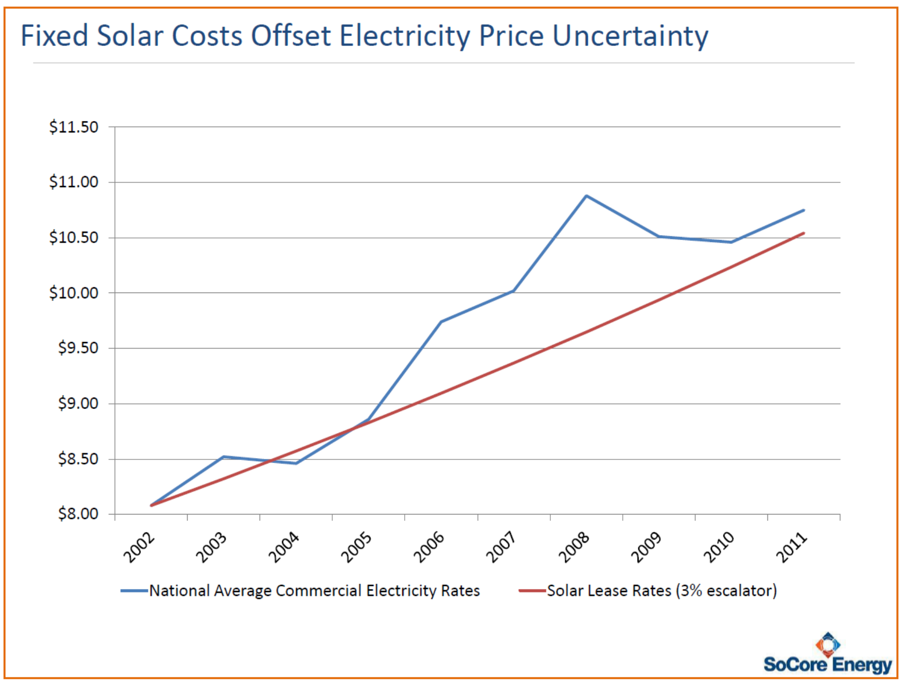
produce over 464 MW of solar power – enough to power 75,200 homes.[23] The average New England household uses 7,452 kWh per year.[24]

Benefits of Solar Power

PV systems are quiet and non-polluting, and offer stable pricing and reduced electricity costs when compared with traditional fuel sources (Exhibit 1). Solar power pricing is estimated to be more stable and less volatile than fossil fuel pricing, resulting in a more predictable and lower electricity bill.

Installing a solar PV system can add equity to a home, and systems that produce more energy than used on site receive a credit on their bill through the process of net metering. Additionally, there are also environmental and health benefits associated with solar power. By switching to solar energy, there is a reduction in the emission of harmful greenhouse gases, cancer causing agents, smog forming VOCs, and particulate matter.

Exhibit 1: Cost of Solar versus Traditional Electricity Sources



Source: SoCore Energy Presentation, November 14, 2012

One of the drawbacks of solar power is that it does not generate power when the sun is not out (e.g. at night, or on rainy days). As a result, it is not typically considered a base power source. However, thanks to new storage technologies, the world's first utility-scale commercial baseload solar power plant is now in existence in the Spanish province of Andalucia. The plant is called Gemasolar and is run by Torresol Energy.[25] Using molten salt heat storage technology, the plant was capable of producing 36

[23] http://www.seia.org/state-solar-policy/massachusetts
[24] Mass CEC Solar Guide
[25] http://www.forbes.com/sites/tonyseba/2011/06/21/the-worlds-first-baseload-247-solar-power-plant

days of 24-hour power production in the summer of 2013. The ability to store solar power and use it as a baseload opens up new opportunities for the use of solar power.

Interconnection

Interconnection is the process of connecting a solar PV system to the electric grid. Prior to interconnecting, solar PV owners must have written approval from the local utility in the form of an 'Interconnection Service Agreement' and 'Authorization to Connect'. Interconnection can occasionally serve as a barrier to solar PV installations. For example, if the power grid is not equipped to handle the amount of power that will be produced from a solar PV project, that project will not be able to move forward. In addition, solar installations that are too far from the interconnection source can prove problematic because it may not be economically feasible to build the infrastructure needed to connect to the grid. It is vital that the interconnection process be streamlined, uniform, and as transparent as possible. Toward that end, Massachusetts has created Distributed Generation (DG) and Interconnection standards, which contain comprehensive information on the utility interconnection process. [26] The Massachusetts Clean Energy Center (MassCEC) also provides guidance on this process through their *Interconnection Guide for Distributed Generation*, which can be found on their website. [27]

Existing Facilities

Solar installations across the Northern Middlesex and Montachusett Regions are listed in the DOER database for Qualified Generation Units for the Renewable Portfolio Standard (RPS) Class I Solar Carve-Out, which contains all the projects currently generating SRECs. While this database is quite extensive, there are some projects that do not produce SREC's and would not be contained in the database. In particular, projects funded through the American Reinvestment and Recovery Act (ARRA) are not included. To obtain the most inclusive list of solar installations across the region we combined the DOER SREC database with the ARRA project database, which contains projects affiliated with the Supplemental Energy Program (SEP), Energy Efficiency Conservation Block Grant (EECBG) program and Clean Energy Results Program (CERP).

Installations listed in the SREC database are categorized as Agricultural, College/University, Commercial/Office, Hospital/Healthcare, Industrial, Mixed-Use, Multi-family Residential, Municipal/Government/Public, Other, Religious, Residential, Restaurant/Food Service, Retail, School (k-12) and Utility. The types of installations listed in the ARRA database are categorized as Commercial, Farm, Municipality, Regional School District, State Agency, State Authority, State Community College, and State University.

To display this data, SREC and ARRA data have been combined using the following general categories: Agricultural, College/University, Commercial, Industrial, Multi-family residential, Municipal, Religious, Residential, Retail, School (k-12) and other. It is important to note that some larger solar installations (e.g. solar parks, solar farms and solar gardens) are classified as "Industrial", while others are classified as "Other". In addition, it is also important to note that despite our effort to create an all-

[26] https://sites.google.com/site/massdgic/
[27] http://www.masscec.com/content/interconnection-guide-distributed-generation

inclusive data asset, some projects may still not be listed in the tables below due to the fast pace at which solar projects are being developed. In particular, projects that have not produced SRECs as of July 9, 2014 (the data download date) may be excluded from the tables and charts below. Whenever possible, an effort has been made to manually add these projects.

Northern Middlesex Region

There are approximately 645 solar installations across the Northern Middlesex region, producing 20,901 kW of solar power, as of July 9th, 2014. Due to the large number of solar installations across the region, individual installations are not shown in the tables and data is presented in a summary format. Solar installations across the region include large-scale solar facilities in Billerica, Westford and Tyngsborough. Additional local projects include solar installations at the Lowell Regional Transit Maintenance Facility, the Lowell Regional Wastewater Treatment Facility, and the United Teen Equality Center (UTEC) in Lowell and the Stony Brook School in Westford. As shown in Table 2, Lowell has the highest number of installations at 187, followed by Billerica at 110.

Projects funded through the Massachusetts Energy Management Pilot Program for Drinking Water and Wastewater are not included in the databases because they do not generate SRECs. These projects have been manually added, and include a 485 kW installation at the Chelmsford Water Treatment Facility, and a 30 kW installation at the Lowell Regional Wastewater Treatment Facility.[28] An 8.8 kW solar installation on the Chelmsford Library as well as a 37 kW installation at the Parker Middle School in Chelmsford were not included in the databases and have been manually added.

Table 2: Number of Solar Installations per Community in the Northern Middlesex Region

Municipality	College/ University	Commercial	Industrial	Multi-family residential	Municipal	Residential	Retail	School (k-12)	Other	Total
Billerica	0	5	1	0	0	104	0	0	1	111
Chelmsford	0	6	0	0	3	88	0	1	0	97
Dracut	0	1	0	1	0	81	0	0	0	83
Dunstable	0	0	0	0	0	7	0	0	0	7
Lowell	5	10	0	6	3	163	0	0	0	187
Pepperell	0	0	0	0	0	11	0	0	0	11
Tewksbury	0	5	0	0	0	33	1	0	0	39
Tyngsborough	0	3	1	0	0	35	0	0	0	39
Westford	0	3	4	0	1	64	0	0	0	72
Total	5	33	6	7	7	586	1	1	1	646

Source: DOER SREC Database July 9, 2014, Massachusetts ARRA Database, DOER
http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/qualified-generation-units.html

28 http://water.epa.gov/aboutow/eparecovery/upload/2010_01_26_eparecovery_ARRA_Mass_EnergyCasyStudy_low-res_10-28-09.pdf

The Northern Middlesex region has five communities - Chelmsford, Lowell, Tewksbury, Tyngsborough and Westford - which have been designated as Green Communities by the Commonwealth of Massachusetts. In addition, Chelmsford and Lowell participated in the SolarizeMass program and both were awarded funding for an Energy Manager. In Westford, the non-profit "Sustainable" Westford partnered with Next Step living to initiate a solar outreach campaign called the Westford Solar Challenge, which was designed to encourage solar at the local level.

Various scale solar facilities have been developed or are proposed in the Northern Middlesex region. The Westford Solar Park is a 4.5 MW solar plant with more than 14,000 panels situated on 22 acres. The Park opened in 2012 and is expected to generate 150 GWh of energy over its lifetime. A 6 MW project is also under development for the closed Shaffer landfill in Billerica. In Chelmsford, town officials are using a $12,500 state grant to explore the possibility of a solar farm at the Swain Road landfill. In addition, as previously mentioned, a solar array on Lowell's closed and capped landfill on Westford Road, recently went live producing 1.5 megawatts of electricity (Exhibit 2).

Exhibit 2: Lowell's closed and capped landfill with solar array

When viewed in terms of kilowatts, as shown in Table 3, Billerica has the highest production with 6,830 kW produced, which is followed by Westford with 5,551 kW produced. These are likely due to the large-scale solar installations in these communities.

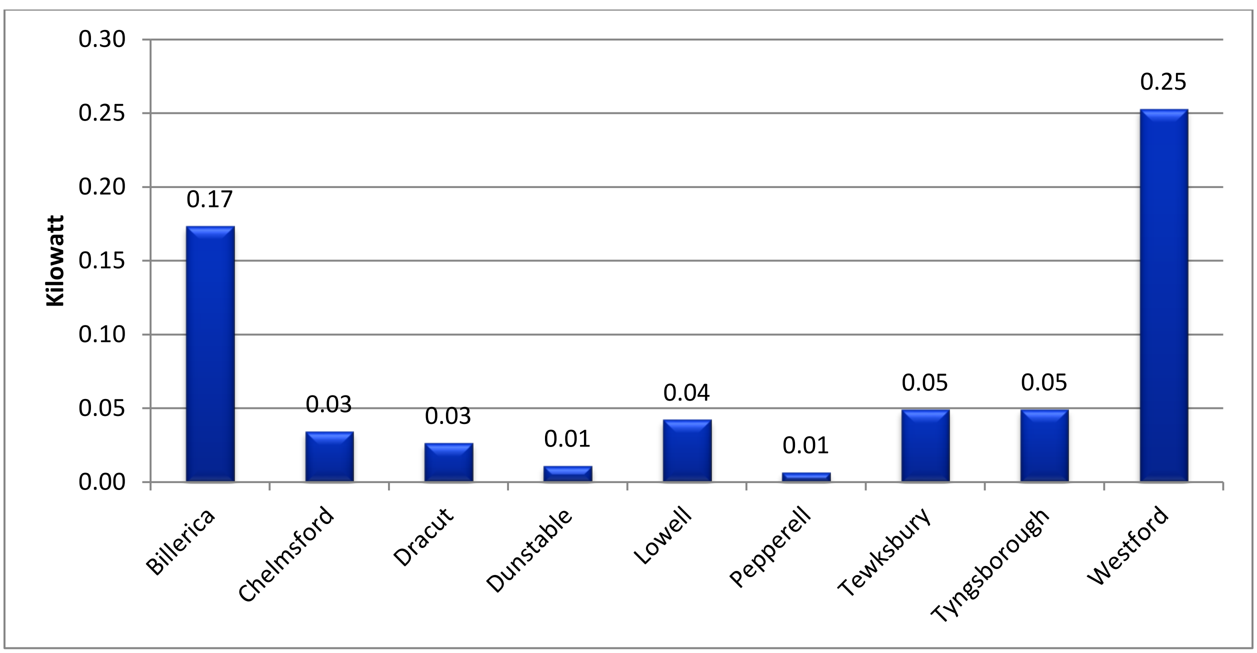
Table 3: Number of kW of Solar Produced by Community in the Northern Middlesex Region

Municipality	College/ University	Commercial	Industrial	Multi-family residential	Municipal	Residential	Retail	School (k-12)	Other	Total
Billerica	0	312	82	0	0	580	0	0	5,999	6,973
Chelmsford	0	140	0	0	515	506	0	37	0	1,161
Dracut	0	65	0	229	0	484	0	0	0	779
Dunstable	0	0	0	0	0	35	0	0	0	35
Lowell	492	642	0	495	2,144	721	0	0	0	4,495
Pepperell	0	0	0	0	0	75	0	0	0	75
Tewksbury	0	898	0	0	0	198	323	0	0	1,420
Tyngsborough	0	298	47	0	0	210	0	0	0	555
Westford	0	526	4,547	0	39	439	0	0	0	5,551
Total	492	2,881	4,676	725	2,698	3,248	323	37	5,999	21,044

Source: DOER SREC Database July 9, 2014, Massachusetts ARRA Database, DOER
http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/qualified-generation-units.html

In terms of kilowatts per capita, Westford has the highest at 0.25kW per capita, followed by Billerica at 0.17 kW per capita, as shown in Exhibit 3.

Exhibit 3: kW of Solar per Capita in the Northern Middlesex Region



Source: DOER SREC Database July 9, 2014, Massachusetts ARRA Database, DOER
http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/qualified-generation-units.html

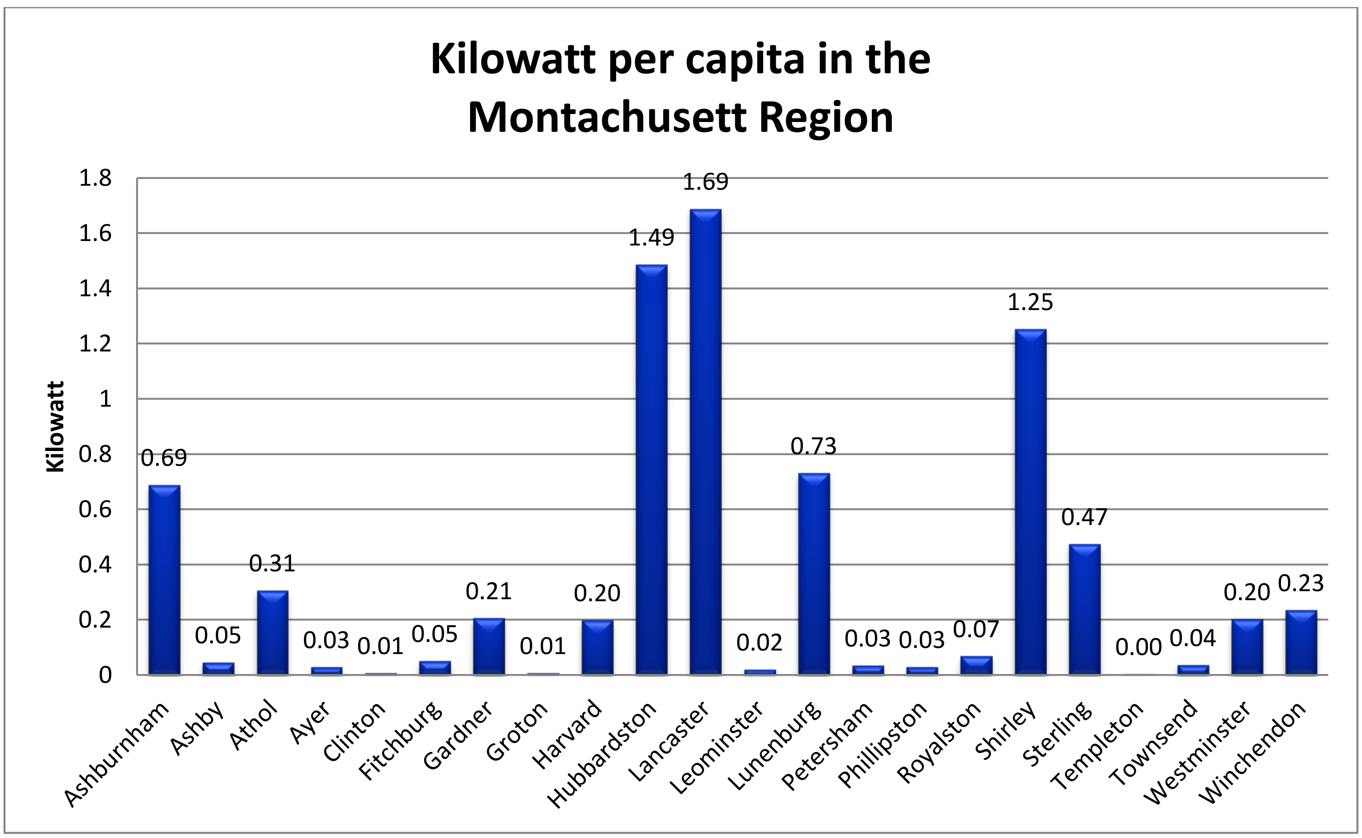
Montachusett Region

According to the SREC and AARA database there are approximately 558 solar installations in the Montachusett Region, producing 56,648 kW of solar power as of July 9th, 2014. MRPC has eleven green communities – Ashby, Athol, Ayer, Gardner, Harvard, Lancaster, Leominster, Petersham, Shirley, Townsend and Westminster. In addition, Harvard and Shirley have participated in the SolarizeMass program.

While many of the solar installations in the Montachusett Region are at the residential level, there are a variety of larger installations throughout the region. In 2012 the Town of Lancaster developed one of the first municipally-owned and operated solar facilities in the State. The Lancaster landfill solar facility consists of a 500kW array on 2.78-acre gravel pit adjacent to the closed landfill. In Shirley, a 3 MW solar array containing 37,047 panels was completed in the spring of 2014 and provides power to Devens.

As with the Northern Middlesex Region, there are some installations in the Montachusett Region not included in the SREC or AARA database. The solar installation at Carlson Orchard in Harvard, MA is not included in the database because its grant funding meant it was not eligible for SRECs. Carlson Orchards received grants totaling $595,000 to help in the installation of the 1,050 solar photovoltaic panels at their Harvard, MA farm. In addition, a 40 KW Townsend Water Treatment Facility Project funded through the Massachusetts Energy Management Pilot Program for Drinking Water and Wastewater has been manually added to the table in Appendix D.1 and D.2.

Exhibit 4: kW of solar produced per capita in the Montachusett Region



Source: DOER SREC Database July 9, 2014, Massachusetts ARRA Database, DOER

In the Montachusett Region the Town of Harvard has the highest number of installations with 86, and is followed by Fitchburg with 55 and Leominster with 53. Lancaster is the highest producer of solar energy with a production of 10,689 kW, followed by Lunenburg at 7,430 kW and Shirley at 7,280 kW. When viewed per capita, Lancaster and Hubbardston have the highest per capita production at 1.69 kW per capita and 1.49 kW per capita respectively, followed by Shirley at 1.25 kW per capita.

Planning, Permitting and Zoning

Installation of a solar PV system requires the same local approvals as any other building construction and electrical work. At the local level, solar PV Systems must obtain a municipal building permit, municipal electrical permit and a Utility Interconnection Agreement. In addition, installations must be in accordance with any local zoning bylaws and must meet standards enforced by the Conservation Commission, the Historical Commission, the Planning Board and the Zoning Board.

The Massachusetts General Laws include a *Solar Easements & Rights Law*, M.G.L. Chapter 40a §9B, which is designed to protect solar exposure and authorize zoning rules that prohibit unreasonable infringements on solar access. In addition, the statute allows local zoning boards to issue permits creating solar rights. Furthermore, M.G.L. c. 40a §3 prohibits local governments from enacting local laws that "unreasonably regulate" solar energy systems. Within the Northern Middlesex Region, the towns of Billerica, Dracut, Dunstable and Tyngsborough have solar bylaws in place, while the towns of Ashburnham, Gardner, Royalston, Templeton, and Winchendon all have bylaws in place in the Montachusett Region. As part of this project, MRPC worked with the Royalston Planning Board to draft a local photovoltaic system that was brought to the Fall 2013 Town Meeting and adopted (it is included as Appendix D.5).

The Massachusetts Executive Office of Energy and Environmental Affairs Department of Energy Resources (DOER) has created two model bylaws for municipalities. The *Model As-of Right Zoning Ordinance or Bylaw for Large-Scale Solar Facilities* was created in 2012 and has served as a model for many municipalities across Massachusetts. [29] However, this bylaw only addresses large scale facilities, and with increasing installation of roof-mounted and small-scale ground mounted systems, municipalities expressed a need for a model bylaw that addressed all solar installations.

Toward that end, in March 2014 DOER released a model zoning bylaw for small-, medium- and large-scale installations as well as both ground-mounted and roof-mounted installations, including canopy-mounted installations. The bylaw, entitled *Model Zoning for the Regulation of Solar Energy Systems* was developed under the SunShot Initiative Rooftop Solar Challenge (RSC). This initiative, through the U.S. Department of Energy, provided incentives to address the “soft costs” (e.g. non-hardware costs) associated with permitting, zoning, metering, and connection for solar installations. The bylaw allows as-of-right siting for small-scale ground-mounted systems (the size that would service a house, small businesses, or small municipal building) as well as for medium-scale ground-mounted systems in all districts except residential zoning districts, where Site Plan Review is required.[30]

[29] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/solar-model-bylaw-mar-2012.pdf
[30] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/model-solar-zoning.pdf

The model bylaw may be modified and adopted, as necessary, by local governments that want to promote solar development. In general, the municipality should establish the zones where solar will be allowed by right as an accessory or as a main use. Solar definitions should be included in the definitions section and the bylaw should clarify that solar is exempt from building height restrictions, and that solar panels need to be built in compliance with State law. A site plan review should be required for systems greater than 250KW. In addition, the by law should stipulate liability insurance for larger installations and should indicate that the panels should be removed within 150 days at the end of useful life. Finally, the bylaw should specify that the utility should be notified and that an operation and maintenance plan should be in place. Municipalities may also want to consider financial surety for removal when the useful life is complete. Construction of solar panels should not be restricted on new construction. [31]

In some instances, the complexity of permitting and zoning requirements can be a barrier to solar PV development. To overcome this, DOER recommends each town create a solar zoning bylaw to clearly outline what is permitted in each community, and to ensure that solar development is consistent with community desires and characteristics. Communities should focus on both large-scale and ground mounted systems.

Special Considerations/Sensitive Areas

Roof-mounted units in historic districts or on historic buildings, ground-mounted units in residential zones, and ground-mounted units on agricultural or forested lands often warrant special consideration. In addition, sensitive areas, such as well-head protection districts, also require additional permissions. Special permits can be used to provide review for use in these sensitive areas. Typically, the municipality should issue a special permit if the use is in harmony with general purpose of the bylaw, if it is a public benefit, if the appearance is not detrimental to the neighborhood and no nuisances are created (noise, odors, etc.).[32]

If solar is going to be placed within the boundary of a Water District the installer needs to get special permission from the Massachusetts Department of Environmental Protection (MassDEP). One of the State's recent initiatives is to assist with the review of solar installations in water districts. Toward that end, the state has developed guidelines for water districts to site solar PV (or wind) on water district owned properties, including those within Zone 1 – 500 feet within a well head.[33]

The guidelines state that public water suppliers shall submit a written certification to MassDEP that the "solar energy project will have no significant adverse impact on the public water supplier's present and future ability to provide continuous adequate service to consumers under routine and emergency operating conditions, including emergencies concerning the contamination of sources of supply, failure of the distribution system and shortage of supply". If a public water supplier submits a

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[31] Siting Renewable Energy Facilities Citizen Planners Training Collaborative & Northern Middlesex Council of Governments, Carolyn Britt AICP

[32] Siting Renewable Energy Facilities Citizen Planners Training Collaborative & Northern Middlesex Council of Governments, Carolyn Britt AICP 3+6

[33] http://www.mass.gov/eea/docs/dep/water/laws/numeric/1101g.pdf

written certification in accordance with this guideline, MassDEP will respond within 30 days of submission.[34]

Siting Photovoltaics

For rooftop, ground-mounted, carport, and landfill solar energy systems, it is crucial to understand the various factors at a site including shadowing, the placement of drains and vents, site undergrowth and allowable structure penetration depth. In addition, it is important to coordinate installations with the weather as well as the site's relation to stakeholders, including Historical Commissions, the National Heritage and Endangered Species Program and the Federal Aviation Administration (FAA). [35]

Both the Environmental Protection Agency (EPA) and the State of Massachusetts have begun to prioritize siting solar facilities on contaminated land, such as Brownfield and landfills. Through the RE-Powering America's Land initiative, EPA encourages renewable energy development on potentially contaminated land when aligned with the community's vision for the site. Massachusetts DOER strongly discourages designating locations that require significant tree cutting, prime farm soils, or land actively farmed due to the important water management, cooling and climate benefits. DOER encourages designating locations in industrial and commercial districts, or on vacant, disturbed land. [36]

EPA and the Department of Energy's National Renewable Energy Laboratory (NREL) have created a decision tree to guide state and local governments and other stakeholders through a process for screening sites for their suitability for future redevelopment with solar photovoltaic (PV) energy (Exhibit 5).[37] Targeted sites include brownfields, Superfund sites, Resource Conservation and Recovery Act (RCRA) sites, mining sites, landfills, abandoned parcels, parking lots, and

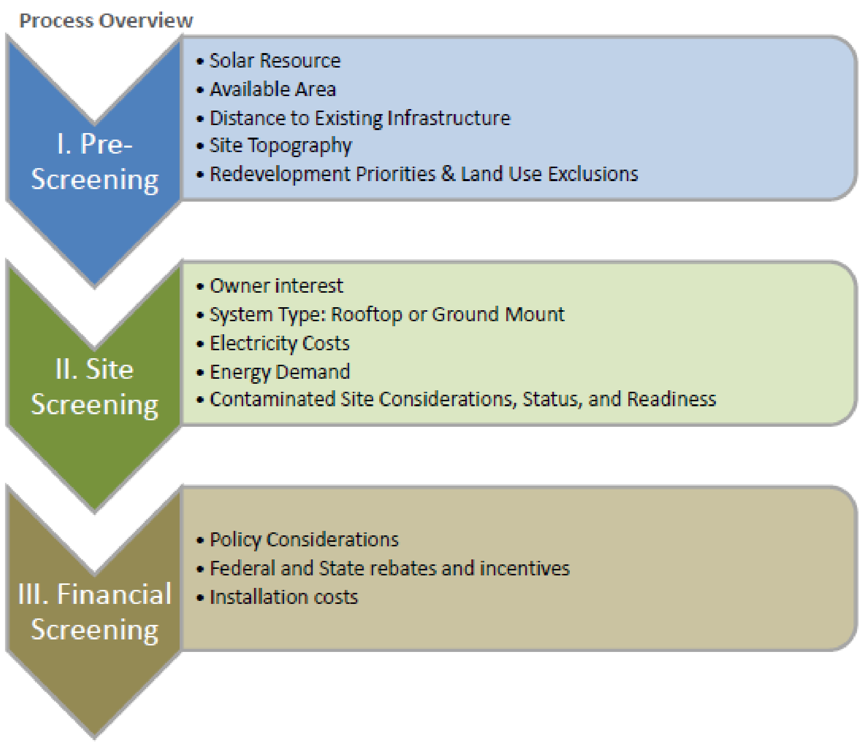

Exhibit 5: Decision Tree for siting Solar PV on contaminated lands

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[34] http://www.mass.gov/eea/docs/dep/water/laws/numeric/1101g.pdf

[35] Solar siting workshop, John Langton, Vice President American Capital Energy Solar Energy Market presentation

[36] Siting Renewable Energy Facilities Citizen Planners Training Collaborative & Northern Middlesex Council of Governments, Carolyn Britt AICP

[37] http://www.epa.gov/oswercpa/docs/solar_decision_tree.pdf

commercial/industrial rooftops. EPA encourages the development of these targeted sites, instead of green space. This decision tree can be used to screen individual sites for solar potential or for a community-scale evaluation of multiple sites. It is not intended to replace or substitute the need for a detailed site-specific assessment that would follow an initial screening based on the decision tree. Tips on how to obtain information relevant to various parameters in the decision tree are provided.

EPA has also created a tool that outlines considerations specific to the redevelopment of potentially contaminated sites. Potentially contaminated land includes sites where contamination is suspected but has not been confirmed and sites where contamination has been identified.[38] EPA's RE-Powering Mapper, a series of maps, makes it possible to view EPA's information about renewable energy potential on contaminated land, landfills, and mine sites, alongside other information contained in Google Earth or in a GIS system.[39] Features include over 66,000 sites for solar, wind, biomass, and geothermal energy. Locations for solar potential on contaminated land in the Northern Middlesex and Montachusett Regions can be found in Appendix D.3. The map highlights "brownfields", landfills, RCRA and superfund sites that would be suitable for solar. Sites outlined in yellow are suitable for large-scale solar.

The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Center for Program Analysis (CPA) initiated the RE-Powering America's Land Initiative to demonstrate the potential that contaminated lands, landfills, and mine sites provide for developing renewable energy in the United States. EPA developed national level site screening criteria in partnership with the U.S. Department of Energy (DOE) National Renewable Energy Laboratory (NREL) for wind, solar, biomass, and geothermal facilities. While the screening criteria demonstrate the potential to reuse contaminated land for renewable energy facilities, the criteria and data are neither designed to identify the best sites for developing renewable energy nor are all-inclusive. Therefore, more detailed, site-specific analysis is necessary to identify or prioritize the best sites for developing renewable energy facilities. EPA cautions that these sites were only pre-screened for renewable energy potential and were not evaluated for land use constraints or current conditions. Additional research and site-specific analysis are needed to verify viability for renewable energy potential at each site.

In addition, students at Worcester Polytechnic Institute (WPI) have created a screening tool to assist with siting renewable energy on Brownfield's in MA. The screening tool is a table that contains information for investors to reference when assessing feasibility of a site. Step-by-step instructions on how to implement the chart are included in the document entitled *Siting Renewable Energy on Brownfields* (Appendix D.4).

Recommendations for Regional Potential

The Northern Middlesex Council of Governments and the Montachusett Regional Planning Commission are committed to helping the region site solar energy facilities and encourage adoption of solar power. This section contains a series of recommendations that NMCOG and MRPC can undertake

[38] http://epa.gov/oswercpa/rd_mapping_tool.htm
[39] http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm#i_map

to overcome barriers such as structural constraints, upfront cost, interconnection, permitting and zoning. Recommendations will also encourage the development of solar power throughout these regions and will encourage private investment in the solar industry to encourage the creation of jobs throughout the region. [40]

Planning

To help promote solar throughout the region, NMCOG and MRPC will help communities clarify goals and priorities related to solar energy use. In particular, the agencies will help incorporate solar energy into the community's master plan and/or comprehensive plan. NMCOG will continue to incorporate solar into the Northern Middlesex Region's Comprehensive Economic Development Strategy (CEDS), and will work on obtaining funding to create a regional energy plan, which will also prioritize solar. MRPC's Regional Energy Plan currently prioritizes solar, and MRPC will work to ensure that the recommendations outlined in the plan are implemented.[41]

NMCOG and MRPC will also help communities write zoning bylaws to eliminate uncertainty around where solar energy systems may or may not be allowed, ensure that installations are placed in appropriate locations, and mitigate any potential negative impacts. Utilizing DOER's *Model Zoning for the Regulation of Solar Energy Systems*, NMCOG and MRPC can adapt the model bylaw to suit the needs of local municipalities.

Clear standards can also help communities avoid conflicts over competing values, such as tree cover or historic character of protected districts or structures. The RPAs will work with communities to ensure zoning ordinances do not restrict the types of districts in which solar facilities are allowed and to ensure there are no height restrictions, lot coverage limitations, or setback requirements that do not allow for the placement of solar panels on existing rooftops or building sites. The RPAs will work with communities to ensure expedited permitting for solar projects and to ensure homeowners' association covenants do not restrict solar. The RPAs could work to create additional unique incentives for solar such as waiving permit fees and allowing density bonuses for developments that use solar power.

Education

NMCOG and MRPC will help educate residents about solar at the regional and community level. As learned through this grant, community workshops can help educate residents and business owners about the local solar market through workshops and outreach events. Community outreach can also be conducted through site visits, via booths/tables at local events, or even within the school system. Education is a crucial component of renewable energy siting because residents who are educated about the importance of renewable energy may be more likely to install solar on their own property, and may be more accepting to large-scale solar installations.

[40] Implementing Residential Solar Energy in the Montachusett Region, Worcester Polytechnic Institute (Feyler 2014); Integrating Solar Energy into Local Development Regulations by Ann Dillemuth, AICP, APA Research Associate.

[41] Montachusett Region Regional Energy Plan

NMCOG and MRPC will also educate land-owners, developers and business owners about solar siting. Documents can be developed that includes a step-by-step process for public and private sector developers and business owners to site solar facilities. The document could include information on zoning regulations, permitting and financing. The RPAs will particularly reach out to those land-owners who have been pre-sited through the EPA RE-mapping technology as especially suitable for solar power.

Capacity Building

MRPC and NMCOG will encourage communities to hire an energy manager to help advocate for solar development and help quantify energy and cost-savings. As previously mentioned, Chelmsford and Lowell recently received funding for full time Energy Managers through the state's Energy Manager Grant Program. The RPAs can assist their communities with Energy Manager Grant Program applications and, in particular, can bring together smaller municipalities to discuss the possibility of a "shared" Energy Manager. A shared Energy Manager may be an option for communities that do not have the capacity for a full time position. The RPAs can also encourage communities to take advantage of various state-run green programs by assisting with SolarizeMass and Green Community applications, and by assisting with group procurement for solar installation.

Financing and Affordability

NMCOG and MRPC can partner with banks to create specialized green loans as a way to reduce costs of solar installations for homeowners. The RPAs could work to promote low-interest loans and group purchasing, and can promote the SolarizeMass program to communities across the region.

Solar Siting

As discussed, less than 20% of homes are suitable for residential solar. NMCOG and MRPC will promote community solar for those homes that are not suitable for residential solar. We will work to pre-site locations for solar farms/community solar gardens on contaminated land, and could conduct outreach to recruit shareholders to participate in the community solar program. The program could be designed specifically for those who do not qualify for residential solar. NMCOG and MRPC should conduct a detailed, site-specific analysis of EPA's RE-mapping sites, to identify or prioritize the best sites for developing renewable energy facilities based on the technical and economic potential. This will involve visiting each site to determine its true suitability for solar and to conduct prioritize locations for installations.

Job Development

NMCOG and MRPC will work closely with the local Workforce Investment Boards to encourage training for solar industry-related jobs throughout the region. Promoting solar throughout the region will help create jobs in installation, manufacturing and development. It will also indirectly help create jobs in research and development. For example, in June 2010 the Greater Lowell Workforce Investment Board received funding from the United States Department of Labor to create an integrated system of education and training to promote skill attainment and career development benefiting business, incumbent workers and job-seekers. Using a portion of this funding, 37 incumbent workers and 36 unemployed individuals received solar related training and obtained HVAC, BPI and LEED; industry recognized credentials. NMCOG and MRPC should continue to work with the local Workforce Investment Boards to encourage job training throughout the regions.[42]

Conclusion

The regulatory and land use policies in a community form the foundation for building renewable energy infrastructure. Effective and streamlined local rules and regulations help reduce installation costs and can significantly improve the market environment for solar energy technologies. Creating consistent permitting policies across the Montachusett and Northern Middlesex regions will encourage the development of renewable energy projects by providing a standard set of practices and procedures, thereby reducing uncertainty for developers and private investors.

NMCOG and MRPC are uniquely poised to work at the local level to remove some of the most critical barriers to widespread adoption of solar technology. By working with municipalities to overcome barriers associated with zoning, upfront cost, technical knowledge, and siting, we can work to encourage solar installations at the local and regional level and advance the use of renewable energy to reduce dependence on fossil fuels. In addition, assisting municipalities with capacity building and job development will also encourage economic growth across the regions. Facilitating the siting of solar projects and implementing the recommendations listed above will assist in meeting the state's renewable energy goals of reducing GHG emissions, preventing global warming, decreasing our reliance on petroleum, reducing energy consumption overall, and creating jobs in the clean energy sector.

[42] Solar siting workshop, Gail Brown presentation

HYDROPOWER

History

Water has been diverted for human use beginning in the 4th millennium BC to irrigate crops in Mesopotamia and Egypt. Water was used to power everything from ancient clocks to mine pumps.

Historically to create energy people created a dam, stopped the flow of a river and created a body of water enabled the flow to be regulated. This system is known as an impoundment because water is stored behind a dam. The water behind this dam (and all along a river system) holds potential energy. Because water flows downhill, the change in the elevation of water is where the potential energy is derived. Generally, forcing the river to flow through a properly crafted hydro turbine or water wheel allows potential energy to be converted to kinetic energy. The change in elevation of water and flow of the river (how much water the system has and how fast it is moving) have been the two key variables in potential energy production of a hydro system. Generally the concept has been that with more height and more water flowing through a river system, the more power can be generated.

Simple mills have been powered by hydropower for thousands of years, turning grindstones and powering saws in Roman lumber mills. Water wheels dominated until the Steam Age, and even then they were still instrumental throughout the Industrial Revolution.

Locally, a complex set of dams and canals powered the textile mills of Lowell and Fitchburg. These two cities were major industrial manufacturing cities because of their natural endowments. Both of these cities have unique geographic features such as elevation differences and large basins, which are ideal for the extraction of water power. The cities of Fitchburg and Lowell took advantage of hydropower to generate mechanical energy across their mill complexes. Countless mills were established in any river that could be dammed, helping to spur the production of everything from paper to tablecloths.

Lowell was chosen to be the site of the mill industry in the 1820s because of the strong flow of the Merrimack River and because the river bends at a ninety degree angle. This geographic feature is key as the change in elevation mean that the mills in the city could access the power of the water from before the bend and expel it further down river and downhill than if the river simply ran parallel. Furthermore there was more of the city exposed to the bank of the river, allowing for larger canals to be built in the uphill portion of the river, and multiple discharges for the canals down river, making canals shorter, and more plentiful without sacrificing flow and volume, and minimizing costs. Lowell was chosen also because the Concord River converges with Merrimack just after the bend in the Merrimack. In fact, one of the most efficient and widely used turbines was invented by James T. Francis of Lowell in 1848. By 1850 almost six miles of canals were completed and flowed through Lowell, delivering 10,000 horsepower to 40 mills filled with almost 10,000 looms, employing well over 10,000 workers[43]. Lowell was considered at the time to be the "Venice of America."

[43] National Park Service Lowell park handbook, http://www.nps.gov/lowe/photosmultimedia/seeds_of_industry.htm

Fitchburg is unique because the river drops more than 300 feet over the course of seven miles within the City. The first water wheel in Fitchburg was built by hand in 1750. The energy created from the water wheel was used first in a grist mill and soon after in a saw mill. Utilizing the river as a source of energy helped both Fitchburg and Lowell thrive. By 1810 Fitchburg had a number of mills creating paper, cotton, and lumber among other products. In 1850 the Nashua River was the lifeline of mills in Fitchburg. Electricity had yet to be harnessed but machines with steam power were thriving in Fitchburg.

The mills within New England began to decline around the 1920s with the advent of electricity powering mills instead of water. The discovery of electricity allowed mills to be built anywhere, so they moved to markets with cheaper factors of production as well as closer to the destination of their products to lower shipping costs. The advent of the Great Depression further served to force mills out of the north east. The next great era of hydropower was poised to begin: the next major period of dam building occurred primarily in the western and southern portions of the United States. This development took place mainly during the Great Depression of the 1930s. Many industries that relied on water power in the northeastern United States relocated to the south because the lower production costs. The Tennessee Valley Authority (TVA) and the Bureau of Reclamation worked with the Public Works Administration (PWA) to build hydropower and irrigation infrastructure throughout the country.

Currently, the U.S. is home to some of the largest hydropower dams in the world; but none are as impressive as the Hoover Dam near Las Vegas, Nevada. The sheer vertical size, magnitude, and striking canyon location of the Hoover Dam marked it as a world wonder when it was built in 1936, until the construction of the Grand Coulee Dam in Washington. Nowadays these dams are dwarfed by the sheer size and magnitude of dams such as China's Three Gorges (the world's largest impoundment) and Tajikistan's Nurek Dam (the world's tallest dam).

Hydropower within the Region

Hydropower transformed New England into a huge center of industry throughout the 1800s and well into the 1900s. Mill towns across New England were mass producing different types of manufactured and industrial goods but, were dependent upon rivers as a source of energy. In 1920, 25% of the nation's electricity was generated from hydropower. By 1940, this number had increased to 40%.[44] Today, this figure is significantly lower – but many are looking back to hydropower as a way to limit carbon emissions, reduce petroleum dependency, diversify energy portfolios, and increase production of low cost power source.

According to the Army Corps of Engineers, Massachusetts dams and rivers have a potential conversion capacity of an additional 67MW of hydropower. However, this estimate does not take into account low pumped storage or conduit hydro systems. Potential production capacity is defined to be the potential electricity production of converting non-powered dams into hydro facilities. This would be enough energy to power about 15,000 homes based on a conservative estimate that 1 MW powers about 225 average American homes.

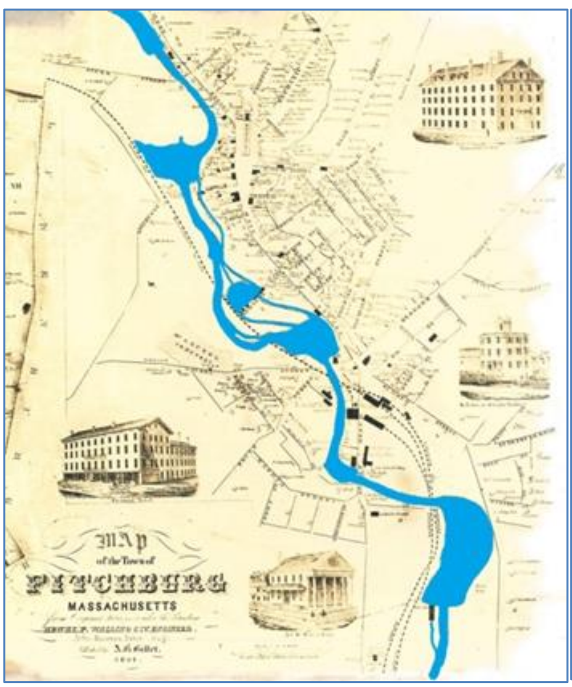
[44] http://energy.gov/eere/water/history-hydropower

Figure 4: Merrimack River Basin

The Original Mill Cities

Lowell was built along the Merrimack River, which is 117 miles long and originates in Franklin, New Hampshire. Figure 4 shows the Merrimack's river basin, which includes the Nashua River. A river basin is all the waterways which eventually join together to form one major river. These tributaries are the major waterways that conjoin with the Merrimack and increase its flow, size, volume and velocity. The Nashua River runs seven full miles within the City of Fitchburg and descends 300 feet in elevation. Mill owners developed a variety of dams and canals to increase the production capacity of energy.

Industrial developers in Lowell and Fitchburg set up shop along the rivers, producing paper, firearms, machines, and textiles. Both cities thrived throughout the industrial revolution. However, beginning in the 1920s, mill owners began re-evaluating their production costs, particularly in terms of labor. This lead to the decline of manufacturing in mill cities as owners began to relocate to the southern United States where labor and property costs were lower. Since then, almost all the manufacturing industries dependent upon hydropower have left Lowell and Fitchburg.



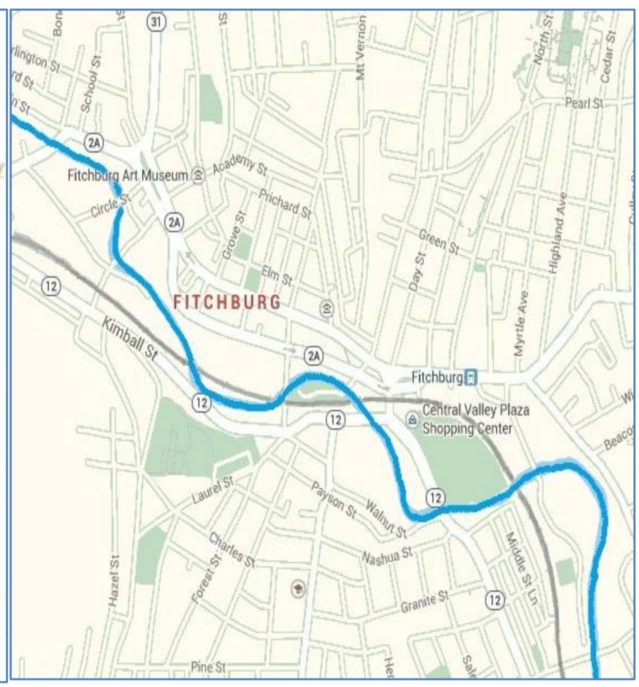


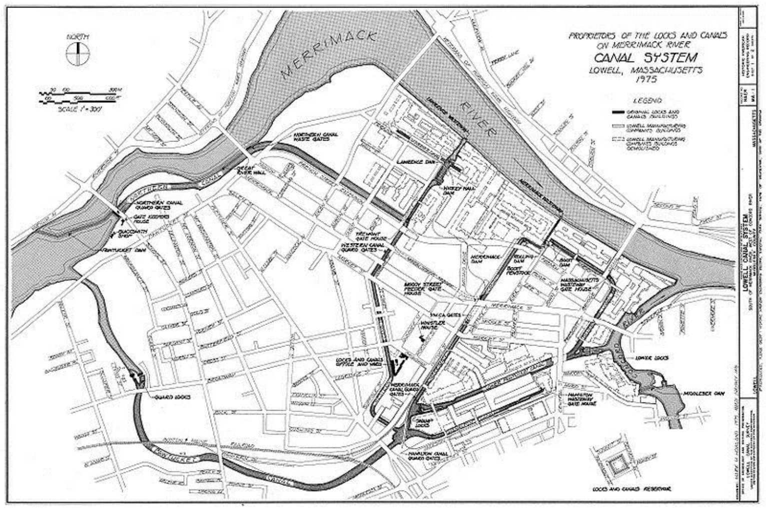
Figure 5: Nashua River, Fitchburg 1854 **Figure 6: Nashua River, Fitchburg Today**

The two images above show the Nashua River in 1854 with the Nashua today. The complex waterways seen in the image on the left show the extent that the mills constructed canals to better suit their needs and maximize the energy capacity of their hydro systems. The ponds seen in the older image of the Nashua River show bodies of water held back by a dam, constructed by a mill to produce low cost energy. Today, the Nashua River faintly resembles the same shape. Since the mills left Fitchburg, the dams retaining water for manufacturing purposes have been removed.

More Dams, More Power

Fitchburg and Lowell progressively developed with the intent of utilizing the river as a natural, abundant resource capable of reducing production costs.

Figure 7: Lowell Canal System



Downtown Lowell developed in the 1820s and became a major textile manufacturing center. Shown in the picture to the left, Lowell has a number of canals throughout the downtown area. It is centered on a ninety degree, downhill bend in the Merrimack River and consists of one of the worlds most developed canal lock and dam systems. Similar to the Nashua River, the Merrimack River was seen as a source of power for Lowell's mills. By the 1850's, Lowell had the largest manufacturing complex in the United States. There were fifteen dams within this downtown canal system. Half of those dams are still used to generate hydroelectric power today.

Environmental Concerns and Costs

As Fitchburg industrialized, it used the Nashua River as a source of energy and waste. Paper production was an industry deeply rooted in Fitchburg throughout the 1800s and 1900s. Water is an input required to make and color paper. Dyes and toxins used in the production of paper in Fitchburg were disposed of in the Nashua River. Until the latter end of the twentieth century, the Nashua River in Fitchburg was a different color almost every day and the water would become more polluted each mile closer to Leominster. Between the heavy metals, toxic compounds and construction chemicals, much of the riverbed and silt are contaminated to this day, and must remain contained behind many existing dams. The cost of cleaning the area prohibits the conversion of many current dams into hydroelectric facilities.

Currently in Massachusetts there is a moratorium on dam building. To further compound the issue of siting a hydropower plant, the State is actively attempting to remove as many dams as possible due to concerns over wildlife and the environment of these rivers and streams. The rules that involve establishing a hydropower facility are strict. The Commonwealth strives to produce and consume more natural resources to diversify energy portfolios but regulators, conservationists, environmentalists and law-makers are extremely vigilant the logistics of hydro developments to preserve the environment. This can lengthen the planning process and can also lead to higher costs in researching and implementing hydro development because all development must abide by federal and state guidelines.

Compared with traditional methods of producing energy, hydropower has significantly lower operational costs. On average, hydropower costs one-third that of nuclear energy or energy from fossil fuels (oil or coal) and less than a quarter the cost of gas turbine electricity production. Without putting harmful pollutants, emissions, or greenhouses gases into the atmosphere – hydroelectric energy can reduce the dependence on finite fuel sources, increase the state's electricity supply portfolio and increase energy security. The technology is simple, available, and cost-competitive. The output of hydroelectric power plants can be controlled to adjust for changes in consumer demand.

The graph in Figure 8 illustrates the total energy production portfolio within the United States. Currently, there is a huge dependency on petroleum, natural gas, and coal; all of which produce greenhouse gases, harm our environment, are more expensive, and less efficient than hydropower.

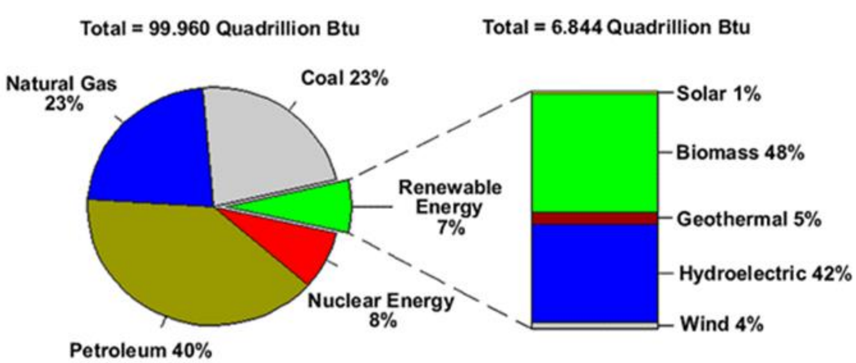


Figure 8: National Dependency on fuel sources for heat

How it works

General concepts

Water is extremely dense and, as it moves along a river system downhill, it holds potential energy which can be harvested into mechanical energy, which is then converted using the turbine to generate electrical energy. Historically, rivers were dammed and the water was aggregated into a pool or reservoir held behind a retaining dam wall. At a controlled rate, this pool of water is directed down piping, called a penstock, and through a waterwheel or impeller (known as a "runner"). At the axis of rotation, a drive shaft is turned, which, to produce electricity also turns a generator, consisting of a magneto (a large magnet) inside a stator (a ring of coils of wire around the magneto), thus producing an alternating current. There are numerous runner designs; each is applicable in different situations to provide the best possible generation given the dynamics of each individual site.

Head

"Head" is the vertical change in height over a relatively short distance. Sites with high head have a large vertical displacement between the stored water and the hydroelectric generator. Head is also a value for amount of pressure in a stationary system, generally measured in meters or feet. "Net Head" is the applicable measurement of pressure at the turbine when the water is flowing. This measurement is always less than the head of the nonmoving circuit. The non-moving circuit is considered gross head, when the discharge valves open the pressure drops and the flowing water is slowed by friction in the penstock, lowering the amount of pressure in the system, known as net head.

Flow

"Flow" is the rate at which the water is moving downstream or downhill. It is the quantity of water which is moving through a river system at any given point in time. It is typically measured in units of "volume per minute or second". This value is most often (and in this study) expressed as cubic feet per second (cfs). "Design Flow" is the flow at which the generator is designed to run; a balance between the cost of the design, versus the efficiency and generation potential.

Theoretical Power Production

When calculating the power generated by a hydroelectric system, a specific study must be conducted to determine the amount of power that can be generated from the development of a turbine at each proposed location. To calculate this, many variables and considerations must be examined. Engineers have three different equations used to numerically predict the amount of power which could be generated by developing a hydropower facility, which are reserved for feasibility studies at a much more detailed level than the recommendations in this document. In the simplest of terms, the equation used in this study is:

POWER = [(HEAD) x (FLOW) x (EFFICIENCY)] / 11.81

POWER = Kilowatt

HEAD (in feet) = change in height of water

FLOW (cubic feet/second) = how fast the water is moving

EFFICIENCY = in short, assumed to be 85%

11.81 = A constant

Capacity and Efficiency

Capacity is the maximum amount of electricity a turbine is capable of producing, while efficiency is the difference between the amounts of energy that enters the system, versus the amount of energy that leaves the system as electricity. For example, a 10MW turbine has the capacity to produce 10MW under the ideal conditions, given the proper amount of head and flow. That same turbine may only have an efficiency of 75%, meaning that if 10MW of energy goes into the turbine, 25% of that energy is lost to friction and other factors, and 7.5MW of energy leave the system in the form of electricity.

Capacity

The capacity of hydropower plants varies with the seasons and the size of the plant. Capacity for commercial dams can range from just a few Megawatts to more than ten Gigawatts. Because hydropower is so efficient, it has four generally accepted levels of capacity: Large (10MW +), Small (100kW to 10MW), Micro (5kW to 100kW), and Pico (5kW and under).

The three most common hydro turbines are the Pelton-, Francis-, and Kaplan-Turbine. The image below depicts how different turbines have different production capacities based on varying head and flow ratios.

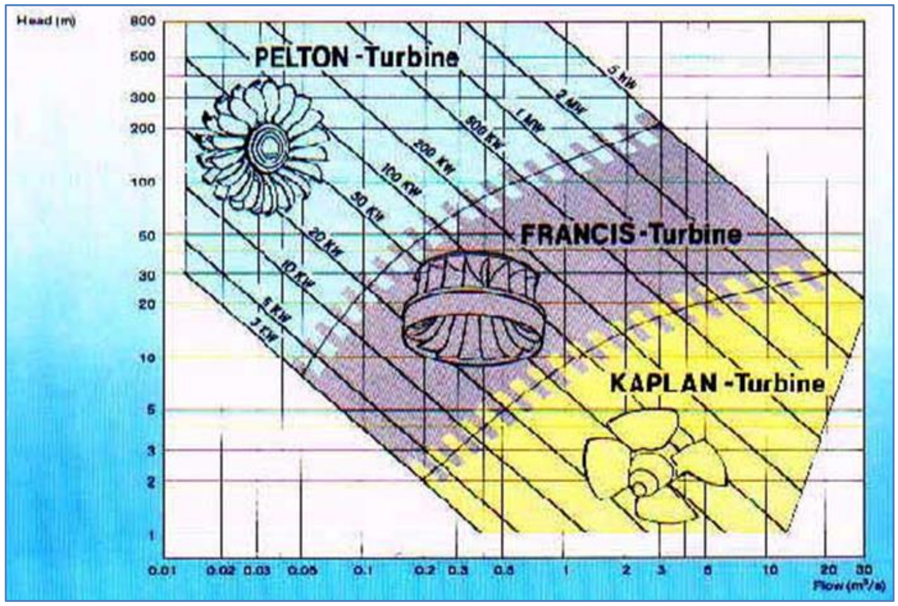


Figure 9: Turbine Efficiency Curves Based on Head and Flow

Each hydro location is distinctive, often based on the head and flow of the river. Which turbine to use is a question best answered with a comprehensive study aided by a certified engineer. To discover the capacity of a system, the theoretical power equation can be used, but this estimate is only theoretical and not appropriate for a comprehensive study. Generally, the more head and flow a system has, the more power it will be capable of producing.

Efficiency

Quantifying a specific value for the efficiency of water technology is difficult. There are a variety of turbines that each has their own efficiencies, oftentimes ranging from 50% to more than 90%. Hydroelectric energy is by far the most efficient form of electricity, primarily because water is more than 816 times denser than air (at one atmosphere with standard temperature and pressure). It is easier to transfer potential energy to kinetic energy using the natural momentum of water to spin turbine blades.

Types of Hydropower

Choosing which type of hydropower system to implement depends greatly on the investor. The return on an investment in hydropower varies for municipalities and private investors. Generally, private investors are willing to develop a hydro site if the return on investment can be achieved within five to ten years. Often, private investors build hydropower sites with a large capacity to maximize profits and get a quick return on investments.

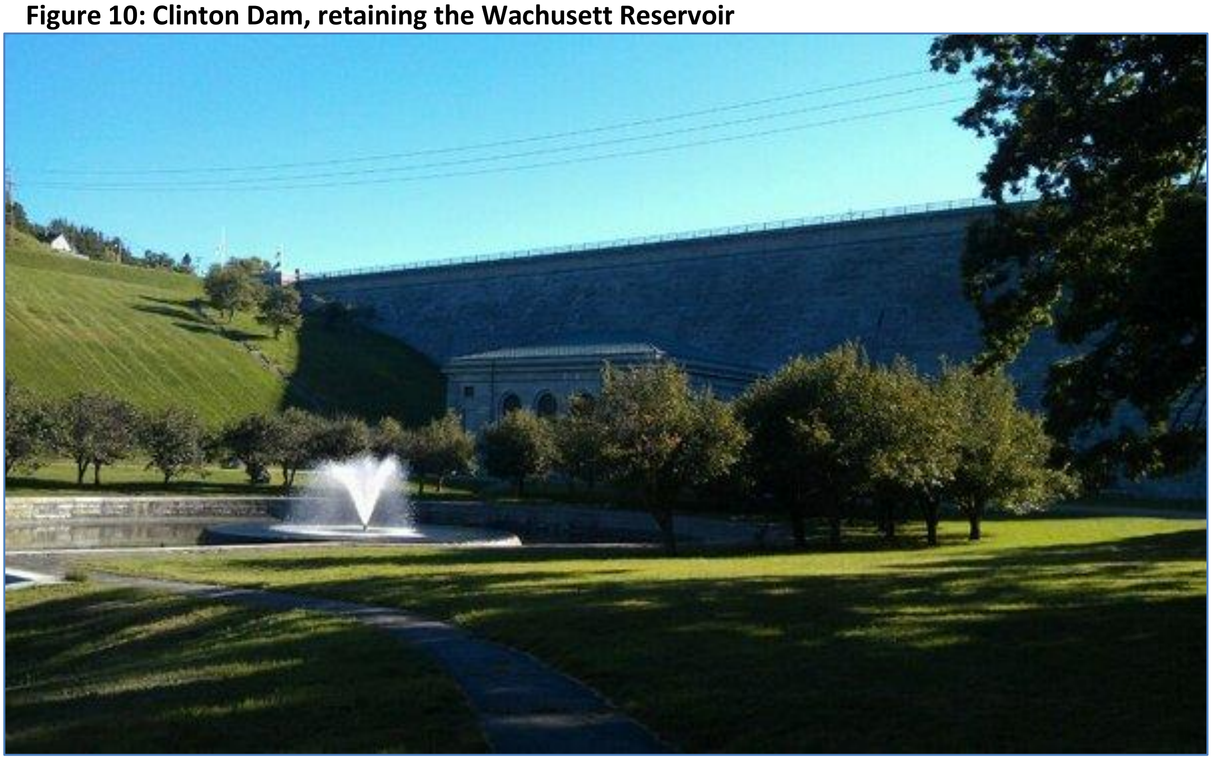
There are a number of different ways to transform the potential energy of water into kinetic energy. In general, a few ways to create hydropower are: (1) conventional run-of-river hydro, (2) pumped storage hydro, (3) low head hydro, and (4) hydrokinetics. Each method varies in regards to capacity, developmental factors, environmental concerns, and risk as explained below In Massachusetts it is preferred to utilize run-of-river technology – ideally reducing the environmental impact.

Conventional hydropower

Impoundment

The Hoover Dam is an example of an impoundment system. The dam stops the flow of water down the Colorado River and a reservoir is created. When the Hoover Dam was established, the environmental regulations were less strict. The Clinton Dam (seen in Figure 10), the Pawtucket Falls Dam and most other dams in Massachusetts are local examples of impoundment dams. Today, people worry about the fish and other environmental factors. Impoundments are not traditionally run-of-river but more recently have been transforming into run-of-river systems. Impoundments that control the flow of the river and create large bodies of water, generate some of the largest and cheapest forms of electricity, but come at detrimental environmental costs. The impoundment of water behind dams floods land and creates a body of water which produces methane, deoxygenizes water, impacts the natural breeding patterns of fish, and displaces humans, plants, and wildlife. Typically, impoundments are created to mass produce energy or to create an aquifer for drinking water. The advantages to this type of hydro system are that flow can be manipulated, increased, or held constant, head can be increased, and system efficiencies are more constant. The downside to this type of hydro system is the negative environmental impacts. Today, impoundments are widely controversial in the global political

Figure 10: Clinton Dam, retaining the Wachusett Reservoir



and economic world; still many of these systems are already established throughout the globe.

Generally, impoundments create large amounts of energy, but alternative forms of hydropower with less environmental impacts are now more common. Impoundments should still be considered for investment opportunities because each site is unique and sometimes water must be retained behind dams to prevent flooding. This system can be developed today, but the likelihood of creating a large reservoir like the Hoover Dam is minimal, especially in Massachusetts. Developing a site that has an established dam that doesn't create a larger reservoir is a more realistic and environmentally preferred scenario. Impoundment sites can be run-of-river given that the flow of the dam is in line with nature's determined flow rate.

Run-of-River Hydro

To preserve nature, it is strongly recommended to install a hydro system that is run-of-river. Run-of-river hydro systems do not store much water. The flow of these systems is often determined based on the daily flow of the river. In locations where dams already exist, the storage of water can be maintained with run-of-river so long as the stored volume of water does not rise.

Run-of-river hydro refers to power generated from the force of water flowing from a higher elevation to a lower one. It is also possible to implement run-of-river hydro without the construction of a dam.

Diversion

The Tazimina Project in Alaska is a prime example of a diversion hydro system. Diversion systems utilize only a portion of the river's natural flow and is therefore run-of-river. The power derived from the Pawtucket Canal in Lowell is a local example (ignoring the dam at the falls). Water from the Merrimack River is diverted into the canal system prior to the falls. The image to the right displays the fundamentals of this type of system. Water is diverted from the river, into a penstock seen at the white arrow labeled "intake", then passing through a turbine, and lastly put right back into the river. This type of system requires neither an impoundment nor a dam. With neither a dam nor large water reserve, it is not possible to artificially control the flow rate; this is environmentally preferred.

Figure 11: Tazimina Project, Alaska

Pumped Storage[45]

[46]Pumped Storage is a type of hydropower facility that uses two different bodies of water located at different elevations to create energy. At the higher elevation, artificial water storage is built. At times of peak demand, water flows down into a penstock, into a turbine, and then into the lower body of water (which may be a lake, river or other artificial impoundment). During the night when energy demand and cost is at its lowest, the turbines run in reverse, pumping water from the lower source, back to the upper storage tank. An example of a pumped storage hydro system within Massachusetts is the Northfield Mountain Pumped Storage system. This site generates 1,080 megawatts

[45] http://www.energystorageexchange.org/projects/375
[46] http://www.northfieldrelicensing.com/Pages/Northfield.aspx

of electricity and is located 800 feet above the Connecticut River holding back 5.6 billion gallons of water (17185.746 acre-feet).[47]

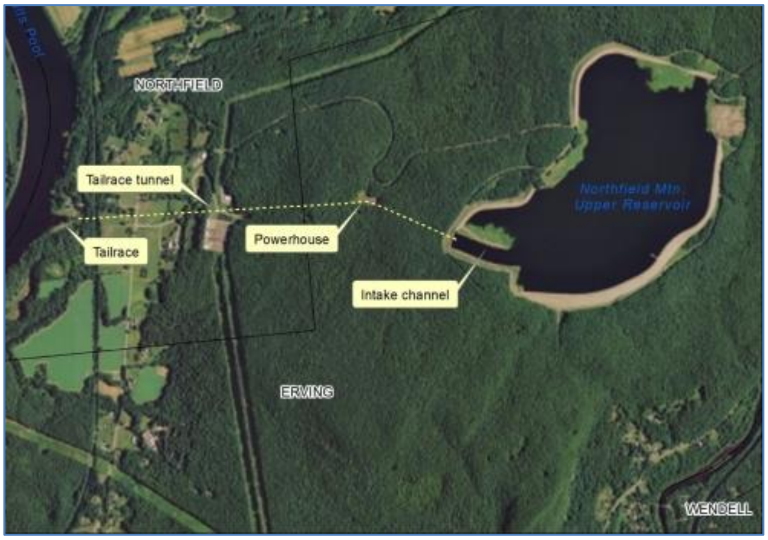


Figure 12: Northfield Mountain Pumped Storage Facility

This type of system can cause environmental problems if the system is closed and supplied with only rain water. Open systems (like rivers) are a more effective way to create a pumped storage facility because rivers are constantly flowing. A run-of-river pumped storage system means that the water pumped up into the upper reservoir is not faster than the rate at which the river is naturally moving. Depending on the size of the elevated reservoir, there can be a risk for those living downstream if the dam fails or walls collapse. Overall, the negative impacts of this system are minimal since pumped storage does not affect the environment the way dams and impoundments do.

The catch to pumped storage is that the higher elevated system can only be drained once per day. It is not possible to have a pumped storage system run constantly like impoundment systems. The upper body of water is filled by using off-peak electricity (usually around 2-4 AM when electricity rates are very low) to spin the hydro turbine in reverse, operating as a pump. When electricity demand peaks (usually between 3pm and 9pm), the upper reservoir is drained and the energy created is sold to the grid or utilized by the hydro owner. Hydro energy is not always sold to the grid – when it is utilized by the hydro producer on site (consumed where it is produced) then the value of the energy created is worth significantly more. Energy can often be sold to the grid at an average value of three to five centers per kilowatt. When energy is consumed on site, it is worth about ten cents per kilowatt. Therefore, it is more cost-effective to produce smaller scale energy systems that consume the energy produced on-site.

Pumped storage is not renewable energy and is not considered green energy because pumping water up to the top reservoir requires energy. Regardless, pumped storage comes with many incentives. When more energy is demanded than supplied, pumped storage facilities can make money. Power supply and demand values are priced every five minutes. Therefore, pumped storage facilities are operated in a highly optimized manner: at the time that demand of energy is high enough to release the storage, and make the most money. Pumped storage facilities often pump out all the water at a high flow rate in an attempt to maximize the energy generation. This is why older pumped storage sites like Northfield run for less than one hour. When siting pumped storage facilities, it is hard to find a site capable of storing billions of gallons of water.

[47] http://www.firstlightpower.com/generation/north.asp

Attempts to combine wind power and pumped storage systems are under development. Wind and hydro combined together can be classified as renewable energy if the system does not require power from the grid. If the wind power can generate enough electricity to pump the water to the upper reservoir, then the system can be defined as renewable. Pumped storage hydro is unique because the more elevated body of water is essentially a battery that can be turned on at any point throughout the day. This is one type of system that can truly create storage of energy to protect the grid in times of need for instantaneous generation.

Low Head Hydro

Low head hydro encompasses several categories of hydropower that require little to no head. Hydrokinetics is an up and coming hydro technology that has almost no environmental impact and can produce energy twenty-four hours a day. Hydrokinetics directly utilizes the kinetic energy of water without an impoundment or gravitation potential.

Conduit Hydro

A conduit hydro system is not quite run-of-river because there is no river involved. Conduit hydro installs a hydro turbine within pipes that are already carrying water from one location to another (see Figure 20[48]). Adding a hydro turbine to water treatment and distribution pipelines or sewer treatment pipelines would constitute a conduit hydro system. Conduit systems have minimal environmental impact because the water is already moving through the system. Oftentimes, water flowing towards a water facility from a reservoir of higher elevation can benefit from conduit hydro because the turbine burns off some energy, so that the input force of water doesn't damage the water system.

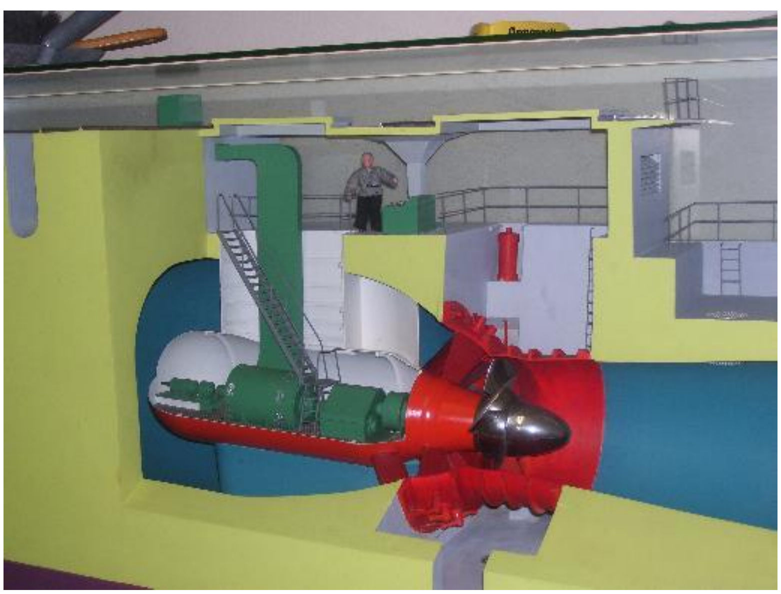


Figure 13: Model of Conduit Hydro in a drinking water supply

Anywhere there is water flowing through a controlled piped system, conduit hydro can be implemented. Most water supply systems have pressure bleed valves. Many municipalities are finding that rather than just losing water and energy through these relief valves, the excess pressure can also be used for turning a small turbine, to lower reliance on the grid. The Quabbin Reservoir aqueduct has several conduit hydro turbines built within the pipelines, which generate power from the natural flow of water. Other plants have implanted turbines directly in the aqueducts to power

[48] http://www.metallbud.eu/big_Kaplan%201-3%2034.JPG

their underground reservoirs and other facilities.

This mode of generation has high potential in the Montachusett and Northern Middlesex regions. To help determine the feasibility of an in-line system, MassDEP has created a tool that is free to public water suppliers.[49]

Hydrokinetics

Hydrokinetic technologies produce renewable electricity by harnessing the kinetic energy of a body of water, the energy that results from its motion. Since water is 816 times denser than air, our tides, waves, ocean currents, and free-flowing rivers represent an untapped, powerful, highly-concentrated and clean energy resource. This is a run-of-river technology that has almost no environmental impact. Hydrokinetic technology is new and generally placed in locations where the tide or flow of water is strong and the depth of the river is deep (so that the turbines can be fully submerged). This technology is somewhat revolutionary because it doesn't require any damming of rivers, nor does it require the creation of a reservoir. Generally, the turbines are sunk into the middle of a river. Since a river never stops flowing, the turbines never stop spinning. The power generated from this system is different because hydrokinetics do not require head. Gravity is not pulling the water down a turbine, but rather, the momentum of naturally flowing water spins a turbine below the surface. This technology is borrowed from the tidal energy industry mixing in elements from wind turbine technology.

Typically, the shrouded turbines are placed in locations where the tide advances and recedes; the blades are turned, giving predictable power at predictable times. By placing this technology in the river, there is no loss of generation during slack-tides. These turbines have been sunk near the mouth of New York City's East River along Roosevelt Island. After initial hardware failures, the third generation turbine has been a great success. These types of turbines have a high startup speed and are unsuitable for slow, shallower rivers, but may be able to function in the larger, more powerful rivers.

For the smaller rivers, a type of turbine that mimics the "eggbeater" style of wind turbine is a better design option. This type of turbine is called the Gorlov Turbine and resembles an enormous DNA helix. Gorlov turbines are much more efficient and less delicate than other turbines because the shape of the blades limits cavitation and lowers startup speeds. In current applications, the turbines are placed parallel along the floor of the ocean or river, and perpendicular to the direction of the tides. These turbines spin by generating lift similar to vertical axis wind turbines. Within the Bay of Fundy (off the coastal border of Maine and Canada), there is a large set of Gorlov Turbines. A similar, smaller set of Gorlov turbines exists in South Korea. A trial of this turbine was also conducted in the Commonwealth near the mouth of the Merrimack River. These turbines were sited with a vertical axis, off a platform under a bridge. After a year it was determined that the turbines must be fully submerged a distance under the surface to reach maximum capacity, as surface water lacks the momentum to turn the blades. As a result, the study determined that the turbine would not be suitable for use.[50] However, there is dispute over this conclusion due to the placement of the turbine without adequate submergence. This

[49] http://www.mass.gov/eea/agencies/massdep/climate-energy/energy/water-utilities/hydropower-project-screening-tool.html
[50] http://www.mainetidalpower.com/files/GORLOVTEST.pdf

type of technology is ideal for rivers with depth, flow, and width. Although hydrokinetic energy does not require head, it does require a river to be deep. This technology is best suited for the Merrimack and Nashua Rivers.

Gravitation Water Vortex Power Plant

A Gravitation Water Vortex Power Plant is one that requires very little head (even as low as 2-3 feet). The first gravitation water vortex system was established in Switzerland in 2009.[51] This system is not fully proven within the United States, but other countries, like Switzerland, believe it is vital to the development of renewable energy. This form of turbine would be extremely useful in areas, such as above the dam in Pepperell and at the little splits on the Nashua River through Fitchburg, where there is elevation change and a natural divergence and confluence of the river around a small island.

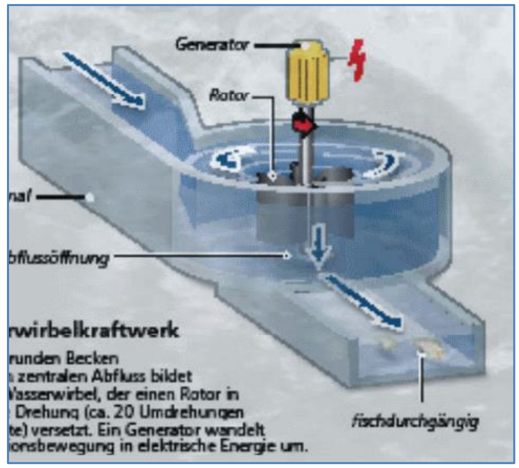


Figure 14: Gravitation Water Vortex Power Plant (Image Labels in German indicate the water swirls around the tub, turning the paddlewheel, which turns the yellow generator hub)

A gravitational water vortex system spins a turbine by flowing water from the river into a circular "tub" which drains out the bottom. To create a vortex within the circular tub, the inflow of water must be at an angle tangent to the circle. The tangent angle input creates a circular flow and a vortex which spins a paddle-wheel tied to a turbine, creating energy.

There are many advantages to gravitational vortex systems. According to the Federal Department of Foreign Affairs, Switzerland, this technology is said to be 100% fish friendly. Since the paddle-wheel is not connected to the output drain, fish can enter and exit the system without coming in contact with the paddle-wheel.[52]

Low head technology and especially gravitational water vortex technology is ideal for the Montachusett and Northern Middlesex regions because the majority of dams are low head. This system could also be a functional aid to power water treatment plants with its capability to pass relatively large debris. Water vortex systems are good for the environment because there is no threat to fish, the system is run-of-river, and with correct planning, can be almost invisible (since it creates no reservoir of water).

Archimedes Screw

The Archimedes screw dates back to the 3rd century BC, as a pump to move water from rivers to irrigation channels above. By putting a shaft around a screw (a helical surface surrounding a central

[51] http://www.wakingtimes.com/2012/10/16/gravitational-water-vortex/

[52] http://www.swissworld.org/en/switzerland/swiss_specials/green_technology/water_vortices_a_new_source_of_alternative_energy/

cylindrical shaft), when the screw is turned, water is drawn up the flights to the top of the shaft. The Archimedes screw turbine works by reversing the flow of water through an Archimedes screw pump, so that the water flows downhill, forcing the screw to turn. This low head hydro application is quite prolific through the low head weirs in the Netherlands and the low head rivers of the United Kingdom, even powering the Queen's Windsor Castle. A hydro-screw runs most efficiently as a generator at a fixed slope of 22 degrees, with a flat efficiency curve up to 90%, meaning varying flows have small influence.[53] Because the majority of dams within the Montachusett and Northern Middlesex regions are weirs, this mode of production would be well suited to the local infrastructure. This would work on the vast majority of dams along the Nashua, Squannacook, Nissitissit, Priest Brook, and Miller's Rivers. There are many other rivers that would be able to sustain this form of hydropower across the commonwealth.

Environmental Considerations and Mitigations

Damming rivers is a challenging prospect at this stage of modernization and environmental consciousness. Dams have far reaching environmental effects and can flood the landscape. The reservoirs created by dams can destroy towns upstream and place towns downstream in jeopardy if the dam were to collapse. The Commonwealth discourages construction of any more dams.

Some negative impacts from dams can include: relocation of people, stagnant water that loses oxygen, the expulsion of methane through the anaerobic decay of plant matter, the loss of habitat for many animals, changes in fish breeding by preventing fish from running upriver, warming of water downstream, and blocking river sediments from running downstream. The opportunity cost that comes with damming a river varies based on the size of the river, dam, and reservoir.

In regard to human impact, when a dam is built it fills the valley behind it with water creating a lake (also called reservoir) potentially displacing valley residents. For example, the Quabbin reservoir swallowed up four towns in its creation, displacing hundreds of residents, destroying over 30 miles of railroad and many more miles of roadways, and requiring diversions around the newly formed lake. It is estimated that 40-50 million people worldwide have been displaced by the creation of reservoirs.

Environmentally, a poorly sited and unmitigated reservoir can wreak havoc on local and river-long ecosystems. Standing water in reservoirs tends to become de-oxygenated due to the pressures built up and the lack of flow. This can strangle out species living downriver and in the reservoir, leading to issues with anaerobic decay and loss of life within the river.

Because reservoirs are often quite large and are mostly sited in valleys, they flood forests and other grass lands. This leads to the decay of plant matter in an anaerobic environment, releasing methane into the air. In some cases this release of methane is a greater release of greenhouse gasses than coal or oil fueled power plants.

Wildlife living along a river is threatened as the river is dammed because they are forced to move out of the area. The impact of wildlife varies based on the size of the dam and reservoir. For dams with large reservoirs specifically for drinking water, the impact on wildlife can be twofold. Once the

[53] http://www.nehydropower.com/how-we-do-it/archimedes-screw-generators

reservoir is filled, the land is generally a protected area, uninhabited by humans, and becomes a wildlife refuge of sorts. But, it also displaces the animals which once lived in the valley.

The largest impact is generally on the population of fish that travel up- or downstream to mate and reproduce. Many fish, like salmon, live in the ocean but spawn in freshwater rivers. Other species, such as eels, live in rivers but spawn in oceans. When a dam is placed across a river, it becomes impassable, and leads to the endangerment of fish species. To mitigate this risk, fish ladders or elevators can be installed, but with added cost and effort. Therefore, it is most ideal for the establishment of a future hydroelectric generator in a location that is already dammed. This will hopefully prevent less destruction to the environment, to people, and to the fish and wildlife species.

The density of water gives a river the ability to push other objects or transport sediments downriver and deposit them in the river delta. Transported sediments are capable of producing small islands as well as being fertile for the growth of plant life along the river. They do, however, pose a risk to dams. When the silt and sediment reaches a dam, it builds up and lowers the volume of the reservoir, as well as increases the water level. In engineering terms, this means a greater chance of the dam overtopping and failing, or even failing due to the extreme horizontal load on the dam because of the sediment resting on it. Thus, it is most ideal to choose a river which is relatively clean (where you can see the bottom) so that you don't risk dam failure or overtopping from sediment buildup.

Local Rivers

It is very difficult to locate a prospective site for hydropower within this region because there are few rivers with high flow and locations (and dams) with high head. Therefore, low flow/ low head hydropower systems are the most realistic systems to develop within the Montachusett and Northern Middlesex regions. However, low flow/low head systems do not yield high energy production levels. This paradox makes it difficult to locate prospective sites for hydropower within these regions.

The major rivers within this region are the Nashua River, the Merrimack River, and the Miller's River. Historical data collected from the U.S. Geological Survey (USGS) is analyzed in the sections below. The USGS uses hydraulic units to monitors the flow rates of select rivers throughout the country. There are six sites within the region which USGS monitors. Data from these sites have been included below.

What is important to realize from this historical flow rate data is that the theoretical power equation uses only one flow rate as an input. The data makes it evident that flow rates are ever changing. From this data, – a mean average is used to establish a baseline flow rate for each of the rivers examined below. This average flow rate can be used within the theoretical power equation. Although this does not make clear how much energy can be generated in any given month or day, it does allow for a starting point to analyze the potential energy held within these local river systems.

United States Geological Survey (USGS) monitored sites are the first place to begin assessing an average river flow. There are three USGS hydrologic units along the Nashua River in Fitchburg, Leominster, and Pepperell.

The Nashua River

The Nashua River has two starting points – one is at the convergence of rivers on the Westminster, Princeton, and Fitchburg border. This is the headwaters of the North Nashua River, which flows seven miles through Fitchburg, into Leominster and converges with the other branch of the Nashua River in Lancaster. The second branch of the Nashua River begins in Clinton at the Wachusett Reservoir. These two branches conjoin in Lancaster and flow north through Pepperell into Nashua, New Hampshire. In Nashua, the Nashua River joins the Merrimack River, which then flows southeast through Lowell and eventually into the Atlantic Ocean.

Fitchburg

The graph on the right show the varying average monthly flow rates of the Nashua River in Fitchburg. On average, daily flow rates range from 46cfs to 244cfs. This study will use averages to gauge flow rates even though the flow of a river is never constant. By summing up the mean monthly discharge values and dividing that number by twelve, the Nashua River in Fitchburg averages an annual flow rate of about 125cfs.

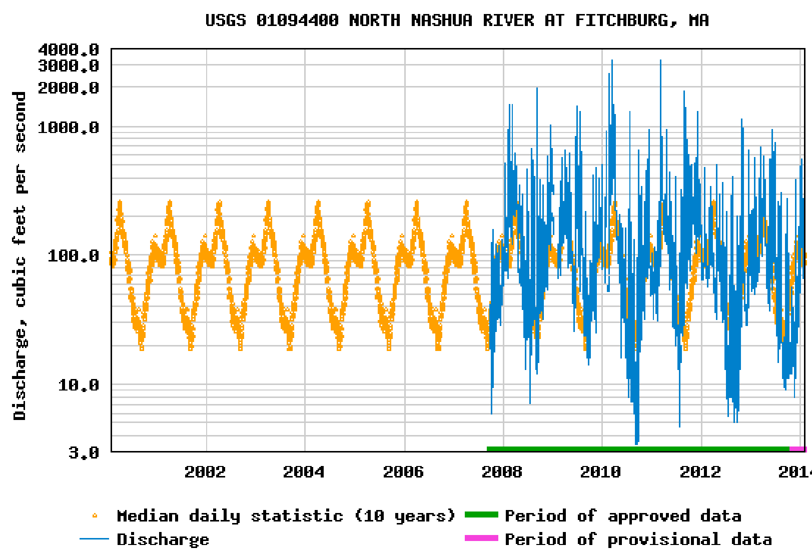


Figure 15: Visual Representation of the variations in flow of the Nashua River

The Nashua River then flows downstream to Leominster. A second USGS hydraulic site is located in Leominster. The historical data from this site are in the Fitchburg table in Appendix E.1

Leominster

The Leominster table Appendix E.1 shows the average flow rate of the Nashua River in Leominster. The average flow rate of the Nashua River in Leominster is 207cfs. This is higher than the rate of the Nashua River in Fitchburg because Leominster is further downstream. Since the North Nashua River begins in Fitchburg, all points below Fitchburg will have a higher flow rate because the river is longer and increases in size, volume, and flow. Therefore, sites located further downstream are generally more preferable because the river has more flow, which is a key variable in the power production equation.

As the North Nashua River passes through Leominster, it converges with the Nashua River from Clinton in Lancaster. From Lancaster, the Nashua River then flows northward towards the Merrimack River in Nashua, New Hampshire, passing through another hydropower site in Pepperell.

Pepperell

The historic data for average monthly flow rates of the Nashua in Pepperell have been recorded by the USGS and are shown in the Pepperell table in Appendix E.1.

The flow rate of the Nashua River in Pepperell is higher than that of Fitchburg and Leominster with an average yearly flow rate of 603 cubic feet per second. Because Pepperell and Leominster are further downstream from Fitchburg, these locations also have large drainage areas. Recall that the drainage area is the landmass that naturally collects water flowing downwards. The more drainage area a river has, the more land mass it has draining rainwater into the river. Fitchburg's hydraulic site has a drainage area of 64 square miles. Leominster's drainage area (which includes Fitchburg's) is 110 square miles. The drainage area of Pepperell's Nashua River is 435 square miles. As you can see, it is important to calculate the drainage area of a system in a particular location because the longer a river flows the greater the drainage area. Comparing the flow rates and drainage area of the one river can help identify the most ideal locations to site a future hydropower facility.

The Merrimack River – Lowell

The USGS has installed a flow gauge along the Merrimack River in Lowell. The Merrimack River is the region's fastest flowing river. The major rivers that combine to form the Merrimack River include the Nashua, Contoocook, Soughegan, and Concord Rivers. The siting of the USGS flow gauge in Lowell is after the induction of the Concord River. The Merrimack River consistently flows throughout the year to provide reliable and lasting power.

As seen in Appendix E.2 the flow of the Merrimack River is much faster than that of the Nashua River. The drainage area of the Merrimack River is far greater than the drainage area of the Nashua. Moreover, because the Nashua River is a tributary of the Merrimack River, the Merrimack River contains the entire flow of the Nashua River in addition to the other rivers mentioned above.

Miller's River

The USGS hydraulic site is located along the Miller's River in Winchendon, where the Miller's River begins. This river is significant within our region because it has a relatively strong flow rate. For detailed information on the river's flow please see Appendix E.3.

Miller's River in Winchendon has an average flow rate of roughly 150 cfs. As Miller's River flows towards its mouth at the Connecticut River, the flow rate increases. The rivers which conjoin to form Miller's River in Athol include the Tully River, Tarbell Brook, and Otter River. To quantify the flow rate of Miller's River in Athol, regression equations are used to calculate a general average. The equation considers variables like the drainage area, the geography of the land, and the typical weather to help define an average flow rate.

Other rivers within the Montachusett and Northern Middlesex regions have been identified; however, data for flow rates and drainage areas are not available. These rivers include the Stony Brook River, the Shawsheen River, Beaver Brook, the Nissitissit River, Reed Brook, Squanacook River, Mulpus Brook, and other tributaries.

Table 4: Average Flow Rates of Regional Rivers

River Name	Location	Flow Rates (cubic feet per second - cfs)			Drainage Area (Mi^2)
		High	Low	Average	
Nashua River	Fitchburg	500	8	125	64
	Pepperell	3,300	45	603	435
	Leominster	1,100	30	207	110
Merrimack River	Lowell	30,100	1,100	7,960	4,635
Miller's River	Winchendon	510	9	148	82
Miller's River	S. Royalston	3,890	10	350	189
Miller's River	Athol	597.8	10.4	600	282
Concord River	Lowell	3,000	200	874	400

Source: MRPC, USGS[54]

Regional Potential

Hydropower is the cleanest form of electric generation, and is the most re-usable resource as it is based on the natural water cycle. It is also the most efficient way to produce electric energy. The National Inventory of Dams quantifies the number of dams within Massachusetts at 1,490, 80% of which are small dams less than twenty-five feet in height. This poses significant difficulties in locating the regional potential for hydropower because very few dams have a high head value. To compensate for low head, high flow is needed to balance the power equation. There is potential for a hydro facility in a location that

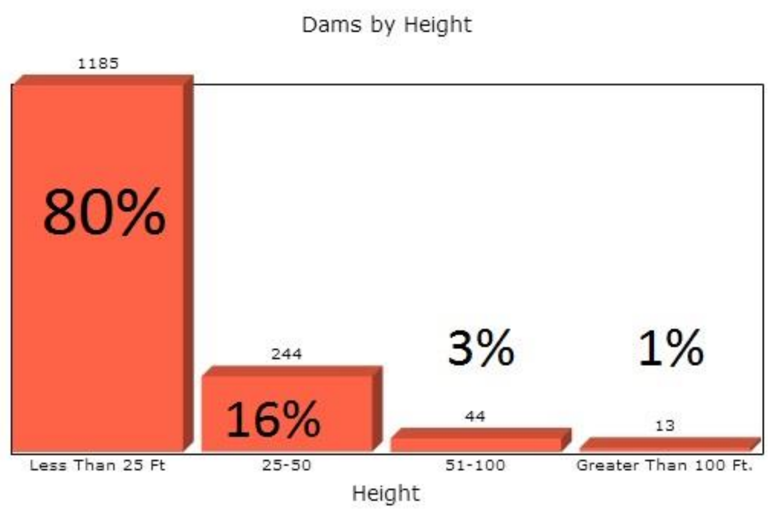


Figure 16: Number of Dams by Height within Massachusetts

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[54] The USGS website has a very helpful interactive map found here: http://water.usgs.gov/osw/streamstats/massachusetts.html and http://streamstatsags.cr.usgs.gov/gages/viewer15.htm?stabbr=GAGES

generates enough power to have a reasonable return on investment.

Of the dams in Massachusetts, 6.6% are used to create hydroelectric power. According to the Army Corps of Engineers, Massachusetts has the potential to generate 67 additional Megawatts of energy through hydroelectric technologies.

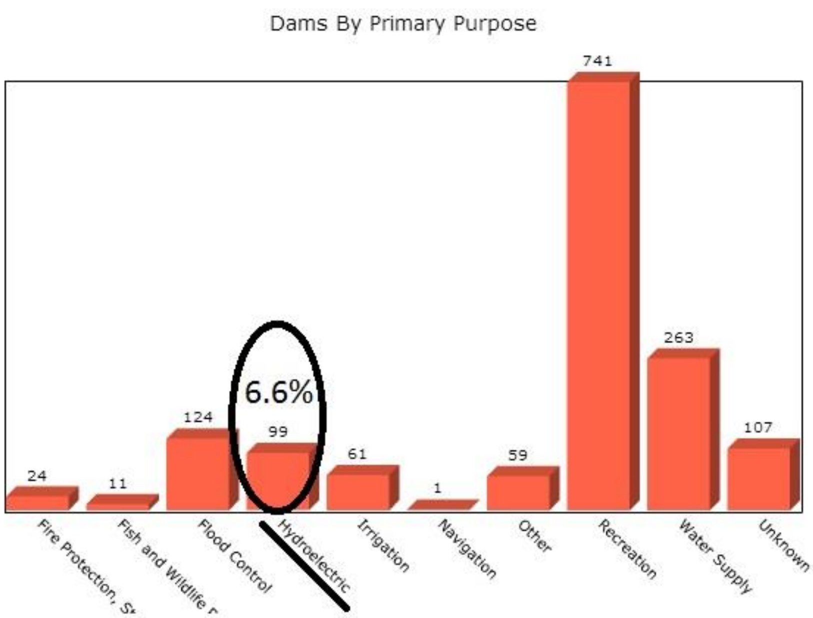


Figure 17: Dams in Massachusetts by Primary Purpose

Within the Montachusett and Northern Middlesex regions, there are approximately 330 dams, some of which currently produce hydropower. The hydroelectric plant located in Pepperell along the Nashua River is a great example of the region's potential. There are three turbines located in Pepperell that generate energy based off a head of 28 feet with varying flow. The chart below shows the monthly MWH generated by the hydro facility in Pepperell. Because the height of the dam is constant – the variations in energy production are based on varying flow rates of the river.

Figure 18 illustrates the flow rate and seasonal differences in energy production. The data is based off the USGS geological data collection station that is in the Nashua River just past the hydro facility. This data has two averages: 18-year average in green and 33-year average in red. Purple is the year 1996. 2001 is marked with dark blue, and 2002 is marked with bright blue. This data helps augment how the change of seasons yields varying levels of power production. This can be applied to the regional potential of any future hydro facilities within North Central Massachusetts and Northern Middlesex County because Pepperell falls within that geographical boundary.

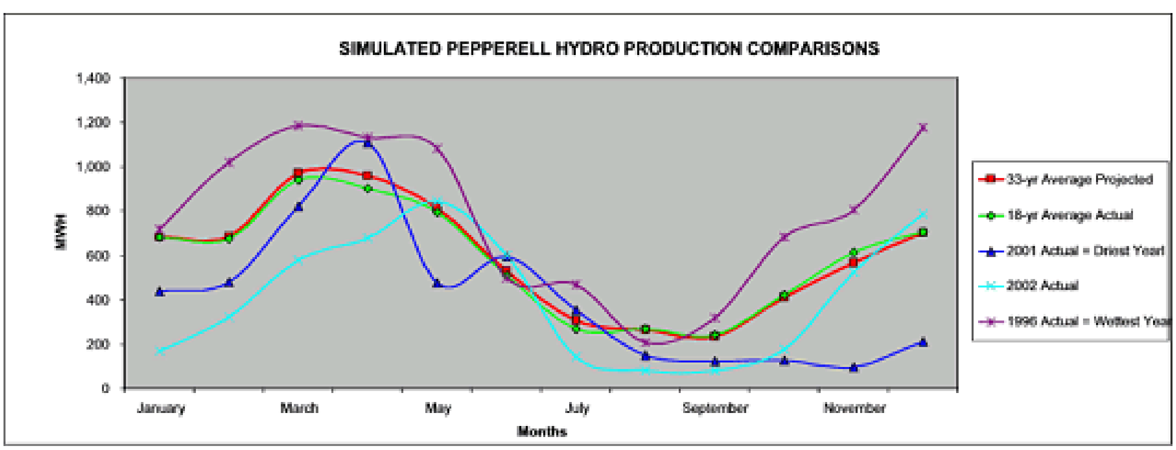


Figure 18: Simulated Pepperell Hydro Production over Varying Years and Averages

The Figure shows that there are three general seasonal trends that affect the production of hydroelectric power in the region. The lowest point on this chart is in summer.

(1) July, August, and September are the months that produce the least amount of electricity. Days during these months are long, hot, and humid. A lot of water is evaporated. With run-of-river technology it should be expected that these months will have the lowest flow rates and lowest energy production rates. Energy production bottom outs around 200MWH/month.

(2) Between November and March there is a positive trend in the chart which peaks in March and April. Comparing energy production levels in November verses April, values increase significantly. As May turns into June and the days grow long, the flow of the river slows once again.

(3) When all the snow has melted and temperatures rise, the graph shows a decrease in power production from May to July. Once September passes and nights begin to grow longer the flow of the river again begins to increase.

Pepperrell sits within the Northern Central Massachusetts and Northern Middlesex region. This site was originally, "Built in 1918, the hydro plant was designed for *3 vertical Francis turbines* selected for the net *head of 28 feet* and a *design flow of 1,035 cubic feet per second*" (Swift River Hydro Website). Today the site has three functional Francis-turbines which receive water intake through a wooden penstock.

The unique characteristics of Pepperrell Hydro are its location, flow rate, height, and efficiency. Built in 1918, the site was generating about the same energy as it does today. The location of the hydro facility is within the regional guidelines. With this information some assumption can be made about the other 329 dams within the region.

(1) Most of the dams are low head, low flow.

(2) The head of the system will be the height of the dam.

(3) The flow of the system will be lowest between July and September. The flow will increase and max out in March or April. From May to July the production will slow until it bottoms out again in the summer months.

(4) Flow can be calculated based off USGS regression equations formulated from River Basin statistics.

(5) Flow can be averaged out to one number per year even though it changes throughout the year.

(6) When considering the amount of energy generated per year, it must be realized that not all months are generating constant values.

Pepperell Hydro is a great model for future low head hydro facilities. Establishing locations that can produce reliable renewable energy is vital to future generations and to the Commonwealth of Massachusetts. The current owners of Pepperell Hydro realized how important renewable energy is to our society and restored it during its final stages of life. In 2002 three Francis-turbines created more than seven gigawatts of energy. According to the Pepperell Hydro owners:

"[We] believe that there are a few select locations where river flows and head combine for efficient hydro generation. Plants at existing dams are already located at such efficient hydro sites, and rebuilding them has helped Massachusetts to rely on local renewable energy resources"

There are about 330 dams located within the Montachusett and Northern Middlesex regions. Each dam within the region is highlighted with a purple square.

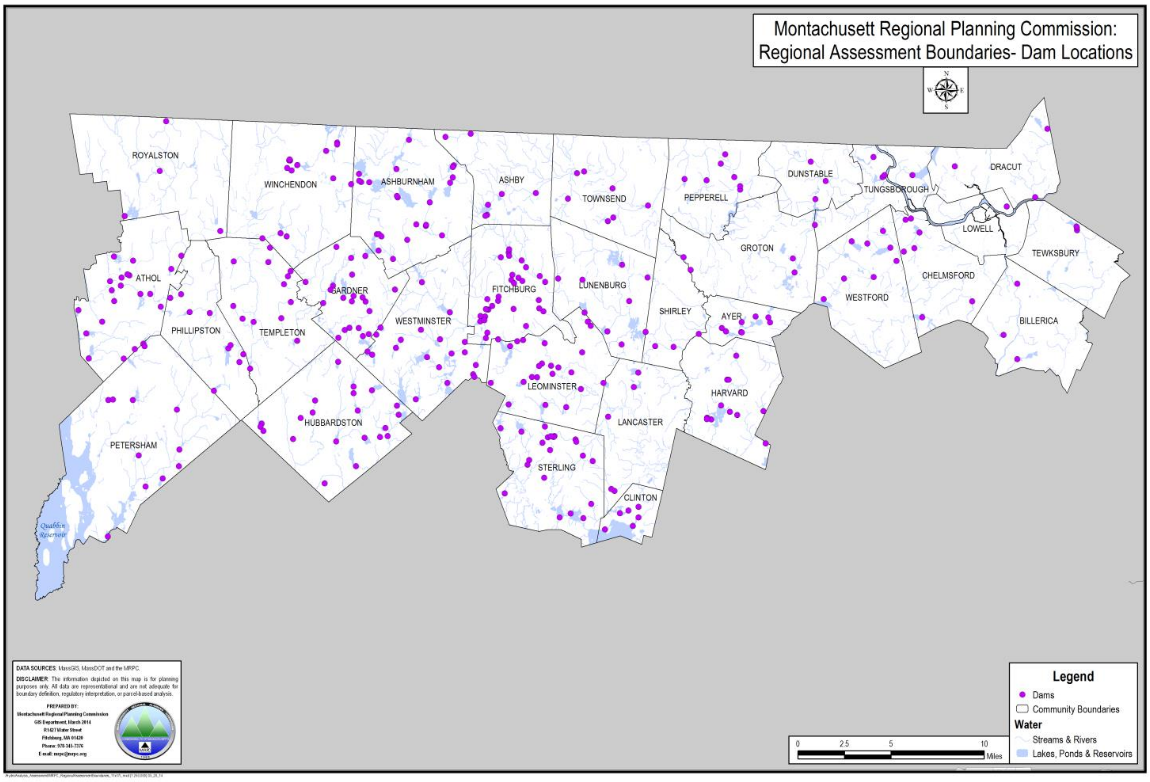


Figure 19: High Head Locations within the Region

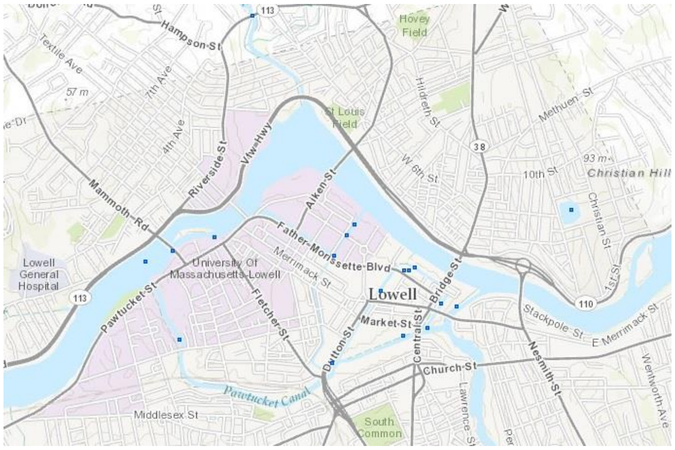
Higher head locations mixed with high flow rates yield the greatest energy production. The National Inventory of Dams has a database provided by the Army Corps of Engineers which provides detailed data on all the registered dams within the United States. Within the Montachusett and Northern Middlesex regions – dams with head values greater than thirty feet have been included in the table below.

Table 5: Dams with Head Values > 30 feet

Dam Name	Location	Owner	Primary Usage	Dam Height (ft)
Tully Dam	Athol	CENAE (New England division of the Army Corps of Engineers)	Flood Control	59
Birch Hill Dam	Athol	CENAE	Flood Control	49
Newton Reservoir Dam	Athol	Town of Athol, Board of Selectmen	Water Supply	30
1000 Acre Pond Dam	Athol	Town of Athol, Public Works	Water Supply	27
Wachusett Reservoir Dam	Clinton	DCR	Water Supply	114
Lovell Reservoir Dam	Fitchburg	City of Fitchburg, Water Division	Water Supply	85
Overlook Reservoir	Fitchburg	City of Fitchburg, Water Division	Abandoned Water Supply	40
Scott Reservoir Dam	Fitchburg	City of Fitchburg	Water Supply	39.5
Snows Mill Pond	Fitchburg	Newark America	Water Supply	28
Ashby Reservoir Dam	Fitchburg	City of Fitchburg, Mayor's Office	Water Supply	28
Perley Brook Reservoir Dam	Gardner	City of Gardner, Public Works	Water Supply	50
Bickford Pond Dam	Hubbardston	City of Fitchburg, Mayor's Office	Water Supply	49.2
Mare Meadow Reservoir Dam	Hubbardston	City of Fitchburg	Water Supply	41
Fall Brook Reservoir Dam	Leominster	City of Leominster, Public Works	Water Supply	37
Simonds Pond Dam	Leominster	City of Leominster, Public Works	Water Supply	30
Notown Reservoir Dam	Leominster	City of Leominster, Public Works	Water Supply	26
Lower Locks Dam, North Canal	Lowell	Essex Company C/O Enel North America, Inc.	Flood Control	42
Lowell Reservoir Dam	Lowell	City of Lowell, Regional Water Utility	Recreational	26
Crocker Pond Dam	Westminster	Whitman River Dam Inc.	Hydroelectric	38.5
Westminster Reservoir Dam	Westminster	Whitman River Dam Inc.	Other	31
Whitney Pond Dam	Winchendon	Town of Winchendon, Public Works	Recreation	26.5

The majority of locations above are part of city water supply. These locations are ideal for conduit hydro. Fitchburg could significantly benefit off the addition of conduit hydro because of the large number of dams owned by the city with retaining water 28 to 85 feet.

Figure 20: Dams within Lowell



In Lowell, the Lower Locks Dam along the North Canal is already generating hydroelectric power. There are fifteen dams located within the Lowell downtown waterway/canal system. The map in Figure 27 shows all of these dams highlighted with small blue squares.

Of the fifteen dams seen within this image, eight belong to a hydroelectric provider (Enel) and seven dams are owned by the U.S. National Park Service. The average flow of the Merrimack River in Lowell, according to the USGS hydraulic unit, is roughly 8,000 cfs. Boott Hydropower must use run-of-river technology, which means the flow of the hydropower units cannot exceed the flow of the river. Fortunately, the canals cut through the City and divert water from the Merrimack River. It is not possible for these canals to have flow rates greater than the Merrimack because they're formed from the Merrimack. Boott Hydropower's primary powerhouse, located on the Merrimack River, has a nominal production capacity of 24 MW. One primary turbine has a head of 37 feet and an average flow of 3,300 cfs, producing (on average) about 17MW of energy. Boott Hydropower has four existing power plants with a total installed capacity of 7.5 MW housed in nineteenth century mill buildings along the canal system.

Suggested Sites

To site a hydropower facility the owner of a property along a river or dam must apply for a license and submit a feasibility study to FERC. Then FERC will work with other organizations to decide if this location is safe, feasible, and good for the river, animals, people, and environment.

Although this region has a number of locations that could be developed for hydropower in the future, four locations that could sustain development today are listed below:

(1) **<u>Lowell, Merrimack River</u>** – Hydrokinetic energy production may have potential. There is good flow in the river; it is relatively deep and wide. Hydrokinetic power would be a great municipal investment for Lowell because the hydropower dams within the City are privately owned. Hydrokinetic power could provide the city government with reduced utility rates over the long-term. Also hydrokinetic has almost no environmental impact, as well as being sub-surface does not have a major visual impact.

(2) **Fitchburg, Overlook Reservoir** – This site is unique because it is located one-half mile from the Nashua River, but 360 feet higher than the river. For this study, it is proposed that this development transform the former Overlook Reservoir into a pumped storage facility. The National Inventory of Dams lists the volume capacity of this reservoir to be 276 acre-feet. In order to create a sustainable development, water must flow at a rate of 20 acre feet per hour for ten to thirteen hours.

Power = [(head) * (flow) * (efficiency)] / 11.81

Head: 360 feet

Flow: 20 acre-feet/hr = 242 cubic feet/sec

Efficiency: estimated at 85%

[(360) * (242) * (.85)] / 11.81 = 6,270.3 KW/hr = 6.2 MW/hr

This system could be sustained at this rate for ten to thirteen hours a day.

Running for 10 hours in one day this system could generate 60 MWh.

(3) It is recommended that ALL municipalities within this region investigate the opportunity cost of developing conduit hydro along their water distribution supply network. Any water treatment facility or sewage treatment plant could sustain the development of conduit hydro. Lowell, Dracut, Chelmsford, Tewksbury, Fitchburg, Leominster, Gardner, and Athol are just some locations that should seriously consider investigating the opportunity cost of conduit hydro within their current water supply and sewage supply systems. Additionally, rivers within the two regions could benefit from the development of hydro. Conduit hydro is a great addition to any water treatment plant because the water already is traveling through pipelines; adding a hydro turbine within this pipeline system comes with minimal risk and no environmental impact. It is recommended for municipalities because they can often sustain longer term returns on investment. Potentially, this could reduce the amount of utility expenses municipalities pay each year, and, in some cases, reduce the cost of utilities paid by the taxpayer.

(4) The Merrimack, Nashua, Concord, and Miller's Rivers are the four largest and fastest flowing in the region. Businesses located along these rivers should consider investing in hydroelectric energy to reduce utility expenses and produce their own sustainable energy. Suggested locations include Athol, Winchendon, Gardner, Fitchburg, Leominster, Lancaster, Groton, Pepperell, Tyngsboro, Lowell, Tewksbury, and Chelmsford. Although these four rivers are the largest in the region – all the cities and towns within the region have dams that are capable of producing hydroelectric energy.

Permitting and Regulation

Regulatory Authorities

State

The siting and maintenance of dams in Massachusetts is governed by the Department of Conservation and Recreation's Office of Dam Safety. The Office of Dam Safety is responsible for upholding the laws as laid out in Part III Chapter 253. These laws regulate all the dams within the Commonwealth of Massachusetts.

Federal

The Federal Energy Regulatory Commission (FERC) is an independent federal agency intended to regulate and oversee the energy industries in the economic, environmental, and safety interests of the American public. FERC promotes the development of a strong national energy infrastructure and does not propose, construct, operate, or own any energy projects but does issue permits and licenses for projects, enforcing the conditions of each license during the term of the project, and conducts project safety and environmental inspections. In sum, FERC has three major regulatory goals: (1) issuing licenses for the construction of new energy projects, (2) issuing licenses for projects already underway (relicensing), and (3) overseeing all ongoing project operations, which include dam safety inspections and environmental monitoring. Within these guidelines FERC works alongside each states office of dam safety.

Any aspect of dam safety and inspections requires FERC consent. For example, construction, operation, exemption, special, pre-license, environmental and public use inspections, engineering evaluations and studies, independent consultant report reviews, emergency action plan development and testing, and engineering guidelines development are all areas which FERC monitors. If you plan to work on any of those items it is required to get FERC licensing and permits so that all federal guidelines are followed.

FERC Licensing

Each license depends on the type of project, for example, hydrokinetic projects, small/low-impact hydropower projects, and pumped storage projects all have different forms for licensing. These forms can be found of FERC's hydropower website: https://www.ferc.gov/industries/hydropower.asp

Prior to applying for a license, it is recommended that one apply for a preliminary permit. It is not necessary to have a preliminary permit to apply or receive a license – but it is recommended. The permit lasts for up to three years and allows for studies to be conducted on site.

Considering all the information within this document, it can be understood that dams, hydropower, and rivers are very complex entities with unique characteristics that vary on a locational basis; each site requires a dense understanding to realize the true potential of converting naturally flowing water into energy. To convert any body of water within the United States into a hydro facility requires licensing with FERC. Each licensing process varies by each location's unique characteristics.

Appendix E.4 contains a matrix that should help identify some of the variables which can arise in the unique characteristics of varying hydropower and dam locations. For more information please see https://www.ferc.gov/industries/hydropower/gen-info/licensing/licen-pro.asp

ILP – Integrated Licensing Process

This is the most common filing for original, new or subsequent licenses. It is also the default process (18 CFR Part 5). The three fundamental efficiency principles expected to be achieved through the ILP are: (1) to provide predictable; (2) efficient; and (3) timely licensing processes which adequately protect natural resources. Consideration is about site feasibility studies submitted from licensed engineers and to time frames, regarding signing of papers and permits signed by all stakeholders.

TLP – Traditional Licensing Process

The Traditional Licensing Process is a more dated version of the ILP. There are three stages to completing all the documents in this application process which requires constant contact with FERC. Reference 18 CFR § 4.38 to see the original licenses and for relicenses check 18 CFR §16.8. The first stage of this process entails a notice of intent, a preliminary application document, a request to use TLP, and a newspaper notice. FERC must approve the use of TLP and then there is a joint agency/public meeting along with a site visit. The second stage of the process requires the applicant to complete necessary studies. FERC will check in through the study to comment as necessary. Not always does the applicant agree with FERC, this is common throughout the drafting process. In this third stage, FERC agrees that the license is going to a location which is safe, economical, effective, and efficient.

ALP – Alternative Licensing Process

The ALP is a hybrid to the two previous traditional licensing processes described above. This process has been designed to increase communication among all entities affected by the licensing process. Reference the forms 18 CFR § 4.34(i); Order No. 596 to apply for the ALP. The pre-filing consultation is ideal for this application. It allows FERC and the applicant to get study all of the unique circumstances of each location prior to beginning the filing process. The ALP pre-filing consultation process allows for various statues, like the National Environmental Policy Act, to be considered and added to each case's feasibility study. Additionally it allows for applicant to prepare an environmental impact statement along with a feasibility study which includes pricing with a chosen contractor.

The table on the next page compares the three licensing processes. Each has its own advantages and disadvantages. The preferred method with FERC is the ALP but they do not discriminate and all processes are acceptable.

Administration and Compliance

Once a license or exemption is granted, FERC staff ensures that regulated entities remain in compliance with the terms and conditions of their respective licenses or exemptions to protect, mitigate and enhance beneficial public uses of hydropower projects.

Post-licensing, FERC staff is responsible for tracking and administrating license requirements, inspecting site conditions, investigating compliance issues, and assessing penalties. Other post-licensing filings that are processed by FERC staff include, updating contact information, amendments, investigations, allegations, transfers, license exemption or surrenders, and timeline extensions.

Comprehensive Plans

FERC has guidelines of ways to improve, develop, and conserve waterways and require all projects to be within Federal or state guidelines. This can be found within FERC's Federal Power Act (FPA) pm Section 10(a)(2)(A) and 16 U.S.C. section 803 (a)(2)(A).

All comprehensives plans submitted to FERC must follow three principal characteristics as defined in the FPA. FERC requires an array of detailed data prior to considering a license applicant. The comprehensive plan should include (1) a description of all waterways within plan with detailed geographical area mapping, (2) data and description of the significant resources of the waterways, (3) data detailing the various existing and planned uses for these resources, and (4) discussion of goals, objectives, recommendations for improving, developing, or conserving the waterway(s) in relation to other resources. In more detail, FERC considers the other resources which affect waterways vital to the study and requires consideration and descriptions of water navigation, power development, energy conservation, fish and wildlife, recreation opportunities, irrigation, flood control, water supply, and other environmental concerns. The plan should contain a micro- and macro-examination of how the license will promote overall public welfare and be for the good of a community. The study should be filed with FERC.

Planning, Siting and Zoning

The planning, siting and zoning processes are lengthy but executing all the steps within the guidelines and timeframe set can allow for the effective development of a hydroelectric site.

Siting a hydropower plant is a very difficult task without a qualified engineer's feasibility study. Engineers will be able to accurately assess the flow and head value for sites by going to the site and taking measurements, but they also have access to more databases and connections. A qualified engineer is vital for any feasibility study because they are the only people who can accurately measure and calculate the variables that affect a hydropower site. Federal and state agencies that oversee the development of dams in Massachusetts include the Federal Energy Regulatory Commission (FERC) the Office of Dam Safety within the Department of Conservation and Recreation (DCR), and the Army Corps of Engineers, which includes the National Inventory of Dams.

There are three forces working against additional hydropower facilities in Massachusetts: 1) the State is attempting to remove as many dams as possible, and 2) many sites that would be perfect for the conversion to hydro are too contaminated to allow water past the dam during construction or in use, and 3) most of the ideal locations already produce hydropower. Aside from these negative factors, there is an array of locations that could house hydropower. The biggest difficulty in locating where these locations should be installed is predicting the amount of power that can be generated by hydro infrastructure.

Planning a location

Many states, such as California and Texas, maintain guides on site planning for dams; unfortunately there is no such guide for Massachusetts – therefore it is recommended to contact a qualified engineer prior to planning.

In a general sense the first step is deciding how large the hydropower facility will be. Will production be micro, small, medium, or large? Is energy production for personal use, business use, or to sell to the grid? These factors weigh heavily in the planning process. Locating a site for personal or business use with a micro or small hydro system is realistic. It is realistic to site a low head hydro within the region because the majority of rivers have low head and this system has little environmental impact and uses run of river technology.

Once the relative size of the system is established, the next step is to identify a location to implement the system. Many variables are required to be understood prior to sending FERC an application. Variables to consider include (1) description of all waterways within plan with detailed geographical area mapping, (2) data and description of the significant resources of the waterways, (3) data detailing the various existing and planned uses for these resources, and (4) discussion of goals, objectives, and recommendations for improving, developing, or conserving the waterway in relation to other resources. In more detail, FERC considers the other resources which affect waterways vital to the study and requires consideration and descriptions of water navigation, power development, energy conservation, fish and wildlife, recreation opportunities, irrigation, flood control, water supply, and other environmental concerns. The plan should contain a micro- and macro-examination of how the license will promote overall public welfare and be for the good of a community.

After the completion of a feasibility study that includes all of the variables listed above, it is time to apply for a license with FERC. The Alternative Licensing Process (ALP) is a blend of the Integrated Licensing Process (ILP) and Traditional Licensing Process (TLP). The ILP is the second quickest process. The TLP is a rather dated process and is typically slower than the ALP and ILP.

The feasibility study will show the dynamics of the future hydro location in addition to the environmental impact, cost, and return on investment. It is imperative that a feasibility study be submitted to FERC who will review it with the Department of Dam Safety. Together, they will conclude whether or not a proposed location is realistic and reach a decision as to whether or not the developer can continue their planning process.

Zoning

There are no direct guidelines about zoning for hydropower in Massachusetts but all feasibility studies will review the specific zoning of a site and determine if it is acceptable or not. The siting of a location will be one that is for the greater good of people and does not harm the environment.

GEOTHERMAL

History

Humans have been aware of Earth's heating properties since the Paleolithic Era (2.6 million years ago) when early hominids used hot springs to bathe.[55] The oldest known spa use of hot springs occurred in 3rd Century BC, where the springs were used as a hot tub in the mountains of China. The Romans were the first to make non-bath related use of natural hot springs in Bath, England, to heat the floors of homes, thus warming the home. The baths at Bath charged an admission fee, representing what is most likely the first commercial use of geothermal energy. The first use of geothermal energy for electricity was pioneered by modern Italians in 1904, where Prince Piero Ginori Conti of Larderello experimented with geothermal energy to light four light bulbs. Ten years later, a 250 kW plant was commissioned to power the boric acid plants in the town. This was the world's only commercial geothermal power plant until another plant was built in New Zealand in 1958.[56] The Larderello plants still produce electricity on the order of about 550 MW, but there are indications that production is falling from peak production.

Figure 21: Prince Conti and his geothermal electric generator

Since the installation of the original plant, geothermal technology has advanced greatly allowing for lower and lower temperatures to be used to generate steam to turn turbines. The first turbine was a dry steam turbine, meaning it operated entirely on steam from the ground. Higher temperatures under greater pressure allow for water to be pumped out of the ground, whereupon reaching lower pressures in a vessel, it flashes (instantaneous change from water) into steam for the turbine. Most modern plants are Binary cycle plants which operate using a flash fluid instead of direct steam from the ground.

Geothermal is nearly carbon neutral and has the additional benefit of maintaining a minimal spatial footprint. Plants average 1.4 square miles per gigawatt. Couple the small plant space, with its minimal harmful emissions and renewability, and Geothermal can be considered to have the least impact on the environment of any power source. The greatest benefit to geothermal power is that it is a natural source of base load power. It does not fluctuate with the season or the time of day, nor does it depend on the wind blowing or the sun shining.

"Home use geothermal" has been gaining traction in recent years. This process involves laying pipes under the local frost level, which are heated using the ground as a thermal reservoir. The earth, under 6m (20ft), stays at a constant 10 to 16^{O}C (50-60^{O}F), no matter the season. Homes run piping down

[55] Cataldi, Raffaele (August 1992), "Review of historiographic aspects of geothermal energy in the Mediterranean and Mesoamerican areas prior to the Modern Age", *Geo-Heat Centre Quarterly Bulletin* (Klamath Falls, Oregon: Oregon Institute of Technology) **18** (1): 13–16, retrieved 2/24/14

[56] Lund, John W. (June 2007), "Characteristics, Development and utilization of geothermal resources", *Geo-Heat Centre Quarterly Bulletin* (Klamath Falls, Oregon: Oregon Institute of Technology) **28** (2): 1–9, retrieved 2/24/14

below the 6m layer and use thermal pumps to collect heat from the surrounding ground, using it as a thermal energy source in the winter and a heat sink in the summer. These systems work utilizing water supplemented with environmentally sensitive antifreeze (propylene glycol), refrigerants, or even air, to minimize the chance that piping would freeze and burst. Geothermal heat pumps have become a major trend in sustainable living and home design.

How it Works

Commercial Geothermal Electricity

There are three types of geothermal power plants (dry steam, flash steam, and binary cycle), each with two methods of removing the heating resource. Each plant has the option of either pulling water/steam out of an underground reserve that already exists, then pumping the exhaust water back into the ground, or starting at a site where there is no reservoir, hydraulically fracturing the area and then pumping fluid into the new fractures to be heated. Furthermore there are "Closed Loop" and "Open Loop" systems. Closed loop systems use and reuse the same water and steam that was already underground, and returns it back to the source. Open loop systems bring in water from a reservoir, inject it to the ground, and allow the steam to escape into the atmosphere without condensing and recycling it.

A well which removes water from the ground is called a "Production Well" while a well which pumps water back into the ground is called an "Injection Well." Another major component of the system are the condensers, which take steam, and either cool it or pressurize it to convert the steam into liquid water again. This allows the plant to recycle the resource, by re-injecting the water into the reservoir.

Geothermal energy has the benefit of being a base-load alternative energy. There is always heat underground, and as long as the plant is maintained properly, it can run indefinitely. This means that it can be used to directly replace fossil fuel source power stations, and does not have the intermittency issues which impact wind and solar power production.

Binary Cycle Power Plant

A Binary Cycle power plant works by pulling a lower temperature geothermal fluid from the ground and using it to flash a fluid (generally a refrigerant of some form) with a low critical point. The two loops are isolated from each other, but are intertwined in a heat exchanger to transfer heat from one system to another. The thermal fluid is condensed and reused in the turbine cycle, while the hot fluid from the ground is re-injected to keep the resource replenished (See Figure22). These closed loop systems have the additional benefit of preventing the geothermal fluid entering the surrounding environment. This prevents naturally occurring greenhouse gasses and toxic elements from endangering the environment.

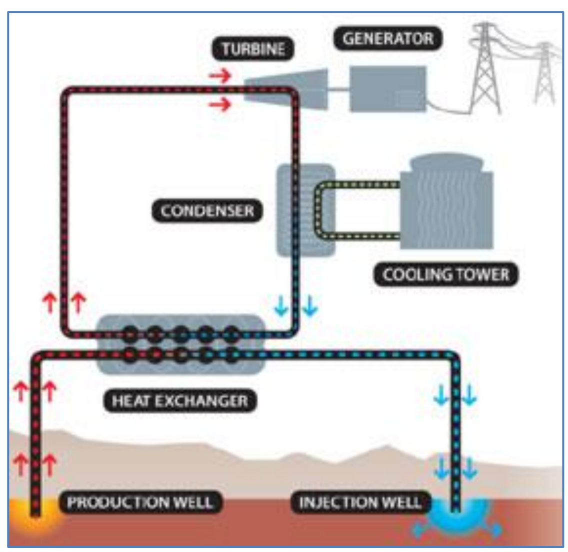


Figure 22: Binary Cycle Plant Diagram

This type of plant is able to work at much lower temperatures (only about 57^{O}C or 134.6^{O}F)[57] such as the temperatures in the MRPC/NMCOG region. Companies such as Ormat are bringing binary cycle plants to lower temperature regions. This is the most modern technology in geothermal power production, and is slowly gaining traction around the world due to its low temperature capability. However, there is a drawback in that this form of geothermal can be expensive to build.

Capacity and Efficiency

Capacity and efficiency differ in that capacity is the maximum amount of electricity a turbine is capable of producing, while efficiency is the difference between the amount of energy that enters the system, versus the amount of energy that leaves the system as electricity. For example, a 10MW turbine has the capacity to produce 10MW under the ideal conditions, given the proper amount of head and flow. That same turbine may only have an efficiency of 75%, meaning that if 10MW of energy goes into the turbine, 25% of that energy is lost to friction and other factors, and 7.5MW of energy leave the system in the form of electricity.

Capacity

The largest of turbines is capable of producing 140 MW[58], however, there are many designs and each site is different, leading to an average capacity of about 30 to 55 MW per turbine. Most plants will make use of multiple turbines, in order to increase cost efficiency, and make full use of the resource. Smaller turbines can be anywhere between 15 and 30 MW, some are built as packages and are capable of being shipped on a flat-bed truck as a complete unit. Currently there is about 11,224 MW installed capacity world-wide.[59] The majority of the installed capacity is in the western United States, with the Philippines, Indonesia, Mexico, and Italy rounding out the top 5 geothermal power producers in the world. Notably, Iceland is not in the top 5, despite Geothermal making up 30% of the Icelandic power portfolio. In the United States, Geothermal Power is mostly used in California. Further geothermal use is centered on and around the various fault lines and the super volcano under Yosemite National Park. Alaska also makes extensive use of geothermal for heating. Geothermal heating is used across the country to heat buildings and melt ice of sidewalks. Geothermal Power makes up less than 0.5% of the electricity used in the country.[60]

Potential Barriers

The main barrier for geothermal power in the Northern Middlesex and Montachusett Regions is the low temperatures of the earth in the area. While some technology is available that could potentially work with the lower temperatures, the cost of the equipment is high and the electricity output is not guaranteed because of the low temperatures. There are no locations in Massachusetts that produce

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[57] Erkan, K.; Holdmann, G.; Benoit, W.; Blackwell, D. (2008), "Understanding the Chena Hot Springs, Alaska, geothermal system using temperature and pressure data", Geothermics 37 (6): 565–585, doi:10.1016/j.geothermics.2008.09.001, ISSN 0375-6505, retrieved 2/27/14

[58] http://www.fujielectric.com/products/thermal_power_generation/geothermal_power/index.html accessed 3-6-14

[59] Geothermal Energy Association; Geothermal Basics: Current Use. http://geo-energy.org/currentUse.aspx accessed 3-6-14

[60] Natural Resources Defense Council

geothermal power. Geothermal heating is however used in the state at various locations including private homes and commercial buildings.

Geothermal power has a high initial capital cost. Wells are extremely expensive to drill; a 3 km well could cost 10 million dollars with a potential failure rate of 20%. Equipment and turbines for geothermal power can also be extremely expensive.

Drilling into the earth carries the same potential risks across all energy industries. There are a multitude of gasses and elements buried underground that can be dissolved in water coming through the production well. Open loop systems can allow these gasses and elements into the environment, but are often outfitted with emissions control systems to mitigate the byproducts of the open loop system. Gasses dissolved in the geothermal fluid can include ammonia, methane and carbon dioxide. Currently, the average plant allows only 122 kg of carbon dioxide to enter the atmosphere per MW-hour, which is an extremely small fraction as compared to fossil fuel resources.[61] Closed loop systems possibly can prevent the gasses and toxic elements from being able to escape the system into the environment altogether. As with any power plant, necessary steps must be taken to maintain clean emissions.

In some instances there have been issues where leaking wells have seeped into an anhydrous layer, creating gypsum, which expands and creates geologic uplift. This is similar to the process that creates frost heaves, but it is a permanent process. Once the anhydrous layer is introduced to water underground, it cannot be dehydrated. This has the potential to cause localized damage to structures by uplifting their foundations. For example, in Staufen im Breisgau, Germany, uplift of the gypsum layer caused the historic town hall's foundation and facade to crack.[62]

Along with the effects of uplift, the opposite function, subsidence, can occur. Subsidence occurs when a cavern is opened up underground and the above rock layers sag and eventually settle, eliminating the cavern. In the case of geothermal, if there is an established underground reservoir that is not replenished, it can create a cavern which may collapse under the weight of the earth above. In order to mitigate this, closed loop systems maintain pressure underground and minimize or even prevent the creation of caverns.

Geothermal injection, involving drilling and fracturing, has the potential to induce seismic activity in the ground as well, similar to hydropower reservoirs inducing seismicity. If a layer is fractured in order to create an underground reservoir, the added weight can lead to small earthquakes occurring. Recently in Basel, Switzerland, over 10,000 earthquakes as strong as 3.4 on the Richter scale occurred as the injection well was being filled. Because of the seismicity, the project was cancelled in order to prevent a larger seismic event. The 6 million dollar project in Basel was found to be the cause of 9

[61] Bertani, Ruggero; Thain, Ian (July 2002),"Geothermal Power Generating Plant CO_2 Emission Survey", *IGA News* (International Geothermal Association) (49): 1–3, archived from the original on 2011-07-26, retrieved 03/10/2014
[62] Staufen: Risse: Hoffnung in Staufen: Quellvorgänge lassen nach. badische-zeitung.de. Retrieved on 03/10/2014

million dollars of minor damages to homes and businesses. This was an experimental project, but a cautionary tale none-the-less.[63]

Using Geothermal for Heating and Cooling

Background

Many homeowners and businesses have realized home heating and cooling cost savings by using the heat of the earth. These systems can have efficiency rates of 300% to 600% compared to air source alternatives at 175% to 250%. As the sun beats down on the ground all summer, the earth warms to between 45^{O} and 75^{O} and stores that energy.[64] The earth generally stays between these temperatures all winter long at depths between 6 and as deep as 400 ft.[65] At these depths, the contractors lay pipes to collect heat with either fluid or air. This is then pumped throughout the house or through a heat exchanger into the house, keeping the base temperature stable. In the winter this acts as heating, while during the summer it acts as air conditioning.

Because of the relatively low temperature of the earth in the Northern Middlesex and Montachusett Regions, geothermal heating and cooling would most likely see more benefits than geothermal electricity production. In Massachusetts, 0.5% of homes are heated with "other fuel" which excludes fossil fuels, wood, and solar power for heating.[66] There is no data available on the number of geothermal heating systems in the region.

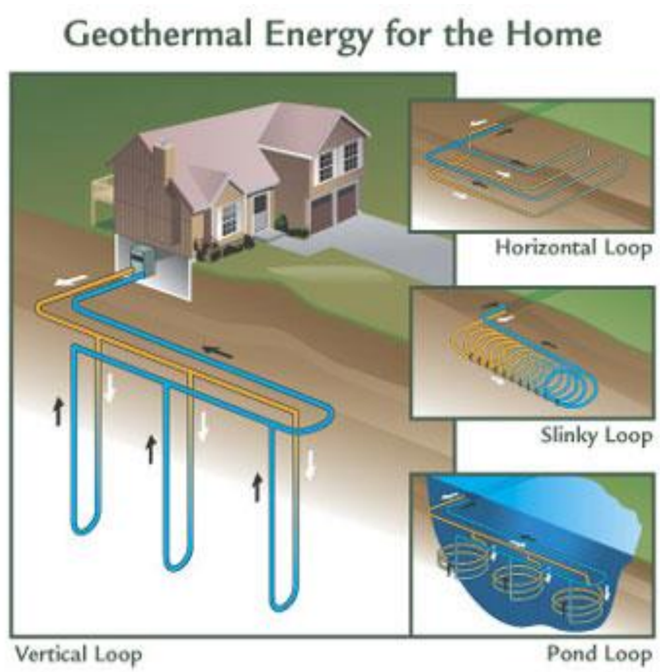

Figure 23: Ground Source Heat Pump Loop Configurations

Structure

There are three main types of systems: Open-, Closed- and Combined- loop, each laid out in 4 different patterns underground/water. Closed loop systems use a heat exchanger and refrigerant, reusing the same air from within the house. These types of systems tend to be more efficient in temperature extremes, as the same air is heated or cooled repeatedly, maintaining a more level temperature. Open

[63] Glanz, James (2009-12-10), "Quake Threat Leads Swiss to Close Geothermal Project", *The New York Times*. Accessed 03/10/2014

[64] US Department of Energy, Energy.gov: Geothermal Heat Pumps. http://energy.gov/energysaver/articles/geothermal-heat-pumps

[65]Image: http://iopscience.iop.org/1748-9326/2/4/044001/fulltext/

[66] 2008-2012 ACS estimates

loop systems withdraw water from the ground, to be used as a thermal source or heat sink for a vapor compression refrigeration system (a heat pump). These systems allow the homeowner to have fresh air circulate, but are more difficult to maintain. Combined systems are a hybrid of both systems and allow the homeowner to take advantage of the benefits of both forms of system. Studies show that while humidity may be an issue, geothermal systems are actually cleaner for homes and lower levels of bacteria and mold spores.

Each of these systems relies on the ground piping which can be laid out in 4 different configurations. Heating and cooling systems can be laid out in vertical, horizontal or slinky loop layouts, based on the amount of space available, depths needed to achieve proper efficiency, and the needs of the structure. Horizontal loops are generally used where there is a lot of space to dig trenches, and tend to be open loop systems. These tend to be more expensive than their comparable slinky loop layout, which is used where space is much more limited, and the budget is lower. Horizontal systems tend to be used in commercial developments where space is at its highest premium, and the capacity factor needs to be greatly increased. For homes situated near a pond or lake in relatively warm climates, the loops can be run out to the bottom of the pond or lake to the same effect as underground piping.

The layout of these systems is generally designed such that there is a heat exchanger pump in the basement of a building, which is connected to the Heating, Ventilation and Air Conditioning (HVAC) system. The pump is also connected to the ground loop, which is either filled with ambient air, water or refrigerant. The ground loop takes in heat from the surrounding ground and returns it to the heat pump, thus heating the house. The process also works such that on hot days, the hot air in the house is drawn into the heat pump, where the heat is transferred to the ground loop, and then to the ground itself.

Cost/Benefit

Many LEED certified office buildings make use of geothermal technology, lowering overhead costs and increasing profit margins. The ability to minimize heating and cooling costs is a major victory in the business world, especially when the comfort of employees has a direct impact on their efficiency and productivity, doubling the impact on the bottom line. According to a 2011 US Department of Energy fact sheet on GSHPs, the average cost of a system is about $2,500 per ton of capacity. In this instance a "ton" is the measure of how much cooling capacity is needed to freeze a ton of ice within 24 hours at 32^{O}C (used to measure cooling), roughly 12,000 BTUs (British Thermal Units, used to measure heating) or depending on the unit, 1.5 to 3.5 kW (used to measure electricity use). The average Massachusetts home requires between 3 and 6 tons. The mechanical pumps have a lifetime of decades, the average warranty lasting 25 years, while the underground piping is warrantied for over 50 years in most cases. The average system will pay for itself within 5 to 10 years, especially when factoring in the Federal tax credit of 30% for systems installed before December 31st, 2016.

District Heating

Businesses are not the only entities to realize the benefits of this technology. Many towns and some cities use geothermal piping to keep sidewalks and streets clear of snow, or as part of district heating schemes (the entire district shares steam heat from the same source). For example, 95% of Iceland's housing is heated through district heating, which is run as a byproduct of geothermal energy production. Most district heating schemes within the US is coal or oil based, but through the application of geothermal energy, we can replace these carbon based sources of energy with clean renewable energy.

In Massachusetts, with our harsh winters, district heating can prove to be financially feasible. Each town should conduct a feasibility study to confirm the cost savings. Given that most of the towns within our regions have small central districts, the ability to heat these areas without oil would save the budgets of many of our local towns. This money could then be diverted to other pressing projects or to the snow plowing budget. Many communities have limited access to natural gas and district heating may prove to be a good alternative.

Siting, Planning and Zoning

Planning a location

Planning a location for a geothermal power plant takes detailed research and patience. Each location must be tested in order to identify the resource below the surface. A major factor is the depth at which the resource resides. If the heat is too deep underground, drilling will become too expensive to make a project viable. Furthermore, there needs to be an understanding that a geothermal well is not guaranteed to produce, as there is a 20% failure rate in the drilling of the wellhead. This means that extra care must be taken to identify a proper site in order to minimize the risk of a failed well. Different depths will produce different temperatures, which means drilling to the proper depth will also depend on the type of facility that is planned for the site. As it stands with current drilling economics, the most cost efficient depth would be between 3.5 and 4 miles, where a binary cycle power plant would be most efficient.

The average geothermal pant requires about 1.4 square miles of land per gigawatt of energy production (most of which is underground), compared to 12 square miles of coal or 3.4 square miles of wind farms. In step with the small footprint, geothermal plants only use about 5.3 gallons of fresh water per megawatt hour, while coal, oil and nuclear each require over 260 gallons per megawatt hour. This means that the average plant has a minimum impact on not only the visual features of the landscape, but also the ecosystem, and the fresh water supply as well.

Attached in Appendix F.1 is a detailed manual to help guide developers through the process of siting and licensing a geothermal power plant. The resource is tailored to the western states, but gives a detailed roadmap, which can be adapted to Massachusetts standards.

Efficiency

Efficiency varies from plant to plant, between turbines and resources. Because of the parasitic load of the pumps, condensers, and various other draws for the plant itself, the overall efficiency for geothermal energy hovers around 10%. This is largely due to the low temperatures that the plant runs on compared to other thermal power plants such as coal or oil (300^{O} vs 1000^{O} respectively).

Zoning

Zoning in terms of a geothermal plant comes with unique challenges. There is not only the zoning of physical land upon which the plant is built, but also the rights to the land below the plant, and the aquifer below the plant. This leads to some unique challenges in terms of the legal status and ownership of a geothermal plant.

Home use geothermal heating through ground source heat pumps are generally governed by each local town's ordinances, although within our regions only one town has a geothermal well bylaw. In conjunction with Department of Environmental Protection (MassDEP) rules,[67] these primarily dictate the placement of wells and underground piping in order to protect the local well water and aquifers from depletion and/or toxicity.

An example of a town bylaw is that of Groton, which governs the siting of geothermal boreholes (part of a ground source heat pump system):

> § 330-12: Geothermal Wells
>
> A. Location of closed-loop geothermal boreholes.
>
> (1) The construction of a closed-loop geothermal borehole is prohibited at other than a safe distance from any potential source of contamination. The minimum safe distances shall apply for the sources listed below:

Minimum Distances	
Source of Structure	**Minimum Lateral/ Circumferential Distance (feet)**
Sewer lines	10
Septic tanks	25
Springs	100
Septic drain fields	50
Water wells	100
House to septic tank connection	10
House to sewer line connection	10

> B. Source of drilling water for closed-loop geothermal boreholes.
>
> (1) All water used in drilling and construction of a closed-loop geothermal borehole shall be from a public water supply or water well.

[67] For more information see www.mass.gov/eea/docs/dep/water/laws/a-thru-h/gshpguid.doc

(2) All water used in the drilling or construction process shall be treated with enough chlorine product to retain a free chlorine residual of at least 10 parts per million.

(3) The driller shall take all steps necessary to maintain safety around the borehole until the closed loop is installed and grouted in the borehole.

C. Reporting of closed-loop geothermal boreholes.

(1) A Report of Well Driller for a closed-loop geothermal borehole system shall be submitted by the driller to the Board of Health within 30 days after the drilling or closure of the last closed-loop borehole in the system at the site.

D. Closed-loop geothermal borings and underground lines associated with heat transfer to geothermal boreholes are required to have detectable underground tape placed above the boring or heat transfer lines within 18 inches of land surface to denote the subsurface location of the installations.

E. For systems with 10 or less closed-loop boreholes, the driller is required to provide a master plat [sic] to both the owner and the Board of Health of the location of each borehole. The sketch shall include related distances from major buildings, septic tanks and field lines and sewer lines and be submitted with the Report of Well Driller within 30 days upon completion of drilling of the last borehole on a given project. Site plans drawn up by a licensed engineer may be used if the driller is unable to provide a master sketch.

Permitting and Regulation

Regulatory Authorities

State

MassDEP

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for monitoring wells that are drilled in MA. This applies to all open loop ground source heat pumps for home heating, as well as geothermal wells. Sites must be tested and approved in order to ensure the safety of the water table and well water supply. Appendix F.2 includes a copy of the guidelines for ground source heat pump wells.

DOER

The Mass Department of Energy Resources is the regulatory body charged with maintaining the state's energy portfolio and protecting the resources that the state has to offer towards renewable and finite energy programs. The DOER would regulate the transmission of power, as well as the safety and operating standards of the plant.

Federal

The Federal Energy Regulatory Commission (FERC) is an independent federal agency intended to regulate and oversee the energy industries in the economic, environmental, and safety interests of the American public. FERC promotes the development of a strong national energy infrastructure and does not propose, construct, operate, or own any energy projects but does issue permits and licenses for projects, enforcing the conditions of each license during the term of the project, and conducts project safety and environmental inspections. In sum, FERC has three major regulatory goals: (1) issuing licenses for the construction of new energy projects, (2) issuing licenses for projects already underway (relicensing), and (3) overseeing all ongoing project operations, which include safety inspections and environmental monitoring. In the instance of geothermal energy, there is no FERC regulation regarding the creation of a geothermal power plant. FERC will only involve itself in the interconnection and transmission licensing of power generated by the new power plant.

Regional Potential

Generation of geothermal electricity in our regions requires further investigation to determine the feasibility of low temperature geothermal. While our regions are hot-spots relative to the rest of the state, our temperatures are at the low end of binary cycle capability. This means that while it is theoretically possible, the temperatures are too low to generate power at high efficiencies. Further inhibiting the economical use of geothermal is the high cost of drilling past 3 km in depth. Promising new technologies that are able to generate power from low temperature geothermal resources are beginning to appear on the market. Companies like Ormat (www.ormat.com) have commercial solutions available today in limited quantities. Appendix F.3 shows areas where the EPA sees potential for Geothermal at brownfields and other tracked sites.

Further potential lies in the ability to manufacture materials for the production of geothermal plants. The state of Massachusetts is a leader in technology and with the manufacturing infrastructure already in place, there is potential to manufacture items such as piping, high pressure containers, and other components of a geothermal power system. Furthermore, the rail line accessibility in most industrial cities in Massachusetts means easily being able to ship these components anywhere in the Americas. The rail lines also link to shipping hubs allowing shipping around the world.

While the use of our geothermal resources is still in the future, ground source heating has major potential for growth. In our climate, heating in the winter is necessary for survival, requiring thousands of gallons of oil to be burnt each winter for each home. Similarly, given our acclimation to a cooler climate, summers with heat waves that would be relatively safe elsewhere can be deadly here. Coupled with the standard use of electricity for air-conditioning via window units and inefficient compressor units, the cost of heating and cooling the average Massachusetts house is quite high. GSHP's can save on energy costs not only to the consumer, but to the environment as well, as less power is required from the grid. When a GSHP system is built along with the house, the GSHP becomes a very small addition to the mortgage, and pays for itself much faster. This technology can help to increase productivity by using it to heat and cool offices and manufacturing plants.

In summary, time and growth will lead to our region being capable of producing geothermal power before the rest of the state, but Ground Source Heat Pumps may prove to be a very useful option. The Northern Middlesex Council of Governments (NMCOG) and the Montachusett Regional Planning Commission (MRPC) can work to help relieve the barriers to geothermal development. There are no zoning by laws in any of the communities that pertains to geothermal power or heating specifically. Groton has zoning by laws for bore holes which applies to the drilling of wells for geothermal as discussed earlier. Changes to zoning by laws may help make it easier for residents and business owners to incorporate geothermal heating in their buildings. NMCOG and MRPC can also work to help educate developers, future homeowners, local boards of health, and building inspectors about geothermal heating and ground source heat pumps. By helping people through the financing and permitting process, more people may be likely to utilize geothermal heating in their new or existing buildings. Studies may also be done on an individual community basis to assess the costs and benefits of retrofitting community and municipal buildings with geothermal heating.

BIOMASS

History

Historically, biomass energy, also known as biopower, began with the burning of organic material. Organic material has energy trapped inside from processes such as photosynthesis and animal digestion. The burning and decomposition of organic materials leads to the release of heat and gasses including carbon dioxide and methane, which can be harvested for energy. Until 2009, biomass was the highest producer of renewable energy in the United States. It has since been overshadowed by wind power; however there is an unused capacity of biomass that could potentially increase the amount of renewable energy created.[68]

Wood Biomass and Forest Products

Wood biomass includes the waste of wood processing including bark and sawdust. Lumber, pulp, and paper mills commonly use their waste products for heat and electricity to run the plants. Other sources of woody biomass include harvested trees. Burning wood and wood pellets at home is a form of small scale biopower but this can also be accomplished on a larger scale. Trees can be chipped on the logging site and then brought to a processing plant to be burned. Trees can be harvested from tree farms where fast growing trees are planted with the purpose of being cut for biopower. Trees from logging jobs including land clearing for house lots and other development or forest thinning can also be used. The trees from logging jobs are generally low quality trees that cannot be used for lumber or other wood products. Tree tops from the good quality trees which are commonly left in the forest to decompose can also be chipped for power plants.[69] Currently, there is one woody biomass plant in Massachusetts located in Westminster called Pinetree Power Fitchburg which has a 15MW capacity. There are also facilities that use biomass for heating, including Mount Wachusett Community College (MWCC).[70] Combined Heat and Power (CHP) is a more efficient way of using woody biomass because the waste heat emitted from the electricity generation process is collected and used to heat buildings. CHP helps increase the efficiency of a woody biomass system which can help reach the efficiency standards required of the permitting process.

Landfill Gas

Municipal Solid Waste landfills are dumping grounds for trash generated by households and businesses. This trash produces various gasses, mostly methane, during the decomposition process. However, as materials decompose, these gasses can build up and can become hazardous. The U.S. Environmental Protection Agency (EPA) has set regulations in place to prevent dangerous gas levels. One way to deal with the gas released from landfills is to collect it to generate power. Landfill gas is sometimes not considered renewable since it is sourced from waste. Many officials and organizations agree that it would be best for the environment to reduce the amount of waste humans create,

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[68] (How Biomass Energy Works, 2010)
[69] Ibid.
[70] MWCC maintains an oil-fired backup boiler, which provides heat during the "shoulder" months of fall and spring. Once the wood system is fired up about November 1st, it meets 100 percent of MWCC's heat and hot water needs through the winter. (http://www.biomasscenter.org/resource-library/case-studies/campuses/mount-wachusett-community-college)

therefore limiting the amount of waste available for gas collection. However, this is a prime opportunity to deal with existing landfills and waste that will be created in the future until trash disposal methods change.[71]

Anaerobic Digestion

Anaerobic digestion is a natural process where organic materials including manure and food waste decompose and release gasses, primarily methane and carbon dioxide. Most forms of biomass are suitable for anaerobic digestion including manure, sewage slurry, food waste, and crop residues. Woody biomass cannot be used because the bacteria which decompose the waste are unable to breakdown lignin, a part of a plant cell wall which gives trees their strength.[72] Currently in Massachusetts there are 133 waste water treatment plants, six of which use Anaerobic Digestion or are in the process of converting.[73].

Capacity and Efficiency

It is important to look at the Capacity and Efficiency of a specific form of renewable energy to see what type of renewable energy would work best in the Northern Middlesex and Montachusett Regions. Woody Biomass, Landfill Gas, and Anaerobic Digestions use different types of technology and have different requirements to operate. For all types of Biomass, Combined Heat and Power (CHP) can be used to increase the efficiency of the system. CHP is the process of collecting the thermal energy created during the generation of electricity. This thermal energy, or heat, can be used to heat nearby buildings. According to National Grid, CHP works best in buildings that require a consistent amount of heat and power including hospitals, nursing homes and universities. CHP is not as useful in residential homes because of the inconsistent heat and electricity needs. In the Northern Middlesex and Montachusett Regions, locations including UMass Lowell, Fitchburg State University, and the various hospitals and health care facilities would be ideal locations for CHP.

Wood Biomass and Forest Products

According to the Massachusetts Office of Energy and Environmental Affairs (EEA) website, 4,000,000 tons of woody biomass can be produced annually in Massachusetts; using half of that for electricity would result in 150MW of biomass-generated power. The Montachusett region is mostly rural with large amounts of forested land. A map of the area where biomass fuel can be harvested efficiently for the Pinetree Power plant in Westminster is shown in Appendix G.1

Landfill Gas

According to the EPA, one million tons of landfilled Municipal Solid Waste (MSW) can create 0.8 MW of electricity. A map of landfill facilities and of potential sites for landfill gas energy production in Massachusetts can be found in Appendix G.2.

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[71] (Biomass Energy in California)
[72] (What is Anaerobic Digestion)
[73] (Protection)

Anaerobic Digestion

Anaerobic digestion can produce 200KW for every ton of organic materials.[74] Three or four tons of waste could power a home for a month. The region has many food businesses which create organic waste (food) that can be used for anaerobic digestion. In Massachusetts, about one million tons of food waste is created annually and 97% of all U.S. food waste ends up in a landfill.[75] Starting on October 1, 2014, any industrial or commercial facility that produces over one ton of food waste a week will be required to divert it from disposal by either composting or processing via anaerobic digestion. There are currently anaerobic digestion facilities at many wastewater treatment facilities, including Deer Island. There are several plants with excess capacity that would be able to process other types of organic materials including food waste.[76]

The following table from an EPA report on anaerobic digestions depicts the kwh per ton of food waste and wastewater.

Table 6: Food and Wastewater kwh Per Ton

Parameter	Unit	Food Waste 15-day MCRT[77] AVG (Range)	Food Waste 10-day MCRT AVG (Range)	Municipal Wastewater Solids 15-day MCRT AVG (Range) (5)
Methane Production Rate	ft.3/dry ton applied(1)	13,300 (9,800 – 17,000)	9,500 (6,600 – 14,400)	10,000 (7,500 – 12,600)
	3 ft. /wet ton delivered(2)	3,300 (2,500 – 4,300)	2,400 (1,700 – 3,600)	NA(6)
	m3/ dry metric ton applied(1)	420 (300 – 530)	300 (200 – 450)	310 (230 – 390)
	m3/wet metric ton delivered(2)	100 (75 – 135)	75 (50 – 110)	NA(6)
	ft.3 per day/ 1,000 ft.3 digester volume	2,300 (1,100 – 3,200)	2,600 (1,800 – 3,800)	750 (550 – 930)
Electricity Production Rate(3)	kWh/dry ton (1) applied	990 (730 – 1,300)	710 (490 – 1,080)	750 (560 – 940)
	kWh/wet ton delivered(2)	250 (190 – 320)	180 (130 – 270)	NA(6)

[74] (Harvest Power)
[75] (PRI.com)
[76] Firm plans to turn table scraps into power in Massachusetts, 2013
[77] Mean Cell Residence Time (MCRT) is the amount of time organic material has to stay in the digestion tank in order to be fully digested.

	kWh/dry metric ton applied(1)	1,100 (800 – 1,400)	780 (540 – 1,190)	830 (620 – 1,040)
	kWh/wet metric ton delivered(2)	280 (200 - 350)	200 (140 - 300)	NA(6)
	kWh per year/ 1,000 ft.3 digester volume	43,700 (21,300 – 62,100)	57,000 (43,000 – 73,700)	14,600 (10,700 – 18,000)
Household Energy Equivalent Rate(4)	households/year/ 100 tons/day	1,100 (800 – 1,400)	800 (550 –1,200)	(6) NA
	households/year/ 100 metric tons/day	1,200 (880 – 1,500)	880 (600 – 1,300)	NA(6)
	households per year/ 1,000 ft.3 digester volume	7.3 (3.6 – 10.3)	8.4 (5.8 – 12.3)	2.4 (1.8 – 3)

Notes:

1. Dry ton applied refers to food waste solids applied to the digesters after processing a wet ton delivered load.
2. Wet ton delivered refers to food waste tonnage (including water) delivered by the hauler prior to processing,
3. Calculated based on 1 ft.3 CH_4 = 1,000 BTUs and 13,400 BTUs = 1 kWh.
4. Calculated based on 2001 EIA residential energy survey for CA where average household energy use is 6,000 kWh annually.
5. Based on data from previous EBMUD bench-scale pilot study. Digesters were fed thickened waste activated sludge and screened primary sludge.

Anaerobic digestion can also be facilitated at wastewater treatment facilities and food waste can also be processed at these facilities when there is excess capacity. Anaerobic digestion of wastewater requires a longer Mean Cell Residence Time (MCRT) because human waste takes longer to break down than food waste. MCRT refers to the amount of time that sludge (wastewater or food) must stay in the tank in order to be fully processed. As indicated by the chart above, with a 15 day MCRT anaerobic digestion can make 990 kWh/dry ton versus using wastewater which creates 750 kWh/dry ton.

There is currently only one active anaerobic digestion facility in the MRPC and NMCOG regions, located in Clinton. Due to the size of the system, not enough gas is produced to even run the facility and it is not seen as cost effective.[78]

How it works

While Woody Biomass, Landfill Gas, and Anaerobic Digestion are all forms of Biomass, they each work differently and use different processing to create energy.

Wood Biomass and Forest Products

General concepts

Biomass can be burned for heat as it has been done for centuries. This is already commonly done with cord wood and wood pellets in residential homes in Massachusetts and the Northeast. According to the 2008-2012 ACS estimates, 1.5% of homes in Massachusetts are heated with wood, the highest of all renewable heat sources in use.

Biomass can also be used to create electricity. Direct combustion burns biomass to create steam which turns a turbine and makes electricity. Direct combustion results in wasted energy from heat loss. This lost energy can be addressed with Combined Heat and Power (CHP) which uses the heat released from combustion to heat nearby buildings. This method would require customers in need of heat to be close to the power plant because of the piping limitations associated with the distribution of the recovered thermal energy. Biomass can also be used in coal plants by either co-firing (burning a mixture of coal and biomass) or by retrofitting coal plants to burn biomass[79]

Pinetree Power Fitchburg in Westminster takes in ten truckloads of wood chips each day, each containing approximately 26-32 tons. The plant produces close to 15MW. There are 20 employees at the plant and there are approximately 100 residual jobs in logging in order to source wood chips.

Examples of successful wood biomass utilization can also be found in New Hampshire, which has seven existing and two proposed biomass plants. 14% of New Hampshire's electricity comes from wood biomass and the seven plants in New Hampshire employ a total of 150 employees. The proposed new facilities would create 63 jobs based on the size of the plants.[80] Biomass plants provide a market for low grade wood and forest residue. The removal of poor quality trees allows for healthy trees to grow and can create more diverse ecosystems or habitats for endangered species, a further benefit of biomass utilization.[81] Woody Biomass is more successful in New Hampshire than in Massachusetts due to more lenient regulations and restrictions on the efficiency of a woody biomass plant.

[78] (Protection)
[79] (How Biomass Energy Works, 2010)
[80] (Biomass Info)
[81] (Kingsley, 2012)

Negative Impacts

A large amount of thermal energy, or heat, is wasted using Direct Combustion. CHP may be used to help collect some of this lost energy, making the system more efficient. Using this type of heat would require intensive planning and is not always economical.

Green woody biomass (wood products straight from the forest) can contain up to 50% water and therefore is not energy dense. Unprocessed biomass is not cost effective when it has to be shipped more than 50-100 (generally 60) miles by truck depending on the local market and economy. Therefore biomass plants need to be smaller and more distributed throughout the region in order to obtain biomass to power the plant and still be cost effective with shipping. [82]

Non-Traditional Technology

Alternatively, Biomass can be processed at the production site before it is shipped. Drying, grinding, and pressing biomass into pellets (like wood pellets used for home heating) increases the energy density. It also increases the cost-effectiveness of shipping and can also make processing at the plant more efficient and easier.[83]

Landfill Gas

General Concepts

Landfill gas is naturally released from landfills and can be collected for energy. Landfill gas is generally burned to meet EPA air quality regulations and by using a landfill gas collection and utilization system, the gas that is already being burned can also be used to create electricity. CHP can also be included in the system to collect the heat produced by the generator.

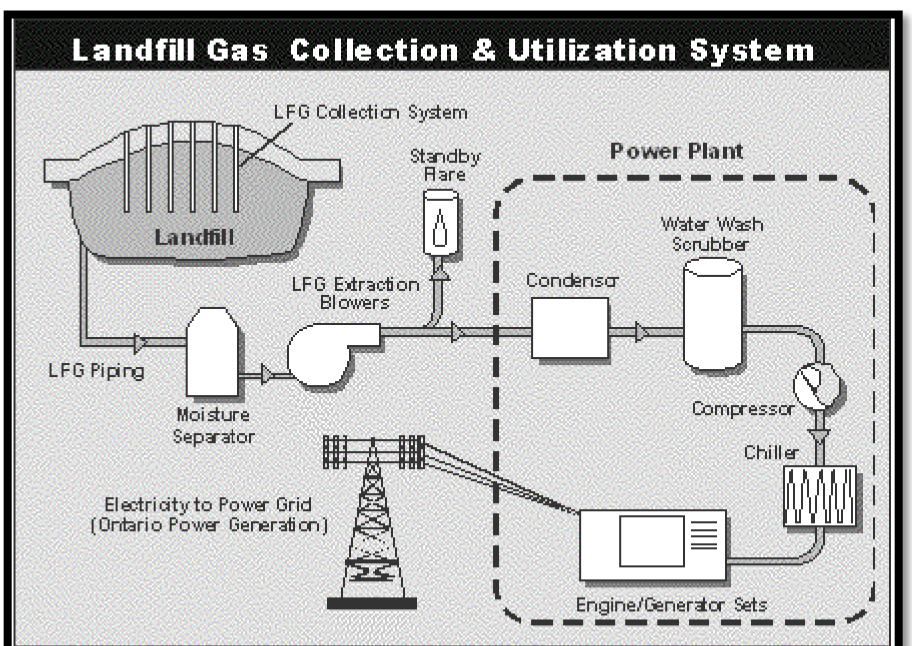

Figure 24: Landfill Gas Turbine Diagram

Wells are drilled into landfills where gas is collected and moisture is separated from the gas. It is then piped into a power plant where the gas is condensed, scrubbed, compressed, and used to create electricity in a generator. Reasons to collect

[82] (How Biomass Energy Works, 2010)
[83] Ibid.

landfill gas for energy include reducing greenhouse gas emissions since the gas is being processed instead of released into the atmosphere. This avoids emission of other harmful gasses and materials such as mercury and lead, and creates new revenue for the municipality from waste that would otherwise be unutilized.[84]

Negative Impacts

Reliance on landfill gas for electricity production can be viewed as an incentive to create waste in conflict with efforts to reduce the amount of waste that enters landfills. Also, harvesting landfill gas releases dioxins which are a known carcinogen.[85] Also, the amount of gas released from landfills decreases over time. With current technology a certain level of gas is required to produce energy.

Non Traditional Technology

Methods used for landfill gas facilities are being improved in order to increase efficiency and output. Changing the environment of the anaerobic digestion chambers (e.g. controlling moisture or PH levels) could potentially increase the output. Also, changes in technology include using a gas impermeable (synthetic) membrane to increase collection efficiency to potentially 100%.[86] Changes in the technology used for landfill gas biomass will lengthen the amount of time a landfill can be productive by continuing to use the small amount of gas released by landfills as they age, for example lengthening the production from the Lowell Landfill.

Anaerobic Digestion

General Concepts

Anaerobic digestion involves putting organic material like food waste and sewage slurry into a

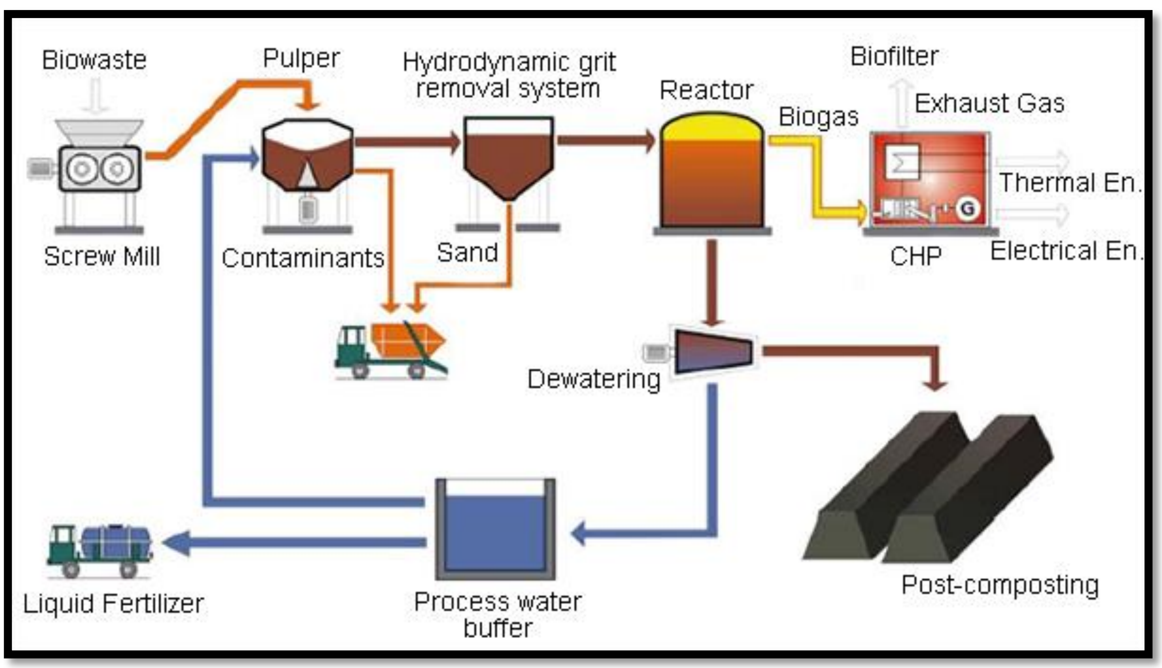

Figure 25: The Anaerobic Digestion Process

84 (Local Governments for Sustainability USA)
85 Ibid.
86 Ibid.

digestion chamber where bacteria break down the material. This process releases methane which can run a Combined Heat and Power (CHP) generator to produce both electrical and thermal energy. The leftover waste in the digestion chamber can then be used for fertilizer. The following figure illustrates the anaerobic digestion process.[87]

Decomposition of organic materials releases methane gas. Anaerobic digestion of food waste is similar to the collection of Landfill Gas with the gas being collected and used to power a generator. Anaerobic digestion creates more kWh per ton of food waste compared to methane produced at waste water treatment plants because food waste decomposes easier and takes less time. However the food waste must be transported to a facility. Waste water treatment plants already exist and those that do not collect methane for electricity production could upgrade their systems to have this capability. Anaerobic Digestion facilities across the country are generally very large in order to make enough electricity to be cost effective. There are some facilities that are small but they do not produce enough electricity to cover the cost of the equipment and installation. In Massachusetts, Deer Island has twelve digesters that use waste water to produce methane gas which is run through a boiler to heat the facility and also produces 3 MW by running the steam from the boilers through a Steam Turbine Generator (STG). The leftover waste from the digestion chambers is turned into fertilizer[88].

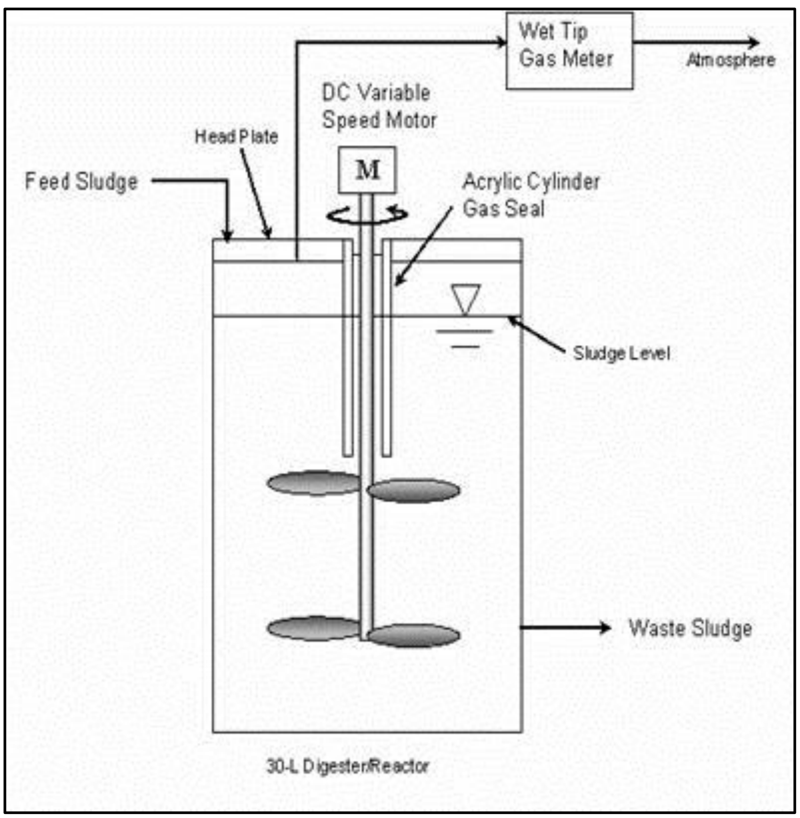

Figure 26: Food Waste Digester schematic[1]

Anaerobic Digestion is commonly used at farms that process animal waste to make heat for their facilities. These smaller scale facilities use organic materials that are sourced from the farm and perhaps from the surrounding area if there is excess capacity. Anaerobic digestion on a smaller scale can have the ability to be cost effective by using newer technology. According to the Ontario Ministry of Agriculture, Food and Rural Affairs, a herd of 100 dairy cows can produce enough manure to continuously generate 25 to 30 kW, and mixing other materials such as grease trap waste into the digester can possibly triple the output. Jordan Farm in Rutland, Mass. was the first of five farms in Massachusetts to build an anaerobic digester. It was installed in 2011. The digester produces enough electricity to

[87] (Anaerobic Digestion Systems)
[88] Ibid.

power 300 homes. The digester at Jordan Farm also uses two truckloads of food waste every day which increases the efficiency[89].

Negative Impacts

In order to be cost effective, Anaerobic digestion is generally integrated into other systems, like waste water treatment plants.[90] Specials measures must be taken for odor control, especially if the plant is close to populated areas. Anaerobic digestion projects can be expensive. Deer Island was a $3.8 billion project to help protect the Boston Harbor from sewage pollution. A facility the size of Deer Island with similar megawatt output would require a significant amount of wastewater and/or food waste. The greater Boston area is more densely populated than the MRPC and NMCOG regions and issues with transporting organic material by truck may be an issue which can be offset by putting the digesters at the location of the organic material, like the digester Jordan Farm. Sourcing either food waste or wastewater, both in terms of available supply and transport, would have to be studied if a plant were proposed. Also, anaerobic digestion plants usually operate on a batch process basis, meaning there is not a continuous production of methane unless the facility contains multiple digesters that are operated on differing schedules.

Planning a location

When planning a location, one must look at any zoning restrictions applicable to the potential location, the feasibility of the location, and type of biomass to be used. GIS mapping can be used to help answer any questions.

Zoning

None of the communities in the MRPC and NMCOG regions have zoning by-laws specifically permitting biomass of any kind. Future biomass plants will likely be required to go through the special permitting process and would be likely placed in existing industrial or agricultural zones[91].

Siting

There is currently one large scale wood biomass plant in Massachusetts, Pinetree Power Fitchburg, located in Westminster. There is also an inactive waste water treatment plant anaerobic digester in Leominster and an active one in Clinton.

To locate a feasible site where biomass energy may be produced it is suggested that feasibility studies be done at existing landfills and waste water treatment plants. Anaerobic digestion is rarely cost effective when done on its own and not combined with waste water treatment plants. Therefore, a study would have to be performed to analyze the costs and benefits of building an anaerobic digestion plant, taking into account the location and supply of biomass, environmental and community impacts, and the economics of production and distribution at the specific site. Woody biomass plants require a smaller amount of area. When siting potential locations traffic routes must be analyzed considering the wood material would be trucked in from logging sites.

[89] Telegram.com
[90] (Energy Independent in Zijldijk)
[91] Information about current zoning in each community can be obtained from local zoning boards

Attached in Appendix G.3 is a map of potential locations for landfill gas. Winchendon, Clinton, and Billerica have landfills with the potential to process landfill gas for energy production. The Northern Middlesex Council of Governments and the Montachusett Regional Planning Commission could help foster the development of these locations by obtaining funding for feasibility studies. The EPA's RE-Powering America's Land map program provides data on potential locations for different forms of renewable energy[92].

Regulatory Authorities

There are various authorities that regulate the development of renewable energy.

State

Department of Energy Resources (DOER)

The DOER oversees all applications for biomass plants, including wood biomass and anaerobic digestion. In 2012 the DOER put into place new regulations for Renewable Portfolio Standards (RPS) I, RPS II, and Alternative Energy Portfolio Standards (APS) biomass plants. The three different forms of biomass (woody, landfill gas, and anaerobic digestion) do not all follow the same regulations for Renewable Portfolio Standards. Landfill Gas and Anaerobic Digestion are considered under the RPS I category, while Woody Biomass is considered under APS.

Massachusetts Department of Environmental Protection (MassDEP)

MassDEP regulates air permits, solid waste facilities, and waste water facilities. Changes in DEP regulations in the past have supported the development of anaerobic digestion. Please see the MassDEP website for more information on their involvement with protecting the environment, and their role regarding Biomass power production.

Federal

Federal Energy Regulatory Commission (FERC)

Under FERC, biomass plants are categorized as Small Power Production Facilities if the plant has an output capacity of less than 80MW. There are exceptions to the size of a plant as stated in the Federal Power Act (FPA) (16 U.S.C. § 796(17)(E)). Also, requirements for a Small Power Production Facility are found in 18 C.F.R. §§ 292.203(a) , 292.203(c) and 292.204. In order to be certified at a Qualifying Facility, the plant must follow 18 C.F.R. § 292.207. Biomass plants and cogeneration[93] plants are exempt from the Public Utility Holding Company Act of 2005 (PUHCA), and state laws and regulations respecting the rates and financial and organizational aspects of utilities. Cogeneration facilities and Small Power Production facilities (30MW or smaller) are exempt from most sections of the Federal Power Act (FPA).

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[92] http://www.epa.gov/oswercpa/rd_mapping_tool.htm#i_map

[93] Cogeneration is the process of collecting the heat released during electricity generation and using it to heat buildings or homes.

Regional Potential

The potential for biomass energy in the region is limited by certain factors. Woody biomass plants have not been built in Massachusetts since the 1970s when the Pinetree Power Fitchburg plant was built. The problem lies in funding future plants. In order for a developer to secure a loan to build a plant they must show that they will have a steady income, generally in the form of Renewable Energy Certificates (RECs).[94] Woody biomass often does not meet Massachusetts efficiency requirements for RECs because plants must be 50% efficient to qualify for half a REC and 60% efficient to qualify for a whole REC. Without the guaranteed income from RECs, a developer would have difficulty qualifying for loans or other funding. Using Combined Heat and Power (CHP), however, can increase the efficiency of woody biomass plants and may help increase the chances of passing regulations, getting permits, and receiving financing and funding. As another option, landfill gas can be captured at capped landfills, which are shown in Appendix G.2. However, landfill gas production decreases over time once a landfill has been capped, and many landfills in Massachusetts have reached an age where landfill gas production is likely to be very low.

While anaerobic digestion may not be cost effective with current technology, it can be used in Waste Water Treatment Plants (WWTPs) that have extra capacity, as well as on farms. Given available and future supply of biomass from a variety of sources and improvements in technology, anaerobic digestion offers a potentially significant opportunity for energy production. The cost of biomass per kWh changes with the type of organic material used. Retrofitting a waste water treatment plant has upfront costs. However there are no added costs to transport the sewage as the system is already in place. Anaerobic digestion and woody biomass both face transportation costs which can increase the cost of production.[95] With the Food Waste Disposal Ban that will take effect in Massachusetts on October 1, 2014, 450,000 tons of food waste will be diverted from landfills every year by 2020. Deer Island uses waste water and their average flow is 365 million gallons per Day (MGD). There is an anaerobic digestion plant in San Jose, CA which went online in November 2013 that processes 90,000 tons of food waste a year and produces 1.6 MW of electricity with its 16 digestion chambers. With the 450,000 tons of food waste to be diverted from landfills each year by 2020, approximately 5 anaerobic digestion plants the size of the San Jose plant could be built which could be expected to produce a total of 8MW of electricity. However the plants would have to be strategically located in areas that would make it cost effective to transport food waste to the anaerobic digestion plant. A study would have to be done to determine the amount of food waste that could be collected per the Food Waste Disposal Ban. The ban only applies to food waste producers who generate over one ton of organic waste per week. The area surrounding the cities of Lowell and Fitchburg/Leominster may possibly create enough waste which would be diverted from landfills by order of the ban but it is not certain.

In 2013, the Massachusetts Clean Energy Center (MassCEC) awarded $624,968 to 12 public entities and one non-profit for studies and other services related to the development of new anaerobic

[94] Renewable energy certificates (RECs) are a tool for implementing Renewable Portfolio Standards (RPS) in Massachusetts. Each megawatt-hour (MWh) of clean energy produced is allocated one REC. These RECs are monitored and traded through the New England Generation Information System (NE-GIS).

[95] Greenelectricityguide.com provides a cost comparison for different types of renewable energy

digestion systems, or the use of existing wastewater digesters to co-digest food wastes. The awardees for these grants included two communities in this region-- the City of Fitchburg and the Town of Ayer. A feasibility study was also conducted at MCI Shirley, to determine whether prison property is suitable for the development of an anaerobic digester. The state is currently reviewing the study. Facilities like MCI Shirley that have high levels of food waste, including schools, hospitals, and other prisons, may have the potential to use the facility's food waste for anaerobic digestion.

The Northern Middlesex Council of Governments and the Montachusett Regional Planning Commission can work to help develop renewable energy projects by providing assistance with grant writing and finding other forms of funding or by organizing feasibility studies. NMCOG and MRPC can also work with local educational institutions to help promote educational opportunities which would give local residents the skills they need to work in the renewable energy field.

POWER GENERATION/INSTALLATION INCENTIVES

For a complete and updated list of incentives, visit the Database of State Incentives for Renewable Energy and Energy Efficiency (DSIRE) at www.dsireusa.org) as well as the DoE guide to *Federal Finance Facilities Available for Energy Efficiency Upgrades and Clean Energy Deployment*.[96]

State

Alternative Energy Portfolio Standards (APS)

APS offers incentives to Massachusetts businesses, governments, and institutions for installing eligible alternative energy systems, which are not renewable. Energy systems including landfill methane and anaerobic digestion use nonrenewable sources.

Similar to the RPS, it requires a certain percentage of the state's electric load to be met by eligible technologies, which for APS include Combined Heat and Power (CHP), flywheel storage, coal gasification, and efficient steam technologies. For the case of biomass, CHP, paper derived fuel, and gasification are most applicable for APS incentives.

These resources contribute to the Commonwealth's clean energy goals by increasing energy efficiency and reducing the need for conventional fossil fuel-based power generation. In 2009, the Suppliers obligation was 1%, and is set to increase 0.5% each following year until 2014, when the growth rate will be reduced to 0.25% per year.[97]

The Community Energy Strategies Pilot Program

This program helps communities identify and enable local opportunities for clean energy development. This program assists municipalities and/or Regional Planning Agencies (RPAs) in identifying and developing strategies for implementing the mix of clean energy projects and incentives best suited to address local interests, needs, and opportunities for clean energy development.

Commonwealth Hydropower Program

The Commonwealth Hydropower Program offers grants for both feasibility studies and construction of hydroelectric facilities. The funding for this comes through The Commonwealth Hydropower Initiative and the Massachusetts Clean Energy Center (MassCEC) but directly from the Massachusetts Renewable Energy Trust Fund. Therefore, to qualify for this funding the project must be within the jurisdiction of a utility provider who pays into the Renewable Energy Trust. Additionally, the project must be qualified for the Massachusetts Renewable Portfolio Standard.

This standard is set to grow the percentage of renewable energy relative to all energy produced within the Commonwealth. The goal is to increase the share of renewable energy produced. The program caps incentives at $40,000 or 80% of actual costs for the feasibility study. Construction projects are capped at the lesser of $600,000 or 50% actual costs.

[96] http://energy.gov/sites/prod/files/2014/09/f18/Federal%20Financing%20Guide%2009%2018%2014.pdf
[97] http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/rps-and-aps-program-summaries.html

Lastly, the project must generate 200,000 kilowatt hours/year of electricity and have at least a twenty year life cycle.[98]

Commonwealth Solar II

Commonwealth Solar II provides rebates for homeowners and businesses in Massachusetts who install solar PV at residential, commercial, industrial, institutional and public facilities. In addition to the base incentive, additional incentives are available for installations using components manufactured in Massachusetts, for individuals with moderate income or home values, and for those who are rebuilding in the wake of a natural disaster.

Green Communities Grant Program

The Green Communities Grant Program is Massachusetts way of trying to create a more sustainable future, in terms of energy use. There is funding for communities investing in renewable energy technologies. To be eligible for this, community must achieve official designation as a "Green Community". In September of 2014, Massachusetts had officially designated 123 communities as "Green Communities. [99]

Green Power Purchasing Commitment

The Green Power Purchasing Commitment established energy targets and mandates for state government buildings under control of the executive office. Executive Order 484 was signed in April of 2007. Two goals established by this Order require that a minimum percentage of state agency's annual electricity consumption be supplied by renewable energy. In 2012, 15% of electricity had to be from "green" energy. The number doubles to 30% by the year 2020. State government agencies can purchase renewable energy certificates (RECs), or produce energy on-site. Sources of renewable energy must qualify for the Massachusetts renewable portfolio standard (RPS). [100]

Qualified Energy Conservation Bonds (QECBs)

According to the Program Opportunity Notice (PON) regarding Qualified Energy Conservation Bonds (PON-ENE-2013-070) of April 18, 2013, published by the State of Massachusetts Department of Energy Resources (DOER), a geothermal project would be eligible for QECBs that the State has been allocated. The State has a remaining $4,069,912 to allocate, of the original $67,412,997 total allowance. It is possible, however that depending on the scale of the project, it may be eligible for a share of the $16,607,086 allocated to Large Local Governments (further research is required).

Each application is reviewed for viability, cost, economic benefit/sustainability, projected energy impact and project narrative. The project is eligible under Section A., Part c. of the PON, which allows for the use of funds for the "Rural development involving the production of electricity from renewable energy sources."

There is, however, a drawback to these bonds: a six month maturation date from the time the project is completed. Should this prove to be a surmountable hurdle, then there are several steps to go

[98] http://masscec.com/index.cfm/page/Commonwealth-Hydro-Program/cdid/11245/pid/11159

[99] www.mass.gov/energy/greencommunities

[100] http://www.epa.gov/greenpower/

through with the bond application. Furthermore, 70% of the funding must be allocated to State projects, while only 30% of the funding is available to private projects.[101]

Renewable Energy Trust Fund

This Trust Fund was established in 1997 by Massachusetts Legislature by The Green Communities Act S.B. 2768. It is supported by the Massachusetts Renewable Energy Portfolio Standard (RPS). RPS was established alongside the Trust Fund. Massachusetts was the first state to have both a RPS and public benefits fund for renewables.

The Trust Fund may provide grants, contracts, loans, equity investments, energy production credits, bill credits and rebates to customers. The amount provided varies per contract but cannot exceed $5 million for any one contract and not exceed $17 million in any one fiscal year. The awards support Class I and Class II renewables.[102]

Renewable Portfolio Standard (RPS)

The Renewable Portfolio Standard (RPS) is a policy in Massachusetts governing the level on energy consumption generated from renewables. It is broken down into Class I and Class II standards, defined by the guidelines which can be found on the website in the footnote. The RPS is a guideline for Massachusetts retail electricity providers mandating that a certain level of total power supplied be from renewable energies. In 2003, RPS regulations required all electricity providers consume at least 1% of their entire power from new renewable-energy sources. By 2014, the total power supplied from Class 1 renewables should be 49%. The goal is to reach 15% by the year 2020.[103]

SAPHIRE Program - Renewable Heating + Energy Efficiency

DOER has launched the SAPHIRE program ("Schools and Public Housing Integrating Renewables and Efficiency") in collaboration with the Department of Housing and Community Development (DHCD) and the Massachusetts School Buildings Authority (MSBA) to promote renewable thermal heating and cooling upgrades in public schools and state public housing across the Commonwealth. These projects will strive to combine renewable thermal heating upgrades with energy efficiency improvements – such as insulation, air sealing, and lighting upgrades – to achieve deeper energy savings and provide cost savings to schools and low-income housing developments.[104]

Solarize Massachusetts (SolarizeMass)

Solarize Mass encourages the adoption of small-scale solar PV projects by deploying a coordinated education, marketing and outreach effort, combined with a group purchasing model that provides increased savings as more people in the community go solar. SolarizeMass has been very effective in helping drive down the installation cost of small-scale solar PV installations within the selected communities.

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[101] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/qecb-pon-round-4.pdf
[102] http://www.epa.gov/chp/policies/incentives/mamassachusettsrenewableenergytrustfund.html
[103] http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/rps-and-aps-program-summaries.html
[104] http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/renewable-thermal/saphire-program-renewable-heating-energy-efficiency.html

Solar Renewable Energy Credits (SRECs)

Beginning in 2010, DOER carved out a portion of the Renewable Portfolio Standard (RPS) to provide a market-based incentive to encourage solar across the Commonwealth. Currently, anyone who generates solar power in Massachusetts generates Solar Renewable Energy Credits (SRECs) – tradable certificates issued at a rate of one SREC per megawatt-hour (1,000 kWh). Installers guide customers through the process of qualifying, and also assist larger customers in finding an aggregator or broker who will facilitate the sales process. SRECs create a way to obtain long-term financing for solar PV systems, and are one of the primary financing methods to help pay for the installation of a residential solar PV system.

The original SREC program (SREC-I) was extremely successful, and Massachusetts reached its goal of developing 400 MW of solar sooner than expected. However, in 2013 the SREC market reached capacity, and the instability in the future of SRECs became a barrier to solar development. Many residential and commercial solar installers depended on SRECs to make a project financially viable and were hesitant to invest in solar projects when SRECs were uncertain. This was highlighted at the NMCOG Solar Siting workshop in April 2013. During that workshop Mr. Jim Goldenberg, co-founder of Cathartes Investments, described the Westford Solar Park project, including purchasing land, securing financing, real estate tax structure, SRECs, net metering, interconnection, long-term contracts, and permitting. He described how variability in SREC prices made it difficult to predict a long term profit. For Cathartes Investments, this was one of the most challenging aspects of the solar project.

On April 25, 2014 the SREC-I program ended and SREC-II began. DOER's goals and objectives for SREC-II are to provide economic support for the expansion of solar installations, control ratepayer costs, maintain growth to reach 1,600 MW by 2020, maintain a competitive market of diverse solar developers, address financing barriers limiting residential and non-profit direct ownership, and minimize regulatory complexity and maintain flexibilities to respond to changing conditions. To participate in SREC-II, projects must have a capacity of 6 MW or less, generate some power on-site, be interconnected to the utility grid, and have a Commercial Operation Date of January 1, 2013 or later. SREC-II incentivizes different types of projects. For example, more credits are provided for disturbed lands (e.g. landfills and “brownfields”), and existing buildings (e.g. parking lot canopies and former office parks, as shown in the Table below.

Table 7: SREC Factors associated with SREC-II

Market Sector	Generation Unit Type	SREC Factor
A	1. Generation Units with a capacity of <=25 kW DC 2. Solar Canopy Generation Units 3. Emergency Power Generation Units 4. Community Shared Solar Generation Units 5. Low or Moderate Income Housing Generation Units	1
B	1. Building Mounted Generation Units 2. Ground mounted Generation Units with a capacity > 25 kW DC with 67% or more of the electric output on an annual basis used by an on-site load	0.9
C	1. Generation Units sited on Eligible Landfills 2. Generation Units sited on Brownfields 3. Ground mounted Generation Units with a capacity of <= 650 kW with less than 67% of the electrical output on an annual basis used by an on-site load.	0.8
Managed Growth	Unit that does not meet the criteria of Market Sector A, B, or C.	0.7
Source: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/rps-solar-carve-out-2/about-solar-carve-out-ii.html		

However, SREC's may not be around forever. New proposed legislation, House Bill 4185, eliminates SRECs and replaces them with a declining block incentive program. In addition, the bill proposes to eliminate the net metering cap, create a minimum utility bill to ensure all customers are paying something each month to cover their fair share of the costs incurred by the utility in developing, maintaining, operating and upgrading the distribution system, reimburse virtual net metering customers at a lower rate to cover their use of the distribution system and create a legally binding mandate to incentivize 1,600 MW of installed solar capacity.[105] While supporters of the bill claim it will result in cost savings for ratepayers and create more certainty for solar developers, opponents object to replacing the SREC-II program with a new incentive structure, and are concerned that the minimum bill requirement will primarily impact solar customer-generators.[106]

[105] http://www.seia.org/research-resources/outline-proposed-legislation-massachusetts-net-metering-solar-incentives

[106] http://www.alta-energy.com/reports/Legislative%20Update%20-%20MA%20HB%204185%20NEM%20SRECs.pdf

As of August 2014, the proposed legislation (H. 4185) had not yet passed through the House and Senate, however, a short-term fix was achieved with the passing of Senate Bill 2214. This bill increases the net metering cap by 2 percent for public projects and 1 percent for private projects, and also sets up a commission to study further cap lifts. It is anticipated that S. 2214 will provide a fix until April 2015.

State Tax Credits and Exemptions

Massachusetts Personal Income Tax Credit:

Most owners of new residential solar PV systems in Massachusetts qualify for a state personal income tax credit for the lesser of 15 percent of the total cost of the solar PV system or $1,000.

Massachusetts Sales Tax Exemption:

Equipment purchased for a residential solar PV system in Massachusetts is usually exempt from the sales tax.

Federal

Energy, Power, and Adaptive Systems Grant Opportunity

The National Science Foundation is providing funding for the engineering costs related to potential and current hydropower facilities. These grants are selective but ideal to fund the cost of developing a feasibility study with a professional engineer.

Federal Loan Guarantee for Commercial Technology Renewable Energy Projects

The federal Energy Policy Act of 2005 (EPAct 2005) has authorized the U.S. Department of Energy (DOE) to provide loan guarantees for projects that avoid, reduce or sequester air pollutants/ greenhouse gasses. The goal is to employ new or improved technologies that increase the energy efficiency of technologies and reduce energy consumption and greenhouse gas emissions. This can be found in the EPAct 2005 under section 1703 of Title XVII. The loan guarantee program is offering more than $10 billion is loan guarantees. The three main projects promoted by the DOE are manufacturing projects, stand-alone projects, and large-scale integration projects that combine multiple eligible renewable energy, energy efficiency and transmission technologies in accordable with a staged development scheme. This loan guarantee typically does not apply to research and development projects.[107]

Geothermal Play Fairway Analysis

The theme of this research and development funding announcement is to address the overarching theme of uncertainty quantification and reduction. A play fairway analysis defines the level of uncertainty with respect to the presence and utility of geothermal system elements. This analysis will produce maps over a geographic area (regional – basin – scale) with results covering areas of up to several thousand miles. The maps should present the most favorable combinations of heat, permeability, and fluid throughout the selected region. DE-FOA-0000841 https://eere-exchange.energy.gov/#FoaId586375f7-008c-47a7-9cc2-63cde3960a85

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[107] http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US48F

U.S. Federal Government – Green Power Purchasing Goal

This goal is to reduce energy use in existing and new federal buildings. Section 203 or EPAct 2005 mandates that the total amount of renewable electric energy consumed by the Federal Government will be at least 3% in fiscal years 2007-2009, 5% in 2010-2012, and 7.5% in 2013 and into the future. This energy credit is doubled if the renewable energy is produced and consumed on-site. This program was designed to help federal agencies meet the guidelines mandated in the EPA Act 2005 and Executive Order 13423.

Integrated Enhanced Geothermal Systems (EGS) Research and Development

The Geothermal Technologies Office (GTO) Enhanced Geothermal Systems (EGS) is looking to address the challenges associated with quantifying geothermal reservoir complexities. In an effort to increase the precision and accuracy of directly measuring parameters, this funding opportunity hopes to gain a better understanding of the physicochemical conditions that optimize subsurface engineering. The results should help facilitate a better understanding of geothermal reservoir complexities and lead to more accurate assessments of the evolution and sustainability for geothermal reservoirs during long-term operations. GTO's main interested is to understand more about matrix to fracture heat transfer areas, fluid mean resident time, in-situ stresses, fracture spacing, fracture aperture distribution, porosity, and reservoir volute. See Funding Opportunity Notice DE-FOA-0000842.[108]

Rural Energy for America Program - Renewable Energy System and Energy Efficiency Improvement Guaranteed Loan and Grant Program (REAP)

The Food, Conservation, and Energy Act of 2008 (H.R. 2419), enacted by Congress in May 2008, converted the federal Renewable Energy Systems and Energy Efficiency Improvements Program, into the Rural Energy for America Program (REAP). REAP promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of (1) grants and loan guarantees for energy efficiency improvements and renewable energy systems, and (2) grants for energy audits and renewable energy development assistance. For the April 2013 grant solicitation, grants for renewable energy must be between $2,500 and $500,000 (up to 25% of eligible project costs). Energy efficiency grants must be between $1,500 and $250,000 (up to 25% of eligible project costs). In order to use this grant, it would require either a local agricultural business or small business to build their own turbine(s), or a regional consortium of local agriculture and businesses to apply for the loan to produce a large scale wind farm, maintain it for a period of time, then sell or lease it to the local utilities provider. Not all towns are eligible for the REAP program. Please see Appendix H.1 for eligibility.[109]

The Renewable Energy Production Incentive (REPI)

The REPI, through the Office of Energy Efficiency and Renewable Energy (EERE), provides an incentive of 2.2 cents per kWh (indexed for inflation) for electricity generated and sold by new qualifying renewable energy generation facilities for the first 10-year period of their operation. The REPI is selective and only provides the payments to certain not for profit utilities, such as cooperatives, public utilities, and tribal and state governments. The incentive is, however, also dependent on annual

[108] https://eere-exchange.energy.gov/#FoaId586375f7-008c-47a7-9cc2-63cde3960a85

[109] http://www.rurdev.usda.gov/SupportDocuments/ma%20state%20map%20BI%20counties%20and%20towns.pdf

appropriations from Congress, meaning they are subject to fall or end due to sequester. More information on this incentive can be found at www.eere.energy.gov/repi/

Federal Tax Credits and Exemptions

48C Phase II Advanced Energy Manufacturing Tax Credit Program

Section 1302 of ARRA requires the Department of Treasury to award $2.3 billion in tax credits to manufacturers investing in advanced energy products or investments supporting new, expanded, or re-reequipped domestic manufacturing facilities. Phase I awarded funding to 183 manufacturers. Phase II is an extension of phase I but is allotting the reaming $150 million that was not distributed during phase I. The goal of this tax credit is to grow the domestic manufacturing industry for clean energy. Ideally it will help stimulate economic growth, create jobs, and reduce greenhouse gas emissions. The MTC provides a 30% credit for investments in new, expanded, or re-equipped advanced energy manufacturing projects. The fund will support total capital investments of almost $7.7 billion in new renewable and advanced energy manufacturing projects.[110]

Business Energy Investment Tax Credit

The federal business energy investment tax credit available under 26 USC § 48 was expanded significantly by the Energy Improvement and Extension Act of 2008 (H.R. 1424), enacted in October 2008. This law extended the duration -- by eight years -- of the existing credits for solar energy, fuel cells and microturbines; increased the credit amount for fuel cells; established new credits for small wind-energy systems, geothermal heat pumps, and combined heat and power (CHP) systems; allowed utilities to use the credits; and allowed taxpayers to take the credit against the alternative minimum tax (AMT), subject to certain limitations. The credit was further expanded by the American Recovery and Reinvestment Act of 2009, enacted in February 2009. Most recently it has been further extended by H.R. 8, the American Taxpayer Relief Act of 2012 for eligible systems placed in service on or before December 31, 2016.[111]

Renewable Energy Property Tax Exemption

Taxable properties are eligible for twenty years of tax exemptions if solar or wind-energy systems are used to provide energy and heat. This Massachusetts law waives the local property tax if a systems owner makes an agreement with the city or town. Homeowners with a solar PV system may be eligible for a property tax exemption on the value added by the system. A similar law is established for hydropower facilities as well. But, the hydro system owner must agree to make a payment of at least 5% of its gross income in the preceding calendar year. The property tax exemption for hydropower lasts twenty years. Homeowners are encouraged to discuss this with their installer and the local tax assessor's office. [112]

[110] http://energy.gov/downloads/48c-phase-ii-advanced-energy-manufacturing-tax-credit-program-selections
[111] http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1
[112] www.state.ma.us/doer

Residential Energy Efficient Property Credit (Section 1121 and 1122)

A result of the ARRA (American Recovery and Reinvestment Act) the government is helping individuals fund energy efficiency improvements within their homes. This credit is a nonrefundable energy tax incentive for taxpayers to help afford for cost the purchasing and implementation home energy improvements. Qualified residential alternative energy equipment will be credited up to 30% of the overall cost. The new law has increased the maximum amount allowed to qualify for the funding. This includes geothermal heat pumps (in addition to solar hot water heaters and wind turbines).[113]

Private Grant Funding

Environmental Community Grant Program

A grassroots environmental project can qualify for this grant and funds are provided via Northeast Utility's Environmental Community Grant Fund. Grants range between $250 and $1,000 and are available to organizations within their service territories in Connecticut, Western Massachusetts, and New Hampshire. http://www.northeastutilitiesfoundation.org/what/index.html

Interconnection Standards

The interconnection standards are agreements adopted by The Commonwealth of Massachusetts. They pertain to net metering and the amount of money it costs to maintain that renewable energy is being provided to its customers when purchased "off the grid". An easier way to break this down is by better defining "on" and "off" the grid. If you build the hoover dam you need to send the energy somewhere, the grid is what transfers the electricity from one location to another. Hydro (and other renewable resources) can be set up "off" the grid if the energy production units are at the location of consumption. A mill building that sits on the banks of the Nashua River and uses hydro power as an energy provider is "off" the grid. This statement implies that the energy is produced and consumed in the same location. Additionally, adding new renewable resources to the grid costs money. It also results in a lower net worth of all energy produced per kilowatt. For example, energy produced on site is typically valued at ten cents a kilowatt. If you sell a kilowatt to the grid it is worth five cents (although sometimes it is worth more). Either way, adding energy to the grid offsets the current balance of distribution and charges. Moreover, when municipalities invest in renewable energy the distribution must be monitored and regulated. The standards set by the interconnection standards of Massachusetts quantify the levels at which utilities can receive benefits.[114]

Net Metering

Net metering is a mechanism that allows solar PV system owners to be compensated for power that is exported to the grid. At the end of each month, on-site generation is credited against any electricity that the customer consumed from the grid. If the customer has net excess generation at the end of the month, the customer receives a credit on their utility bill. The total amount of net metering capacity on a utility's system is capped at 6% of the utility system's peak load: 3% for private facilities, and 3% for public facilities.

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[113] http://www.irs.gov/uac/Energy-Incentives-for-Individuals-in-the-American-Recovery-and-Reinvestment-Act

[114] http://www.mass.gov/eea/docs/doer/renewables/dg-inter.pdf

Massachusetts has created a System of Assurance of Net Metering Eligibility (MassACA) to enable customers that are developing solar PV systems to reserve space under a utility's cap. Small, solar PV systems (10 kW or smaller in a single-phase circuit and 25 kW or smaller on a three-phase circuit) are exempt from the cap.[115] To support these regulatory initiatives, DOER provides a database with electric customer migration data, lists of competitive suppliers for electricity and natural gas, energy reports, and applicable regulations. To access this data, communities can visit the Energy Market Data website: www.mass.gov/eea/energy-utilities-clean-tech/home-auto-fuel-price-info/emergy-market-data/.

National Grid's historical peak load of 5,131 MWs occurred on August 2, 2006 in its Massachusetts Electric territory; making each 3% limit equal to 153.93MW. According to MassACA, National Grid has only 1,539 kW capacity available under its public facilities cap with 11,483kW on the "Waiting List" pending additional cap space[116]. While some of these facilities may not move forward, reaching the net metering cap may limit future solar PV potential in the Northern Middlesex and Montachusett regions as National Grid is the primary electric service provider in the region.

[115] https://sites.google.com/site/massdgic/home/net-metering
[116] https://app.massaca.org/allocationreport/report.aspx accessed 2/17/2014

LEED Certification

Introduction

As a voluntary certification program for buildings, homes and communities, Leadership in Energy and Environmental Design (LEED), provides third-party verification of green buildings. Beginning in March 2000, the goal of the LEED Certification program was to conserve energy and water, reduce landfill waste and greenhouse gas emissions and provide a healthier and safer indoor environment for occupants. The program is run through the U.S Green Building Council (USGBC), which is a 501(c)(3) nonprofit organization "committed to a prosperous and sustainable future for our nation through cost-efficient and energy-saving green buildings". To date USGBC has 77 chapters, 13,000 member companies and organizations, and more than 181,000 professionals who hold LEED credentials as of June 2014. [117]

According to USGBC, LEED is "the most widely recognized and widely used green building program across the globe". Today, there are more than 53,000 LEED projects, comprising more than 10.1 billion square feet of construction space. USCBC claims that by becoming LEED certified, buildings can experience lower operating costs and increased asset values, and can become qualified for tax rebates, zoning allowances, and other incentives. [118]

According to USGBC, LEED v4 will "open up LEED to a wider range of building types and manufacturing industries, delivering the benefits of green building up and down the supply chain. It will advance environmental footprint issues, like climate change, and encourage optimization of energy and water use."

LEED Certification can be pursued across a variety of industries and sectors, and through its implementation, can promote economic growth in the clean energy, biotechnology, nanotechnology, and green business sectors. Throughout the nation, tools such as zoning regulations, green building ordinances, and streamlined permitting have been used to promote LEED. This section examines the process of LEED Certification, as well as the barriers and opportunities associated with implementing LEED. Recommendations are also made on how to promote LEED in the Montachusett and Northern Middlesex Regions so as to encourage economic growth across the region through increased private investment, while also promoting a clean, healthy environment.

LEED Certification

LEED is continuously evolving and improving, and has gone through a variety of different versions over the years. The U.S. Green Building Council released the most recent version, LEED 4.0 (LEED v4), in November 2013. The new version reaches new market sectors, including data centers, warehouses and distribution centers, hospitality facilities (i.e. hotels), schools and retail, and includes a new category of LEED for Homes Mid-Rise. It also includes revisions to credit weights, new credit categories, and an

[117] http://www.usgbc.org/about/history
[118] http://www.usgbc.org/about

increased emphasis on measurement and performance. It also introduces tools to increase efficiency for the LEED documentation process.

There are five categories of LEED Certification for LEEDv4, which includes (1) Building Design and Construction, (2) Interior Design and Construction, (3) Building Operation and Maintenance, (4) Neighborhood Development (ND), and (5) Homes (Table 1).

Table 8: The Categories of LEEDv4 Certification

LEED Certification	Description
LEED Building Design and Construction	Applies to buildings that are being newly constructed or going through a major renovation including new construction, core and shell, schools, retail, healthcare, data centers, hospitality and warehouses and distribution.
Interior Design and Construction (ID+C)	Applies to projects that are a complete interior refurbishing including commercial interiors, retail and hospitality.
Building Operations and Maintenance (O+M)	Applies to existing buildings that are undergoing improvement work and little to no construction. Relevant to existing buildings, data centers, warehouses and Distribution Centers, Hospitality, Schools and Retail.
LEED for Homes	Applies to single family homes, low-rise multi-family (one to three stories), or mid-rise multi-family (four to six stories).
LEED for Neighborhood Development	Applies to new land development projects or redevelopment projects containing residential uses, nonresidential uses, or a mix. Projects can be at any stage of the development process, from conceptual planning to construction.
Source: http://www.usgbc.org/leed	

While the majority of LEED Certification projects deal with individual buildings, LEED ND (Neighborhood Development) promotes sustainability in design and development at the neighborhood scale. LEED ND certifies whole neighborhoods, or multi-building projects that contribute to neighborhoods. This certification prioritizes site location, urban design, transportation, housing affordability, pedestrian access, socio-economics, and neighborhood-wide green infrastructure. Projects can vary widely in size and type, but certification is most appropriate for projects that are smaller than 320 acres, larger than one building, developed by a single developer and constructed within a predictable timeframe.

LEED Certification Process

Each LEED project becomes certified through a rating system that consists of prerequisites and credits. Prerequisites must be met before a project can then be considered for LEED Certification. Examples of prerequisites include stipulations that a project must comply with environmental laws, be a complete, permanent building or space, use a reasonable site boundary, comply with minimum floor area requirements, and occupancy rates, and commit to sharing whole-building energy and water usage data. These are outlined on the LEED Project application form. Once prerequisites are met, a menu of available credits is then available to the project Team, with the achieved Credits combined to meet the various certification levels.

Credits are earned during the certification process and seek to reduce the environmental consequences of the construction and operation of buildings and infrastructure (Table 9). They also promote walkable neighborhoods with efficient transportation options, open space, and connections to nearby communities. They encourage construction on previously developed or infill sites and are designed to provide home builders, real estate professionals, homeowners, tenants and building managers with the education and tools they need to understand and make the most of the green building features, while also promoting regional environmental priorities (Table 9).

Table 9: LEED Credit Categories

Credit Name	Description
Sustainable sites credits	Credits encourage strategies that minimize the impact on ecosystems and water resources .
Water efficiency credits	Credits promote smarter use of water, inside and out, to reduce potable water consumption.
Energy & atmosphere credits	Credits promote better building energy performance through innovative strategies.
Innovation	Credits address sustainable building expertise as well as design measures not covered under the five LEED credit categories.
Indoor environmental quality credits	Credits promote better indoor air quality and access to daylight and views.
Regional priority credits	Credits address regional environmental priorities for buildings in different geographic regions.
Additional LEED for Neighborhood Development Credit Categories	
Smart location & linkage credits	Credits promote walkable neighborhoods with efficient transportation options and open space.
Neighborhood pattern & design	Credits emphasize compact, walkable, vibrant, mixed-use neighborhoods with good connections to nearby communities.
Green infrastructure & buildings	Credits reduce the environmental consequences of the construction and operation of buildings and infrastructure.
Source: USGBC http://www.usgbc.org/leed	

The method of earning credits is complex, and varies with each different type of LEED certification. To assist with this process, USGBC has provided a credit library and credit scorecards, which contains a list of all the possible credits for each certification. Credits may be earned for a variety of actions, including water use reduction, use of renewable energy, recycling, and using low-emitting materials. Credits differ for each category and can change over time. As such, the LEED Credit Library contains the most comprehensive and up-to-date list of the credits available. It can be accessed at the following site: http://www.usgbc.org/credits.

Basic certification requires that a project earn a minimum of 40 credit points. Earning more than the 40 credit points allows a project to achieve a more prestigious level of certification. Projects earning

50 points achieve silver certification, 60 points receive gold certification, and 80 or more points receive platinum certification. The highest number of points that can be earned is 100.[119]

One of the primary goals of LEED is not only sustainable design, but also sustainable operation. The LEED for Existing Buildings Recertification Program is intended to either certify an existing building that was not previously certified under a LEED Design and Construction rating, or to recertify an existing building that was previously certified. This recertification can be done annually, but no less frequent than every five years, and ensures that the building's design remains compatible with LEED. The LEED for Existing Buildings: Operations and Maintenance Recertification Guidance is the first of several steps USGBC is taking to establish a clear LEED recertification program.[120]

LEED Implementation

For projects wishing to obtain LEED certification, a LEED project team should be developed as early as possible. This team, consisting of architects, landscape architects, urban planners, engineers, and other professionals, is responsible for integrating a broad range of sustainable design elements into the building project. The LEED Certification Process is typically divided into four phases that include registration, verification, review and certification (Table 10).

Table 10: Steps to LEED Certification

Phase	Description
Register	• Compile project team, discuss the approach, and outline a strategy for moving forward. • Register the project by selecting the team, completing key forms and submitting payment. • Registration will preserve the version of LEED used at the time of registration.[1]
Verify	• Verify project milestones and achievements through the on-site verification process.
Review	• Have USGBC conduct a Design Phase Review, so as to understand the degree to which the project team has fulfilled all design-based prerequisites and credits. • Submit the necessary information, calculations and documentation. • The LEED application is then reviewed by GBCI.
Certify	• Receive the certification decision. • If certification is not awarded, then the project team appeals credits, if necessary.

1. Rating systems are periodically updated, usually becoming more stringent, and if an update occurs while a project is in the design or construction phase and the project is not registered, eligibility for these credits can be lost if it fails to meet the newer LEED standards.
Source: **http://www.usgbc.org/cert-guide/homes**

LEED requirements should be integrated into a project early in the planning process. Postponing the discussion on LEED could overburden a project schedule and budget if the issue is discussed too late in the design process.

Project Fees

LEED registration and certification fees differ depending on the certifications system. Registration is a flat fee paid up front, and rates are based on the date of registration. The certification fee is based on a project's rating system and size and it is calculated and paid when the project team

[119] http://www.usgbc.org/certification
[120] http://www.usgbc.org/articles/recertification-guidance-existing-buildings

submits documentation for review in LEED Online. For previous versions of LEED, the fees for all single-building projects were the same. However, for LEEDv4, each category is subject to a different fee structure. The fees associated with Building Design and Construction are shown below to provide a general idea of project fees. All other fees can be found on the USGBC website at: http://www.usgbc.org/cert-guide/fees#bdc

Table 11: LEED Certification Fees

Building Design and Construction Fees	ORGANIZATIONAL LEVEL OR NON-MEMBERS	SILVER, GOLD AND PLATINUM LEVEL MEMBERS	MEMBER SAVINGS
REGISTRATION	$1,200	$900	$300
PRECERTIFICATION REVIEW (optional, LEED CS only)			
Flat fee (per building)	$4,250	$3,250	**$1,000**
Expedited review (reduce from 20-25 business days to 10-12, available based on GBCI review capacity)	$5,000		
COMBINED REVIEW: DESIGN & CONSTRUCTION			
Project gross floor area (excluding parking): less than 50,000 square feet	$2,750	$2,250	**$500**
Project gross floor area (excluding parking): 50,000-500,000 square feet	$0.055/sf	$0.045/sf	**$0.01/sf**
Project gross floor area (excluding parking): more than 500,000 square feet	$27,500	$22,500	**$5,000**
Expedited review (reduce from 20-25 business days to 10-12, available based on GBCI review capacity)	$10,000		
SPLIT REVIEW: DESIGN			
Project gross floor area (excluding parking): less than 50,000 square feet	$2,250	$2,000	**$250**
Project gross floor area (excluding parking): 50,000-500,000 square feet	$0.045/sf	$0.04/sf	**$0.005/sf**
Project gross floor area (excluding parking): more than 500,000 square feet	$22,500	$20,000	**$2,500**
Expedited review (reduce from 20-25 business days to 10-12, available based on GBCI review capacity)	$5,000		
SPLIT REVIEW: CONSTRUCTION			
Project gross floor area (excluding parking): less than 50,000 square feet	$750	$500	**$250**
Project gross floor area (excluding parking): 50,000-500,000 square feet	$0.015/sf	$0.01/sf	**$0.005/sf**
Project gross floor area (excluding parking): more than 500,000 square feet	$7,500	$5,000	**$2,500**
Expedited review (reduce from 20-25 business days to 10-12, available based on GBCI review capacity)	$5,000		
APPEALS			
Complex credits	$800/credit		
All other credits	$500/credit		
Expedited review (reduce from 20-25 business days to 10-12, available based on GBCI review capacity)	+ $500/credit		

The fee structure outlined above indicates there is a significant financial component for LEED Certification. In particular, LEED ND is the most expensive certification, with an $18,000 to $25,000 surcharge for the initial review. As a result, the fees associated with LEED, the cost of compliance, and the need to have a LEED accredited professional as part of the project team, all pose a significant barrier to implementation for many developers and building owners – especially for small or mid-size projects. In addition to high project fees, many developers interested in pursuing green building projects hesitate to do so because they are unfamiliar with the standards and requirements for building green. For this reason many organizations use LEED certifications, such as LEED ND, as guidance for sustainable development, without actually pursuing formal certification. While fees are commonly sited as a barrier to LEED, the direct cost associated with seeking LEED certification have been estimated to be below 2% of the total project cost.[121]

Industrial and Commercial Economy

USGBC believes the economic impact from green building construction is significant and will continue to grow as the demand for green buildings rises. According to the USGB *Green Jobs Study*, LEED-related spending generated 15,000 jobs between 2000 and 2012, and by 2013 an additional 230,000 jobs have been created. In addition, estimates suggest that LEED related spending will generate an additional $12.5 billion dollars in Gross Domestic Product (GDP), and provide $10.7 billion in wage earnings. There are also indirect impacts as a result of LEED Certification – according to USGCB, LEED-based construction created more jobs in the manufacturing and service sectors, including lighting, HVAC, water heating, motors and drives, office equipment, environmental controls, and envelope improvements[122] (Table 12). *The Clean Energy Economy* report also indicates that programs such as LEED positively impact the economy by creating new jobs in the clean energy, energy efficiency and environmentally friendly production sectors. [123]

By promoting clean energy and energy efficiency, LEED encourages research and development, manufacturing and green businesses. LEED also will create jobs for chemists and engineers to develop technology, researchers and technicians to perfect and implement technologies, manufactures to create the products, and electricians, engineers and plumbers to install products in homes, businesses and government buildings. LEED promotes the transportation industry through the promotion of hybrid diesel buses, traffic monitoring software and liquid biofuels, as well as the manufacturing industry through the encouragement of environmentally sound packaging, equipment and surface cleaning and the construction industry through the promotion of green building material, green building design and construction services. The agricultural industry is also supported through smart irrigation systems, alternative pest controls, and agricultural sustainability planning. Energy production can be promoted through the encouragement of gasification, and carbon capture and sequestration (CCS).

[121] http://www.josre.org/wp-content/uploads/2012/09/Cost_of_LEED_Analysis_of_Construction_Costs-JOSRE_v3-131.pdf

[122] *A New Retrofit Industry: An analysis of the job creation potential of tax incentives for energy efficiency in commercial buildings and other components of the Better Buildings Initiative.*

[123] Pew 2009. *The Clean Energy Economy.*

Table 12: Indirect Impacts of USGBC LEED Certification

Direct Impacts	Industries indirectly impacted
Lighting	Wholesale trade, power equipment and transformer manufacturing, truck transportation, building services, machine shops
HVAC	Wholesale trade, truck transportation, services to buildings, machine shops, ferrous metal foundries, iron and steel mills
Water heating	Wholesale trade, machine shops, truck transportation, services to buildings, business support services, architecture and engineering
Motors and drives	Wholesale trade, truck transportation, services to buildings, copper rolling and drawing, crown and closure manufacturing, iron and steel mills
Office equipment	Wholesale trade, semiconductor manufacturing, software publishers, scientific R&D, advertising
Environmental controls	Wholesale trade, scientific R&D, software publishers, services to buildings, custom computer programming, semiconductor manufacturing
Envelope improvements	Wholesale trade, truck transportation, services to buildings, accounting, maintenance and repair construction, architecture and engineering
Source: Employment Estimates for Energy Efficiency Retrofits of Commercial Buildings, Heidi Garrett-Peltier, June 2011	

LEED promotes research and development and manufacturing in industries, such as biotechnology and nanotechnology. The biotechnology industry uses cellular and biomolecular processes to develop technologies and products that help improve health and the environment.[124] The nanotechnology industry involves the engineering of functional systems at the molecular scale to make complete, high performance products[125].

Additional Considerations

The International Organization for Standardization (ISO) is the world's largest developer of voluntary international standards for products and services, designed to make industry more efficient and effective. Developed through global consensus, these standards help to break down barriers to international trade. LEED and ISO standards can dovetail in an effort to promote the local/regional growth of environmentally sustainable businesses and business sectors (e.g., bio/nanotech, clean energy sector). While LEED standards address the sustainability of buildings and other infrastructure, ISO standards address the sustainability of the activity accommodated by that infrastructure. Specifically, the ISO 14000 family of standards provides practical tools for companies and organizations looking to identify and control their environmental impact and improve their performance.

Regulatory Barriers and Opportunities

Traditional zoning, which encourages the separation of land uses, may be incompatible with mixed-use development and can actually discourage, rather than encourage, green building. There are many tactics available for overcoming these barriers to promote economic development and to

[124] http://www.bio.org/articles/what-biotechnology
[125] http://crnano.org/whatis.htm

encourage a clean energy economy. Municipalities and state governments have promoted LEED through zoning codes, parking ratios, laws regarding the installation of green technology, and green building bylaws/ordinances. Additionally, these entities have also used policy statements, financial incentives, expedited review and technology assistance to encourage LEED. Each strategy is discussed below.

Zoning Codes

As implemented in many communities today, building setbacks may not be compatible with compact development, and parking ratios may also be incompatible with certain LEED certification categories. To overcome this barrier, zoning regulations can be revised to align with, and encourage, LEED principles, even if LEED certification is not mandated. Simple modifications in zoning permitting and review processes can encourage developers and building owners to follow green building and development standards. For example, communities can revise zoning pavement regulations, and pavement widths in new subdivisions can be revised to allow for less pavement. Off street parking could also be revised to require less pavement based on new definitions of floor space. Porous pavers could be encouraged and communities could establish strict impervious lot area maximums in all zones.

While municipalities across the state and the nation have promoted LEED through zoning in a variety of ways, only one town in the Montachusett and Northern Middlesex Regions mentions LEED in their zoning regulations: the Town of Westford Zoning Regulations encourage LEED by stating that "Compliance with the Leadership in Energy and Environmental Design (LEED) certification standards and other evolving environmental efficiency standards shall be encouraged" for major commercial or retail projects (§9.3A p. 104). Lowell requires the submission of a "Green Checklist" for special permit development projects. While the Planning Board encourages the implementation of green building methods in development projects, implementation of performance standards based on the LEED checklist is still voluntary.

Outside of the Region, the Town of Bedford's Zoning Bylaw states that new projects should incorporate LEED criteria where practicable (§ 16.6.8), while the Town of Pembroke's Zoning Bylaw states that all new construction and major renovations on town-owned land and buildings must meet the Massachusetts LEED Plus Standards (Article XII-A). The City of Boston Zoning Code requires LEED certification or proof of a comparable level of measurable accountability for all public and private development projects over 50,000 square feet. Permits and certificates of occupancy can be denied for noncompliant projects. The Boston Redevelopment Authority requires a LEED checklist to be submitted for all projects (Article 37 Green Buildings). The Town of Arlington requires all new buildings, major renovation projects, and additions to achieve a minimum of LEED Silver Certification (Title 1, Article 16, § 4). In Cambridge, the City Council adopted a green building zoning amendment which requires that all new construction and major renovations of municipal buildings, including public schools, follow LEED guidelines (Article 22 of the Zoning Ordinance).

Modifications in zoning, such as a shift to form-based code, may help communities align with LEED-based principles, sustainability and green building. While conventional zoning neglects an "integrated built form", form-based code:

[Uses] physical form (rather than separation of uses) as the organizing principle for the code…Form-based codes address ….the form and mass of buildings in relation to one another, and the scale and types of streets and blocks….Form-based codes are regulatory, not advisory. They are drafted to implement a community plan. They try to achieve a community vision based on time-tested forms of urbanism. Ultimately, a form-based code is a tool; the quality of development outcomes depends on the quality and objectives of the community plan that a code implements.[126]

Some municipalities have begun switching from traditional zoning to form-based code in order to encourage smart growth, as well as LEED development. Within the Northern Middlesex Region, the City of Lowell has established form based codes in the Hamilton Canal Overlay District[127]. Outside of the Region the Ashland Zoning Bylaw states that consideration should be given to LEED criteria in the construction of new buildings in the Pond Street Mixed-Use Overlay District (§ 8.9.1-7). In Grand Rapids, Michigan, a new zoning code follows a form- and performance-based model and strongly encourages sustainable development. Grand Rapids planning staff consulted LEED for Neighborhood Development standards as they were creating the new code ensuring that new projects that meet the code's site and design requirements are likely eligible to score enough points to become LEED ND certified. [128] Both the Northern Middlesex Council of Governments and the Montachusett Regional Planning Commission can encourage LEED throughout the Regions by promoting the integration of LEED into the zoning code.

Laws and policy regarding the installation of Green Technology

Another opportunity for encouraging LEED at the local level is to adopt a municipal policy regarding green technology. Currently, none of the municipalities in the Northern Middlesex or Montachusett Regions have a formal policy regarding the installation of green technology. However, outside of the Regions, the Boston Redevelopment Authority Columbia Point Master Plan requires all new buildings to be certified at a LEED silver level and that all multiple building developments include at least one LEED silver building. The Plan also highlights all policies and implementation actions that relate to LEED for Neighborhood Development. On April 13, 2007, Boston Mayor Thomas Menino issued an Executive Order requiring LEED silver certification for all city-owned new construction and major renovation projects and LEED certification for all city-supported development projects. [129] Similarly, in 2005, the City of Medford issued the Energy and Resource Efficiency Policy, requiring that all new municipal construction achieve LEED certification. [130] At the statewide level, in 2007 Governor Deval Patrick signed Executive Order 484, "Leading by Example – Clean Energy and Efficient Buildings", which instructed all Executive agencies to adhere to the Massachusetts LEED Plus standard for new construction and major renovation projects that are 20,000 square feet or larger and are designed for use by a public entity. For projects smaller than 20,000 square feet, there is an option of either adhering to the Massachusetts LEED Plus standard or other green building standards.[131]

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[126] http://www.formbasedcodes.org/what-are-form-based-codes
[127] http://www.hamiltoncanal.com/Default.aspx
[128] http://www.mml.org/green/pdf/GrandRapids_Zoning_Case.pdf
[129] http://www.cityofboston.gov/Images_Documents/Clim_Action_Exec_Or_tcm3-3890.pdf
[130] http://www.medford.org/pages/medfordma_energy/Energy_Efficiency_Policy.pdf
[131] http://www.mass.gov/anf/docs/dcam/dlforms/energy/energy-eo484-final.pdf

Public transit and housing authorities can also influence LEED-based development through their policies. Public housing authorities, in particular, can make optimal use of the LEED for Homes rating system. For example, in New York City, the Blue Ribbon Commission on Sustainability and the Metropolitan Transportation Authority (MTA) analyzed the existing operational structure of the MTA and issued a report outlining practices that would make the agency and region more sustainable. Among other policies, the report encouraged policies that provide incentives to developers who design and construct LEED for Neighborhood Development gold-level projects.[132] In Chattanooga, Tennessee the Chattanooga Housing Authority recently initiated two LEED for Homes projects to replace existing dilapidated multi-family housing. The first project received 50% of its funding as an incentive grant to pursue platinum certification. The second project was developed by a for-profit affordable housing developer with no incentive funding. [133] Throughout our regions, the Regional Planning Agencies can help municipalities adopt municipal policies regarding that promote green technology and LEED certification.

Green Building Bylaws/Ordinance Models

Green building ordinances and Green Communities are becoming increasingly popular throughout the country and are often a highly effective opportunity for promoting LEED. While some municipalities require certification for projects receiving a certain level of financial support from the municipality, many require projects to meet specific LEED standards without obtaining certification.

In Massachusetts, one of the premier ways to promote LEED Green Building Ordinances is through the Green Communities Program. The Green Communities Designation and Grant Program helps a municipality become designated as a “Green Community” and provides funding to qualified municipalities for energy efficiency and renewable energy initiatives. The Program is open to all communities served by investor-owned utilities and those served by municipal light plants that adopt the renewable energy charge.

According to the Department of Energy Resources (DOER), to achieve “Green Community” designation, a municipality must meet five clean energy benchmarks:

- Provide as-of-right siting: A city or town must zone designated locations for as-of-right siting for one of the following: renewable/alternative energy-generating facilities, renewable/alternative energy research and development facilities, or renewable/alternative energy manufacturing facilities. As-of-right siting means the development may proceed without the need for a special permit, variance, amendment or other discretionary approval.

- Expedited Permitting: The municipality must adopt an expedited application and permitting process, not to exceed one year, for the siting of facilities outlined in the first criterion.

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[132] http://mta.info/environment/pdf/draft_final3.pdf
[133] http://www.chahousing.org/s/

- Establish an Energy Baseline/20 Percent Energy Reduction Plan: The municipality must establish an energy use baseline inventory for all municipal buildings, vehicles, and street and traffic lights, and it must put in place a comprehensive program designed to reduce this baseline by 20 percent within five years.

- Purchase Only Fuel Efficient Vehicles: All municipal departments must purchase only fuel-efficient vehicles when they are commercially available and practical.

- Minimize Life-Cycle Costs: The municipality must require all new residential construction over 3,000 square feet and all new commercial and industrial construction to minimize life-cycle costs of the facility with energy efficiency and other renewable or alternative energy technologies. This requirement is met by adopting the state's "stretch code", an energy building code that requires construction practices and building materials that are 20% more efficient than the baseline state energy building code.

Green Communities and LEED

To comply with Green Communities Criterion 5, municipalities must adopt the Massachusetts Stretch Energy Code, which is 20% more stringent than the state's building code. According to DOER, the stretch energy code, as it applies to homes and businesses, is synonymous with LEED Silver certification. DOER feels that "because LEED for Homes and the stretch code share the same Home Energy Rating System (HERS) and Energy Star underpinnings they are fully compatible". (A description of HERS is provided in the inset to the right.) NMCOG and MRPC can assist municipalities with the Green Communities application process to encourage LEED throughout the region.

HERS stands for 'Home Energy Rating System,' and is a national standard that uses information on the design of the energy systems in a home to calculate, via computer modeling, the average energy needs of that home and give it a rating score…

On the HERS 2006 index scale smaller numbers are better, with 0 representing a net zero energy home, and 100 representing a home built to meet the national model energy code in 2006 (the IECC 2004 with 2005 amendments). A HERS rating of 65 means that the home uses about 35% less energy than the same size home built to the 2004/2005 IECC code requirements. The Residential Stretch code is based on the nationally successful 'Energy Star for Homes' program requirements, which utilize HERS ratings.

Permitting and Regulations

Many local government have turned to financial and development incentives in order to promote green building and construction. These have been found to be the most effective strategies for encouraging LEED, as well as green building and development. Rewarding developers and builders who choose to build green is a crucial way to encourage the adoption of best practices in design, construction, and operations while spurring innovation and demand for green building technologies. Financial incentives, such as tax credits or fee reductions, are a highly successful means of encouraging developers to follow green building and neighborhood practices.

Density Bonus

While there are no municipalities in our region who have promoted LEED through density bonuses, there are municipalities outside of our region who have done so. In Massachusetts, the Town of Acton adopted a zoning bylaw allowing a density bonus for buildings achieving a LEED certification in the East Acton Village District (§ 5.5B.2.2.d). Outside of Massachusetts, Arlington County, Virginia allows commercial projects and private developments earning LEED certification to develop sites at a higher density than conventional projects with bonuses varying depending on the level of LEED certification. Bar Harbor, Maine awards a density bonus of an additional market-rate dwelling unit for construction projects for which all dwelling units meet LEED standards. This bonus applies to projects within a Planned Unit Development (PUD) and compliance is determined by either application or by affidavit for adherence during construction. Cranford, New Jersey offers a green building density incentive program through which redevelopers who achieve LEED certification and comply with the specific program requirements may earn a development density bonus. Portsmouth, New Hampshire offers a density bonus for private projects that use LEED. Seattle, Washington offers a height or density bonus to commercial or residential projects that achieve at least LEED silver certification and contribute to affordable housing. Sunnyvale, California offers density and building height bonuses for certain types of LEED certification.[134]

Expedited Permitting and Fee Reduction

Expedited permitting processes can provide extra incentive for a developer to pursue LEED certification, and while there are no examples from our region, there are many examples from across the country where expedited permitting has been used to encourage LEED certification. The State of Hawaii requires priority processing for all construction and development permits for projects that achieve LEED silver or equivalent. Alachua County, Florida provides a fast-track building permit incentive and a 50% reduction in the cost of building permit fees for private contractors who use LEED. Hillsborough County, Florida offers expedited permitting to home builders with a completed scorecard from either the LEED for Homes program or the Florida Green Home Standard Checklist. Miami Lakes allows for expedited permitting for private developers who build to minimal LEED requirements. Sarasota County provides fast-track permitting for residential and commercial green developments.

Costa Mesa, California offers expedited permitting processes for green buildings, including LEED certified buildings. The City of Los Angeles expedites processing through all departments if LEED silver designation is met. In San Diego commercial projects achieving LEED silver certification benefit from expedited discretionary processes. In San Francisco there is a priority permit review for all new and renovated buildings that achieve a LEED gold certification or higher. In Santa Monica, LEED registered projects receive expedited permitting. In Issaquah, Washington, projects achieving LEED certification are placed at the head of the building permit review line. [18]

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[134] http://www.slocounty.ca.gov/Assets/PL/Green+Building/USGBC+Public+Policy+Database.pdf

Another way LEED is encouraged through permitting is by waiving the permitting fee. Mecklenburg County in North Carolina offers permit fee rebates to projects with proof of LEED certification. Rebates increase proportionate to the level of certification achieved: 10% reduction for LEED certified, 15% for LEED silver, 20% for LEED gold, and 25% for LEED platinum. Babylon, New York requires LEED certification for any new construction of commercial, office, and industrial buildings, as well as multiple residences and senior citizen multiple residences over 4,000 square feet. The town refunds all certification fees paid to USGBC by the developer. Gainesville, Miami Lakes and Sarasota County, Florida offer a 50% reduction in the cost of building permit fees to private contractors who use LEED. San Antonio, Texas provides an administrative waiver or a reduction of certain development fees for projects achieving certain LEED standards. [18]

Tax Credits

At the state level, Maryland, New Mexico, New York, and Oregon provide tax credits to businesses that construct or rehabilitate a building that conforms to certain LEED and other sustainability standards.

In Baltimore County, Maryland, tax credits are offered to incentivize LEED certified residential and commercial buildings while Howard County, Maryland offers a five-year property tax credit for projects that achieve LEED new construction or core and shell. Chatham County, Georgia offers full property state and county tax abatement for commercial buildings achieving LEED gold certification for the first five years and then decreasing by 20% each year until the tenth year. Harris County, Texas offers partial tax abatement for costs incurred by developers to certify buildings with the USGBC. Cincinnati, Ohio offers an automatic 100% real property tax exemption of the assessed property value for newly-constructed or rehabilitated commercial or residential properties that earn LEED certification. [18]

Grants

Grants are also a way to help address the cost issue. The Commonwealth of Pennsylvania provides several hundred dollars of funding per pupil for public schools that achieve LEED silver or higher. The State of Illinois issues grants to school projects using LEED for schools. King County, Washington offers $15,000 to $25,000 in grant funding to building owners who meet a minimum of LEED silver for certain rating systems. El Paso, Texas awards grants at increasing amounts based on LEED certification level. Pasadena, California awards grants at increasing amounts based on LEED certification level ($15,000 for certified, $20,000 for silver, $25,000 for gold, and $30,000 for platinum) and Santa Monica, California awards grants at increasing amounts based on LEED certification level. [18]

Marketing Assistance

Developers and owners of green buildings and neighborhoods, as well as municipalities and other jurisdictions, have much to gain from the increased marketability of third-party certified, high-performance green real estate. Toward this end, some municipalities and counties offer free marketing assistance to help green builders rent and sell properties more effectively. Charlotte County, Florida provides free marketing, including signage, promotional mailings, press releases, newsletters, websites, and awards for LEED certified projects. Oakland, California offers free public promotion for LEED and other green building projects. San Diego, California sponsors a public recognition program for innovative LEED and other green building projects designed to encourage and recognize outstanding environmental protection and energy conservation projects. [18]

Technical Assistance

Developers interested in pursuing green building projects often hesitate to do so because they are unfamiliar with the standards and requirements for building green. There are opportunities for bridging this gap through technical assistance, public-private partnerships, and numerous educational initiatives. The State of Minnesota requires utilities to provide technical assistance for commercial and residential projects that incorporate LEED and other green building strategies into the construction process. Oakland and Pasadena, California, as well as Washington, D.C., offer free technical assistance for LEED and other green building projects. San Diego, California provides green building training, support, and education for private sector building projects registering for LEED certification. West Hollywood, California provides a resource center at City Hall, which serves as a source of information to developers and homeowners interested in incorporating LEED and other green building strategies into their projects. [18]

Public Private Partnerships

A public-private partnership – where the local entity sells or issues a ground lease for the land, or serves as an active member of the development team – can facilitate LEED-based development, especially if the development program includes new public infrastructure or multiple facilities dedicated to public use. A variety of municipal departments can be involved at different levels or may simply establish policies that support such an initiative. For example, in Rockville, Maryland, the Washington Metropolitan Area Transit Authority (WMATA) acted as a co-developer with the JBG Companies on a project to transform 26 acres of a WMATA-owned commuter parking lot around a transit station into a mixed-use development. The Twinbrook Station project earned gold-level certification for its plan under the LEED for Neighborhood Development pilot program. [18]

Revolving Loan Funds

Revolving Loan Funds can also be used to create incentives for LEED. While the funds described below are not officially LEED-based, they all can be used as incentives for LEED certification. Babylon, New York's Long Island Green Homes (LIGH) program offers energy efficiency upgrades to residents at little or no out-of-pocket cost. For already efficient homes, LIGH may finance on-site renewable energy projects. All expenses are repaid by residents on a schedule that allows residents to take advantage of savings and repay retrofit costs. The Berkeley FIRST program in Berkley, California enables residents to make long-term investments in residential photovoltaics with little up-front cost. Projects are repaid through a property tax on individual program participants over a period of 20 years. The solar-electric system and the tax obligation remain with the property, allowing initial program participants to transfer their obligations to future homeowners. The Milwaukee Energy Efficiency (Me2) program in Milwaukee, Wisconsin, offers financing of home energy retrofits for building owners and occupants with immediate savings and no upfront costs. Using both public funds and private capital, Me2 offers longer-term repayment for retrofits through simple additions to municipal services or utility bills at less than the value of energy saved. In California, the Sonoma County Energy Independence Program gives commercial and residential property owners the opportunity to borrow funds to increase their property's energy efficiency. The money is paid back as an assessment on the property, due at the same time as property taxes. Five-, ten-, and twenty-year terms are available at 7% interest. Technical assistance, public-private partnerships and revolving loan funds are all tools that can be used to overcome the lack of familiarity with the standards and requirements for building green. [18]

Another financing option is Property Assessed Clean Energy (PACE) financing, which provides property owners access to low-cost financing repaid as a property tax assessment for up to 20 years. This method has been used nationwide for decades to finance improvements to private property that meet a public purpose. PACE programs can result in consumer savings on utility bills, as well as local job promotion. Today, 31 states and the District of Columbia have adopted (or already had) legislation that enables local governments to offer PACE benefits to building owners.[135]

In July 2014 the Massachusetts senate passed proposed bill (S.2225), which according to the US Green Building Council (USGBC), will make necessary improvements to the Commonwealth's current PACE program, creating a streamlined, centrally administered PACE program that is capable of achieving economies of scale and will be easily adopted by municipalities. The new program will require lender consent and will focus on the demand for energy efficiency and disaster-resilience financing in the commercial and industrial sector. Passage of S. 2255 will fuel job creation and spur private investment. The legislation also will allow property owners to upgrade buildings with resiliency improvements, to reduce or eliminate damage caused by extreme weather events.[136]

By assisting municipalities with these incentives discussed above, we can work to encourage LEED throughout the region.

Potential Locations in the Montachusett and Northern Middlesex Regions

Both LEED Registered and LEED Certified Projects are present throughout the Montachusett and Northern Middlesex Regions. LEED Registered projects are those that are still in the process of Certification, while LEED Certified projects refer to those that have completed construction and are fully certified. In the Montachusett region, there are seven (7) fully certified projects, which are located in Devens, Leominster, and Townsend and nine (9) registered projects, which are located in Athol, Ayer, Fitchburg, Gardner, Harvard and Townsend. In the Northern Middlesex region there are ten (10) fully certified projects, which are found in Billerica, Chelmsford, and Lowell, and nine (9) registered projects located in Billerica, Chelmsford, Lowell and Westford (Table 13 and Table 14 follow). Also see map in Appendix I.1.

[135] http://pacenow.org/about-pace/what-is-pace/
[136] http://usgbcma.blogspot.com/2014/07/progress-on-pace-legislation.html

Table 13: LEED Certified and Registered Buildings in the Northern Middlesex Region

Project Name	Certification date	City	Rating system	Version	Certification level
EMD Project Bridgeway	--	Billerica	Commercial Interiors	v2009	--
300 Apollo Recert	--	Chelmsford	Existing Buildings	v2009	--
Chelmsford, MA	7-Oct-13	Chelmsford	Retail - New Construction	v1.0 pilot	Certified
LeBlanc Residence	--	Westford	Homes	v2008	--
U.S. EPA, New England Regional Laboratory	2-Feb-03	Chelmsford	New Construction	v1.0 pilot	Gold
UMass Lowell - University Crossing	--	Lowell	New Construction	v2009	--
UMASS-ETIC	1-Aug-13	Lowell	New Construction	v2.2	Gold
Parexel	15-Dec-09	Billerica	Commercial Interiors	v2.0	Certified
Nobis Engineering Merrimack Valley HQ	20-Jan-10	Lowell	New Construction	v2.2	Gold
United Teen Equality Center (UTEC)	12-Nov-12	Lowell	New Construction	v2.2	Platinum
SDM0801-DC1 Billerica BLDG U3 Expansion	--	Billerica	New Construction	v2009	--
UMass Lowell New South Academic Building	--	Lowell	New Construction	v2009	--
Chelmsford Relocation	28-Feb-12	Chelmsford	Commercial Interiors	v2009	Silver
DYouville Transitional Care Unit	--	Lowell	New Construction	v2009	--
Brookside Mill Re-Development	--	Westford	New Construction	v2.1	--
Concord Road Corporate Center	--	Billerica	Existing Buildings	v2009	--
EMD Serono Research Institute	7-Mar-11	Billerica	New Construction	v2.2	Gold
One Main Financial, Chelmsford MA	13-Apr-09	Chelmsford	Retail - Commercial Interiors	v1.0 pilot	Certified
Concord Road Corporate Center	20-Aug-09	Billerica	Existing Buildings	v2008	Certified

-- indicates project is registered, but not yet certified
Source: USGBC LEED Project Database, Downloaded June 20, 2014

Table 14: LEED Certified and Registered Buildings in the Montachusett Region

Project Name	Certification Date	City	Rating system	Version	Certification level
North Middlesex Regional High School	--	Townsend	Schools - New Construction	v2009	--
"Townsend Woods, HUD 202 Senior Housing"	4-May-12	Townsend	Homes	v2008	Silver
Kohl's Leominster	19-Apr-12	Leominster	Existing Buildings	v2009	Certified
5 Penny Lane	24-Jan-11	Townsend	Homes	v2008	Gold
Ayer Shirley Regional High School	--	Ayer	Schools - New Construction	v2009	--
Preservation Mill	--	Fitchburg	New Construction	v2.2	--
Harvard UU Fellowship Building	--	Harvard	New Construction	v2.2	--
LSCC - MFG	1-Apr-10	Devens	New Construction	v2.2	Silver
Fitchburg State College - Science Bldg.	--	Fitchburg	New Construction	v2.2	--
Athol Public Library Renovation/Addition	--	Athol	New Construction	v2.2	--
LSCC-LOC	15-Dec-09	Devens	New Construction	v2.2	Gold
Devens Public Safety Building	--	Devens	New Construction	v2009	--
Devens Transitional Housing	19-Aug-10	Devens	Homes	v2008	Gold
Modified Record Fire Range	--	Devens	New Construction	v2.2	--
Hammond Student Center Fitchburg State	--	Fitchburg	Commercial Interiors	v2009	--
Doyle Conservation Center	26-Jun-06	Leominster	New Construction	v2.0	Gold

-- indicates project is registered, but not yet certified
Source: USGBC LEED Project Database, Downloaded June 20, 2014

Suggested Locations

In the Montachusett and Northern Middlesex regions, LEED can be promoted using a variety of strategies including zoning, policy statements, green building ordinances, and financial incentives. In addition, specific locations for LEED implementation could be selected based on factors such as proximity to transit, public water and wastewater infrastructure, community services, previously developed land, wetlands, and water bodies, soil characteristics and proximity to floodplains. While all these tools have proven successful across the country, the tool in Massachusetts that has proven the most successful is the use of green building ordinances through the Green Communities program. The Green Communities Designation Program encourages green building through the adoption of the "stretch energy code", which is currently synonymous with LEED Silver Certification, and is implemented at the community level.

Green communities in the Northern Middlesex region include Chelmsford, Lowell, Tewksbury and Tyngsborough and Westford. Those in the Montachusett region include Ashby, Athol, Ayer, Gardner, Harvard, Lancaster, Leominster, Petersham, Shirley, Townsend and Westminster. In these Green Communities, any building built since the date of designation will be synonymous with LEED Silver criteria. However, it is important to note that these building are not required to register as LEED certified buildings. A map of green communities is included in Appendix I.1.

Promotion of the Green Communities Program across the Northern Middlesex and Montachusett communities would promote job growth across the clean energy, biotechnology, nanotechnology, and green business sectors. Encouraging green building ordinances through the Green Communities Program will also allow developers to create a building that is synonymous with LEED Silver, without having to pay the cost of certification and will provide communities with access to technical support and grant funding.

Toward that end, MRPC should focus its efforts on promoting the Green Communities program in the communities of Ashburnham, Clinton, Fitchburg, Groton, Hubbardston, Lunenburg, Phillipston, Royalston, Sterling, Templeton, and Winchendon. NMCOG should focus its efforts on Billerica, Dracut, Dunstable and Pepperell.

Recommendations for NMCOG and MRPC

NMCOG and MRPC can work with the DOER regional representatives to promote Green Communities across the regions. Specifically, NMCOG and MRPC can provide education to municipalities who are not yet designated as Green Communities, and can provide technical assistance to help these communities through the application process.

The agencies can also work to promote and initiate Green Building Commissions and Sustainable Councils throughout the region. Municipal commissions and private organizations can be a vital component of a city or town's sustainable planning effort. Lowell has a city-manager appointed Green Building Commission which promotes and advocates for "green" design, construction, and development practices in the City of Lowell through identification and implementation of policies and programs that will increase environmental sustainability. Westford has a private group - Sustainable Westford - whose mission is to serve as a venue for raising awareness and providing education and inspiration on issues of sustainability. Working with the community and related organizations to advance our mutual missions, Sustainable Westford provides access to local sustainable foods; recycling programs; renewable energy options; conservation of natural resources; and health and wellness programs.

In terms of education, MRPC and NMCOG should conduct workshops and seminars in target communities to encourage municipalities to apply for the Green Communities Program. The agencies could also conduct outreach to energy committees, municipal staff and administrators to promote the Green Communities Program and can assist communities with the application process, especially with the adoption of the state's "stretch energy code".

NMCOG and MRPC should also assist with the following:

- Encourage municipalities to transition from traditional zoning to form-based code;
- Encourage municipalities to promote LEED by incorporating it into their zoning code;
- Encourage municipalities to adopt a municipal policy regarding green technology;
- Encourage local government to use financial and development incentives to promote green building and construction through density bonuses, expedited permitting, fee reduction and tax credits;
- Provide technical assistance to developers seeking LEED certification; and
- Provide education on LEED certification programs to planners and engineers throughout the region.

By helping communities to promote LEED, NMCOG and MRPC will be promoting the clean energy economy. In particular, if all communities in the Montachusett and Northern Middlesex regions become green communities, then every new building built will be synonymous with LEED silver, and builders would not have to pay certification costs. In addition, communities would receive grant funding and technical assistance. This method would promote LEED and the clean energy economy while also addressing some of the barriers to LEED Development (e.g. cost of certification).

Promoting LEED across the region will encourage growth in the areas of research and development, biotechnology, nanotechnology, manufacturing and green businesses. It will promote a clean economy, and healthy communities, and could serve as a model for other regions and states who also want to promote energy efficiency in the commercial and industrial sectors.

RENEWABLE ENERGY MANUFACTURING & LABOR FORCE ASSESSMENT

Introduction

Historically, manufacturing has been at the heart of the American economy, representing nearly 12 percent of the nation's gross domestic product and providing good quality, high-paying jobs. With the passage of the Energy Independence and Security Act[137] (which contains the Green Jobs Act) and the American Recovery and Reinvestment Act of 2009[138] (ARRA) at the federal level, billions of dollars were made available to jump start the renewable energy industry. As the United States transitions to a clean energy economy, Massachusetts is well positioned to capture its fair share of this rapidly growing market and its associated manufacturing sector. The Patrick Administration has focused on growing the State's clean energy sector as a way to create local jobs and retain more energy dollars in the state economy. Therefore, promoting the deployment, production and development of renewable energy

[137] http://energy.gov/eere/femp/energy-independence-and-security-act
[138] http://www.irs.gov/uac/The-American-Recovery-and-Reinvestment-Act-of-2009:-Information-Center

facilities in the region represents a significant economic development opportunity. As explained by the Organization for Economic Co-operation and Development (OECD), "sustainability within the energy sector increases efficiency and security, encouraging prosperity and growth through energy access, industry development, job creation and competitive technological innovation"[139]. Regional growth in the number of renewable energy firms and associated jobs also has the potential to replace many of the lost manufacturing jobs and to capitalize on the rich manufacturing legacy of the Montachusett and Northern Middlesex regions.

This section of the Renewable Energy Facilities Siting Plan focuses on the role played by existing renewable energy facilities in Massachusetts and the Northern Middlesex and Montachusett regions, the potential demand for additional renewable energy facilities statewide and regionally and the identification of the barriers facing these industries in providing additional employment opportunities for the region. An overall labor force assessment by energy sector has been included, as well as the potential employment opportunities in the future. In addition, location and siting considerations are addressed, specific industrial and commercial sites are identified and the regional potential for an expanded renewable energy sector, particularly in terms of manufacturing firms, is discussed. Through this overall assessment, specific recommendations have been made regarding how the region can become more welcoming to renewable energy manufacturing firms and capitalize on the rising demand for renewable energy across the region, state and nation.

Background

For the purposes of this report, 'renewable energy' includes the following categories and segments: wind, solar, LEED, hydropower, biomass and geothermal energy manufacturing. The renewable energy manufacturing industry is also defined as firms that focus on the manufacturing of renewable energy materials, components and systems.

Since most of the available information focuses on 'clean energy', the data is limited in regard to specifically capturing renewable energy manufacturing in some instances. In addition to the energy sectors identified above, 'clean energy' also includes biofuels, carbon management, energy efficiency, and alternative transportation, such as clean cars. Regional-level and company-level data is also not consistently available for the renewable energy sector, which creates some consistency problems.

In addition, the North American Industry Classification System (NAICS), the standard used by federal statistical agencies in classifying business establishments and tracking jobs, does not account very well for green industries and their numerous distinctions. The NAICS, for instance, currently lumps items like solar, wind, and tidal into a single "Other Electric Power Generation" category and does not specify categories for hybrid electric vehicles, green buildings, recycling, and many other key sectors.

The renewable energy manufacturing industry has undergone significant growth in Massachusetts over recent years. The 2013 Massachusetts Clean Energy Industry Report found that

[139] OECD, *Green growth and energy,* http://www.oecd.org/greengrowth/greening-energy/greengrowthandenergy.htm (accessed May 23, 2014).

there are 564 firms in Massachusetts involved in the manufacturing and assembly of clean energy[140]. According to the Massachusetts Clean Energy Center (MassCEC), more than 13,458 people were employed statewide in the manufacturing and assembly of renewable energy in the state in 2013.[141]

Within the Northern Middlesex and Montachusett regions, manufacturing has historically driven growth and development. The industrialization of the Northern Middlesex region began in 1811, with the introduction of wool manufacturing in North Billerica. Subsequently, the first planned industrial city in America was created in Lowell, utilizing the hydraulic power of the Merrimack River at Pawtucket Falls. By 1836 the City of Lowell had eight major textile firms employing approximately 7,000 people. The region surrounding Lowell was also impacted by industrialization, as small industrial settlements grew into extensive textile mill villages. Additional industrialization in the region occurred between 1850 and 1890 with the introduction of the railroad.

While the Montachusett region's earliest settlements were founded as trading outposts for the Massachusetts Bay Colony, manufacturing soon became the region's driving economic force. Montachusett communities utilized local streams and rivers to power manufacturing facilities. The first mills were allied with agricultural production, followed by the establishment of other industries, including paper, textile and woodworking industries in the mid-19th Century. Similar the Greater Lowell region, industrial growth was accelerated by railroads, which enabled the easy transport of raw materials, finished goods and people.[142]

By the 20th Century, both regions experienced economic decline as a result of the Great Depression and the migration of manufacturing industries to the southern United States. While manufacturing has continued to decline due to the national transition to a more serviced-based economy, new and innovative industries, including renewable energy development, have begun to establish themselves in the Northern Middlesex and Montachusett regions. Many of the communities within both regions are experiencing growth in renewable energy and are evolving from their formally specialized manufacturing industries to more diverse enterprises. The role of renewable energy in the Commonwealth of Massachusetts and the Northern Middlesex and Montachusett regions is described in the next few sections.

Renewable Energy in the Commonwealth of Massachusetts

Massachusetts consistently ranks high as a renewable energy leader among other states. According to the American Council for an Energy-Efficient Economy (ACEEE), Massachusetts was ranked number one for implementing energy efficiency programs and policies in 2013.[143] The State was ranked second in clean energy technology, according to the 2013 U.S. Clean Tech Leadership Index. Massachusetts has taken extremely proactive measures to reduce the greenhouse gas emissions and

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[140] A clean energy firm is defined by the MassCEC as an employer engaged in whole or in part in providing goods and services related to renewable energy, energy efficiency, alternative transportation, and carbon management.

[141] MassCEC, *Massachusetts Clean Energy Industry Report, 2013*, http://www.masscec.com/content/2013-clean-energy-industry-report (accessed May 20, 2014)

[142] Montachusett Regional Planning Commission, *Montachusett Regional Strategic Framework Plan*, April 2011.

[143] http://www.aceee.org/sector/state-policy/massachusetts

diversify the composition of energy consumption. These measures have helped spur growth in the "green economy".

In 2002 the Massachusetts Department of Energy Resources (DOER) adopted the Renewable Energy Portfolio Standard (RPS) and Alternative Energy Portfolio Standard (APS). The RPS and APS are statutory obligations that align with the Commonwealth's energy goals of increasing energy efficiencies and reducing the need for conventional fossil-fuel based power generation. The RPS mandates that energy suppliers obtain a percentage of all electricity from qualifying renewable energy producers. The APS is an opportunity for Massachusetts businesses, institutions, and governments to receive incentives for installing eligible alternative systems that are not renewable, including Combined Heat and Power (CHP), where the heat emitted from electricity production is collected and used to heat buildings.[144]

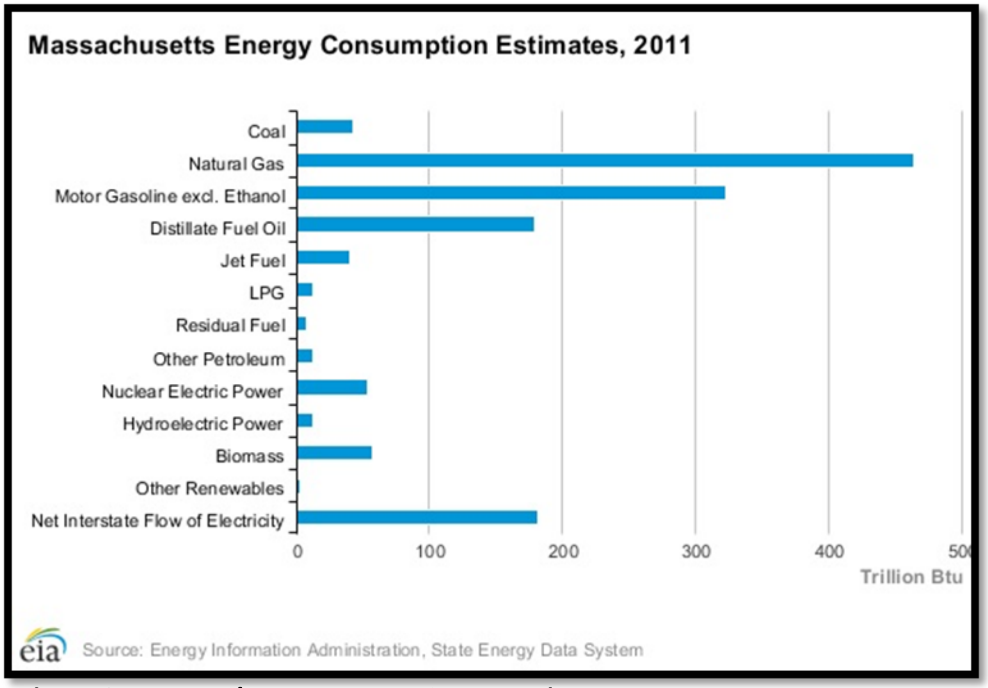

Figure 27: Massachusetts Energy Consumption

In 2011 the Energy Information Administration, State Energy Data System reported that the Commonwealth consumed very little renewable energy and had a high dependency on natural gas, ethanol, and fuel oil. The chart above shows that the State consumes a relatively small amount of energy generated from renewable resources. In response, the Commonwealth of Massachusetts has established a number of goals and incentives to increase the efficiency of buildings, increase the consumption of energy generated from renewable resources, decrease the Commonwealth's reliance on fossil fuels, and decrease the emissions of greenhouse gases.

[144] http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/

The RPS and APS, in addition to other state and federal funding incentives for renewable energies, have significantly increased the number of renewable energy installations within the Commonwealth over the past fifteen years. The image below shows all of the sites in Massachusetts that were generating energy from renewable resources in 2006.

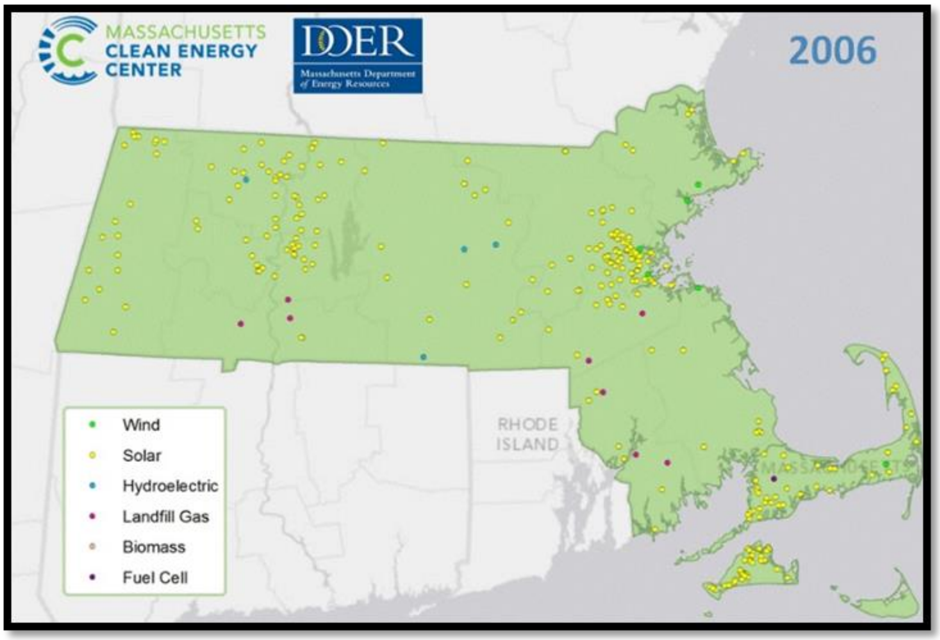

Figure 28: Sites Generating Energy from Renewable Sources in 2006

In 2006 there were few sites generating energy from energy renewable sources. The 2013 image below shows the number of sites that were generating renewable energy in 2013. While renewable energy has been growing in Massachusetts, there is still a high dependence on fossil fuels and there is room for growth within the renewable energy sector.

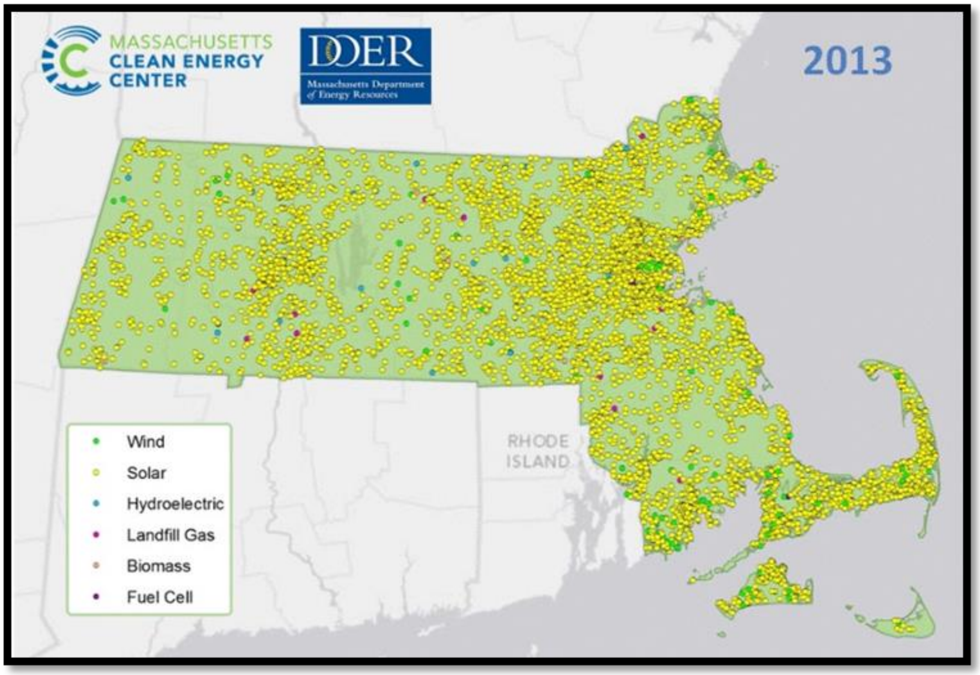

Figure 29: Sites Producing Electricity from Renewable Source in 2013

As indicated in the previous maps, there has been a large increase in the number of sites producing energy from renewable resources between 2006 and 2013.[145] In particular, there has been a large increase in the production of photovoltaic energy. The reason for the substantial jump in the generation of solar energy within Massachusetts is because of the current solar incentive policy called the Solar Carve-Out Program. The original goal of the program was to expand solar energy capacity to 400 MW. This goal was attained in 2013 when the Solar Energy Industry Association reported that Massachusetts had a total installed solar capacity of 464 MW. In 2013 Massachusetts ranked fifth in the country for installed solar capacity and fourth in the country for installing 237 MW of solar energy from 2012 to 2013.[146] The new Solar Carve-Out Goal expands the solar energy capacity from 400 MW to 800 MW by 2017.

As tax incentives and state regulations make renewable energy more affordable, additional businesses, municipalities, and individuals have invested in renewable energy. The increase in renewable energy sites expands the renewable energy labor force. In Massachusetts there are more than 286 companies supporting the solar industry, which employ more than 6,400 workers. The solar industry in Massachusetts has roughly 59 manufacturers, 27 manufacturing facilities, 119 contractors/installers, 26 project developers, 12 distributors, and 70 other support companies (such as finance and law).[147] Based on the Commonwealth's established goal to increase the percentage of energy produced from renewable resources, the renewable energy labor force will certainly expand.

[145] Image 2: http://www.masscec.com/content/clean-energy-progress-animation
[146] http://www.seia.org/state-solar-policy/massachusetts
[147] http://www.seia.org/state-solar-policy/massachusetts

Existing renewable energy manufacturing facilities in the region

According to the MassCEC, there are 5,577 clean energy firms in Massachusetts with 2,312 of these firms specifically involved in the renewable energy industry. Of the renewable energy firms, 564 are associated with manufacturing. In the Montachusett and Northern Middlesex regions, a relatively modest number of renewable energy manufacturing facilities have been identified. Eighteen (18) establishments, including two firms that work across both wind and solar, have been identified through a review of a variety of federal, state and local sources and databases[148]. The results of this analysis show that there is a cluster of solar manufacturing companies in the Northern Middlesex region, particularly in Billerica, while the Montachusett region has a number of hydropower-related and wind-energy related supply chain manufacturing facilities.

It is also important to note that a number of the identified establishments are involved in the manufacture and supply of renewable energy materials, components and parts, rather than the systems themselves. In terms of the manufacturing supply chain, these firms are known as Tier 1 and Tier 2 suppliers, while firms that make, assemble and sell renewable energy systems are defined as Original Equipment Manufacturers (OEMs)[149]. In addition, some establishments are part of global companies so it is unclear what is specifically manufactured by those establishments within the Montachusett and Northern Middlesex regions.

Wind energy manufacturing facilities

Figure 30: American Superconductor 354,000 ft^2 facility in Devens

Source: Cutler Associates
http://cutlerdb.com/portfolio/corporations-industry/american-superconductor

America's wind-energy industry supports an increasing domestic industrial base. The American Wind Energy Association (AWEA) has determined that the wind industry in the United States has more than 550 manufacturing facilities producing products ranging from blade, tower and turbine assembly facilities to raw component suppliers, such as fiberglass and steel. While there is a growing cluster of wind-energy research establishments in Massachusetts, including the recently developed Wind Technology Testing Center in Charlestown and UMass Lowell's Wind Energy Research Group, the number of firms that focus on wind-energy manufacturing is limited to component and equipment manufacturing in the region. Through research of the National Renewable

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148 The following databases were examined: http://energy.sourceguides.com/businesses/byB/manufacturers/manufacturers.shtml,, State Wind Energy Statistics: Massachusetts, http://www.awea.org/Resources/state.aspx?ItemNumber=5218, Solar Companies in Massachusetts, http://www.seia.org/state-solar-policy/Massachusetts; National Hydropower Association, U.S. Hydropower Industryhttps://fortress.maptive.com/ver3/ushydropowerindustry

149 For example, wind-energy OEMs purchase or make components, then assemble and sell completed turbines to wind farm developers. Tier 1 suppliers support OEMs through production of large components such as towers and blades. Tier 2 suppliers support the supply chain by manufacturing machined parts, motors, fiberglass, electrical parts, etc.

Energy Laboratory's (NREL) online database and other relevant wind energy databases, the following local firms have been identified:

Table 15: Wind Energy Manufacturing Facilities

Company Name	Address	Products and Services
American Superconductor	64 Jackson Rd, Devens	Megawatt-scale wind turbine designs and electrical control systems.
Assembly Guidance Systems	27 Industrial Ave #5, Chelmsford	Large laser projection systems used in producing wind turbine blades and tooling.
BJA Magnetics	7 Moore St, Leominster	Engineered permanent magnets used in wind turbines.
Ranor Inc,	1 Bella Dr, Westminster	Larger scale machining and fabrication of wind housings, turbine shafts, mounting rings and generators.

Solar Manufacturing Facilities

According to The Solar Foundation, the solar industry employs nearly 30,000 people in the manufacturing sector across 1,484 solar manufacturing establishments in the nation. Over a quarter of these establishments serve as U.S. headquarters for manufacturing that is conducted abroad[150]. Within Massachusetts the Solar Energy Industry Association (SEIA) has identified 60 solar manufacturers and 26 solar manufacturing facilities.[151] The following ten manufacturers and facilities have been identified within the Montachusett and Northern Middlesex regions:

Table 16: Solar Manufacturing Facilities

Company Name	Address	Products and Services
American Super Conductor	64 Jackson Rd, Devens	Smart Grid technologies for power grid operators, including superconductor power cable systems, grid-level surge protectors and stabilization systems.
Anderson Power Products	13 Pratts Junction Rd, Sterling	High current, quick-disconnect power connectors and interconnect solutions for the solar industry.
Beacon Power LLC	65 Middlesex Rd, Tyngsborough	Flywheel energy storage systems.
Bruce Technologies Inc	18 Esquire Rd, North Billerica	Solar cell manufacturing equipment.
Bruker Corp	40 Manning Rd, Manning Park, Billerica,	Manufacturer and developer of advanced materials for applications in energy, including superconductors.
BTU International	23 Esquire Rd, North Billerica	Solar cell manufacturing equipment, diffusion furnaces, doping, cell coating equipment, drying furnace, firing furnace.
Entegris, Inc.	129 Concord Rd, Billerica	Delivers technology, product and service solutions that purify, protect and transport critical materials used in the semiconductor and high-tech industries.
Epoxy Technology	14 Fortune Dr, Billerica	Specialty adhesives for advanced industries
Ranor Inc	1 Bella Dr, Westminster	Large-scale component fabrication and machining services, including the manufacturing of vacuum chambers used in the

[150] The Solar Foundation, *National Solar Jobs Census 2013: The Annual Review of the U.S. Solar Workforce*, 2014
[151] SEIA, *State Solar Policy – Massachusetts*, http://www.seia.org/state-solar-policy/Massachusetts (accessed June 30, 2014)

		creation of poly-silicon (poly-Si) based technology, amorphous-silicon (a-Si) and CIGs based technologies, and HEM Sapphire technologies.
Semilab USA LLC	47 Manning Rd, Billerica	Front-end electrical characterization of the solar cell manufacturing process in the silicon-based PV market.

While not located within the study area, there are a number of solar manufacturing and design firms located nearby in Lawrence, Methuen and North Andover.

Although there is a cluster of solar manufacturing firms in both regions, there have been a number of recent factory closings. Konarka Technologies Inc, formerly located in Lowell, filed for bankruptcy in 2012, despite securing $20 million in government grants and more than $150 million in venture capital investment. The company manufactured thin, flexible, organic solar panels. Evergreen Solar also closed down its $430 million Devens factory in 2011 and relocated its operations to China. The company cited competition from manufacturers that are subsidized by the Chinese government, which have brought prices for solar panels far below previous forecasts, as their principal reason for closing. The experience of these two companies is similar to other solar firms across the state.

Michael El-Hillow, Konarka's chief executive, said in a statement that his company had decided to close the Massachusetts factory in response to plunging prices for solar panels. World prices have fallen as much as two-thirds in the last three years — including a drop of 10 percent during last year's fourth quarter alone.

Chinese manufacturers, Mr. El-Hillow said in the statement, have been able to push prices down sharply because they receive considerable help from the Chinese government and state-owned banks, and because manufacturing costs are generally lower in China.

Hydropower manufacturing facilities

Figure 31 ***Water control gates manufactured by Steel-Fab Inc.***

Source: http://www.steel-fab-inc.com/

Hydropower transformed New England into a center of industrial activity by the mid 19th Century with mill towns dotted across the region. According to the National Hydropower Association (NHA), New England is also home to some of the nation's leading hydro-manufacturing and engineering firms. The following manufacturing establishments are located in the Montachusett region.

Table 17: Hydropower Manufacturing Facilities

Company Name	Address	Products and Services
Capacitec	87 Fitchburg Road, Ayer	Design and manufacture of non-contact capacitive displacement sensors, gap sensors, hole probes and parallelism sensing systems.
Steel Fab Inc.	430 Crawford Street, Fitchburg	Design and manufacture water control gates and valves for hydroelectric plants.
Universal Machine & Design Corp.	323 Princeton Road, Fitchburg	Metal production and prototypes.

Biomass manufacturing facilities

Based on the Source Guides Renewable Energy Directory (http://energy.sourceguides.com), there are no firms or facilities associated with the development and/or manufacturing of commercial-scale biomass systems and components in the Montachusett and Northern Middlesex regions. The nearest manufacturing facility, Biomass Combustion Systems, Inc., is located in Princeton, Massachusetts.

Geothermal energy manufacturing facilities

There are a number of geothermal energy installers in the Montachusett and Northern Middlesex regions, according to the New England Geothermal Professionals Association's (NEGPA) database. However, there are no known manufacturing facilities or firms associated with the geothermal energy manufacturing supply chain. The nearest firm, Watts Water Technologies, is located in North Andover and manufacturers pipes, valves, fittings and safety devices for the plumbing, HVAC, irrigation and backflow prevention industries.

Demand for Renewable Energy Manufacturing

In 2013 the global market for clean, renewable energies reached a record estimated $260 billion – and is expected to grow into the trillions over the next twenty years. In the United States alone, $36 billion was invested in renewable energy in 2013. This capital has, in part, been invested to create domestic supply chains that support both the domestic and global renewable energy market[152]. Recently, there has been major growth in wind and solar photovoltaic (PV) technologies across the nation. Other renewable technologies, such as hydropower, geothermal and biomass, have also continued to grow due to a strong established base. The success in the solar and wind energy industries has been driven by energy policy changes at the federal and state levels, which has helped these industries grow considerably over the last decade. Utility-scale and rooftop solar PV generation has experienced major growth in the past few years, resulting from both energy policy changes and the decline in the cost of PV modules.

[152] U.S Partnership for Renewable Energy Finance (US PREF), *Renewable Energy Finance, Market & Policy Overview,* April 2014

Future renewable energy generation is expected to be driven, in part, by federal incentives and renewable portfolio standards mandated in many states. The *Emergency Economic Stabilization Act of 2008 (EESA)* and the *American Recovery and Reinvestment Act of 2009 (ARRA),* created a favorable long-term policy environment for renewable energy. Investment in the renewable energy industry was an important component of both laws, which were aimed at economic recovery and encouraging future growth in the U.S. economy. Among the policy developments created in these two pieces of legislation, manufacturing and investment tax credits were key measures that supported the renewable energy manufacturing industry. Furthermore, the U.S. Congress continues to deliberate on long-term policy, such as a National Renewable Energy Standard and carbon emissions caps that will impact future renewable energy markets. Much of the debate is focused on how to increase U.S. economic competitiveness and create jobs growth, which often results in a focus on revitalizing the nation's manufacturing sector. Due to this policy setting, the long-term outlook for renewable energy is considered positive, and in particular, the wind and solar energy markets are expected to see significant investment from renewable energy manufacturers[153]. However, the federal incentives for the renewable energy industry largely expired last year.

New England start-ups will need to come up with truly breakthrough technologies to make solar materials much more efficient at converting sunlight into electricity or new manufacturing processes perhaps using automated assembly lines that don't rely as much on workers. "I absolutely think that the panel that winds up on your roof or your business in the next decade could be made in the US, instead of China,'' says Taneja, a venture capitalist at Cambridge-based General Catalyst Partners. "But the key is making giant leaps, not small incremental improvements.'' Boston Globe by Scott Kirsner Globe Correspondent / November 7, 2010

Consumer desires for higher levels of renewable energy electricity and "green" lifestyles, as well as growing climate change concerns, are also anticipated to drive demand. Fortunately, the United States has diverse and abundant renewable energy resources that are available to contribute higher levels of electricity generation over the next decades and meet this growing demand[154]. While this is likely to lead to increased deployment of renewable energy facilities across the nation, domestic manufacturing is also likely to grow.

To evaluate the future potential of renewable energy manufacturing in the Montachusett and Northern Middlesex regions, each of the sectors will be examined in terms of their short- and long-term forecasts. While the data specific to each region may be limited, generalizations will need to be made based on available industry data and forecasts for the nation and state.

Solar energy manufacturing

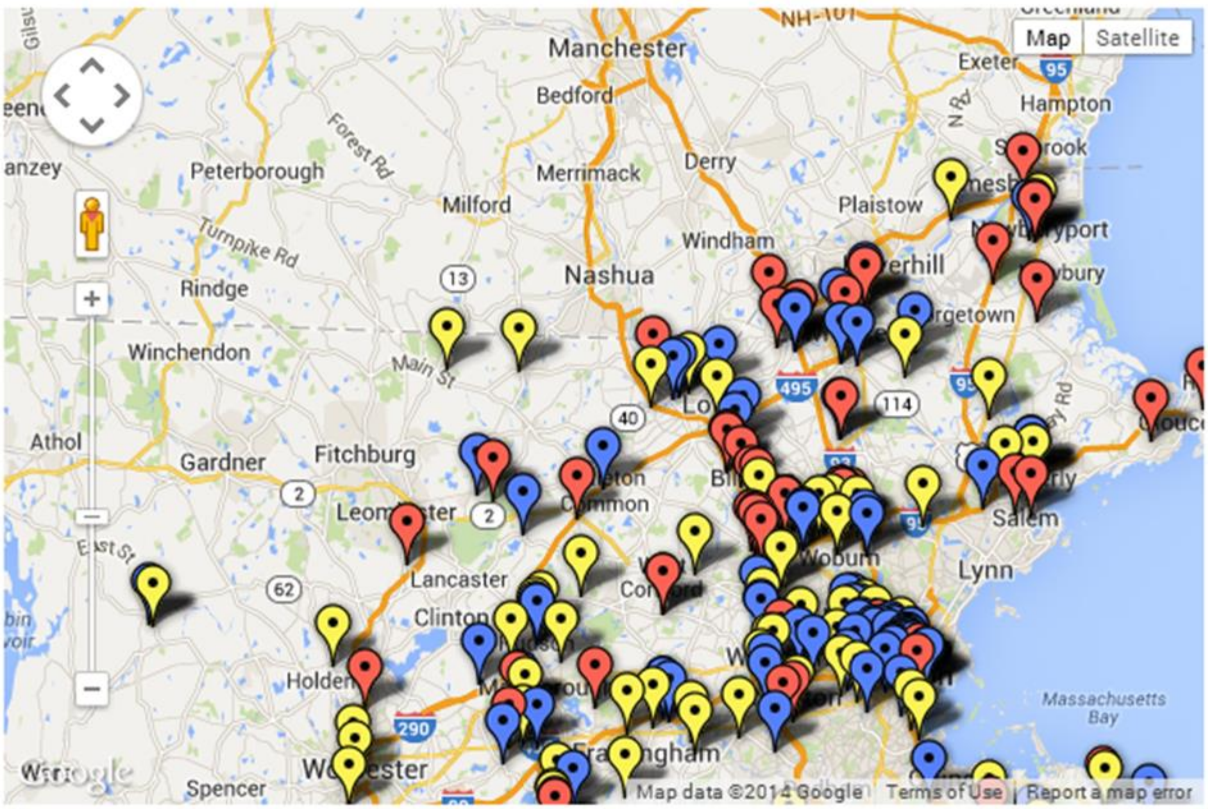
The solar energy industry is growing dramatically in the United States. In 2013 solar installations proliferated by increasing 41% since 2012 to reach 4,751 MW of new solar energy capacity. By the end of 2013, there was a total 13,000 MW of solar energy capacity installed nationwide. Therefore, the total installed utility-scale electrical generating capacity in the U.S. is 1,158 GW; thereby accounting for 1.1%

[153] National Renewable Energy Laboratory (NREL), *State Clean Energy Policies Analysis (SCEPA): State Policy and the Pursuit of Renewable Energy Manufacturing, Technical Report,* February 2010.
[154] National Renewable Energy Laboratory (NREL), *Renewable Electricity Futures Study,* 2014.

of the nation's electrical generating capacity. The increasing number of solar installations has also bolstered the national economy. In 2013 solar electric installations were valued at $13.7 billion, compared to $11.5 billion in 2012 and $8.6 billion in 2011. The U.S. Solar Market Insight Report forecasts a 26% overall growth in the U.S. solar market in 2014 with new installations projected to reach nearly 6,000 MW.

In Massachusetts the solar energy market is booming. As described in Chapter X, the combination of strong government policies, consumer demand, local community support, PV cost reductions, improved financing terms, tax breaks and public incentives has influenced the high growth in the State's solar energy-generating capacity. Massachusetts had 465 MW of solar energy installed by the end of 2013 and $789 million was invested to install solar for home.

Figure 32: Snapshot of Solar firms in north east Massachusetts



Key: Manufacturer Installer Other

Source: SEIA National Solar Database, 2014

There are currently more than 290 firms operating within the solar value chain in Massachusetts. These firms provide solar products and services ranging from the primary business and utility use in 2013. This represents a 50% increase over the previous year and is expected to grow again in 2014.

These firms provide solar products and services ranging from the primary components of a solar PV system, such as solar-grade polysilicon, wafers, cells, solar modules, and inverters, to the glass and steel components used in utility-scale solar power plants. As mentioned previously, 60 of the solar firms operating in Massachusetts are manufacturers and 26 are manufacturing facilities (Refer to Figure 3 below for a snapshot of the regions' solar firms).

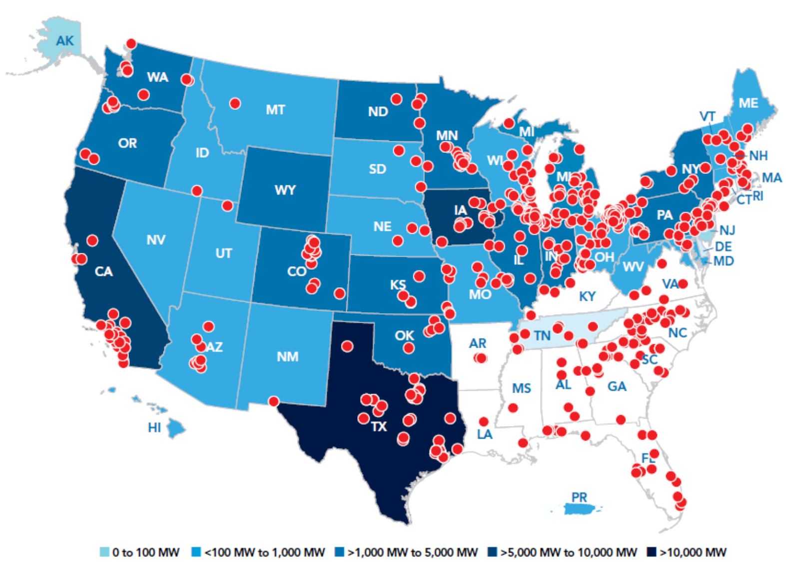
After meeting the State goal of 250 MW of solar power installations four years ahead of schedule, Governor Patrick set a new goal of 1,600 MW by 2020. Similar goals and incentives are in place or are being considered in most states across the United States. Such broad scale policy directions are likely to ensure that solar energy continues to be in demand and that the solar manufacturing base in Massachusetts continues to expand. Given the recent closing of solar firms in the Northern Middlesex and Montachusett regions, industry experts have suggested that solar manufacturing in Massachusetts will need to evolve and grow in order to compete with low-cost Chinese manufacturers and declining PV costs.

Wind Energy manufacturing

The wind industry achieved 61 GW of cumulative wind energy capacity in the United States in 2012 with more than 45,000 wind turbines installed across the nation. According to the AWEA, there are 560 wind-related manufacturing facilities in the United States producing more than 8,000 components that comprise a typical wind turbine (Refer to Figure 33).

Prior to 2005, only one wind turbine original equipment manufacturer (OEM) assembled utility-scale turbines in the United States. By the end of 2012, a total of twelve assembly facilities were online. This growth in wind-related manufacturing has occurred across the entire value chain – there are currently thirteen facilities producing blades and twelve tower manufacturing facilities.

Figure 33: Online Wind-Related Manufacturing Facilities as of 2013



Source: American Wind Energy Association

Recently, new wind power project installations have grown at an average rate of 36% per year, creating new opportunities throughout the wind energy supply chain. A relatively stable policy environment attracted major wind manufacturers to invest in U.S.-based facilities, often bringing their supply chain with them. This has helped bring down wind turbine costs and has boosted domestic content from less than 25% in 2005 to more than 67% in 2013. However, in 2014 the industry lacks the long-term policy support needed to guarantee a stable market, and manufacturing levels in the U.S. are anticipated to exceed domestic demand for select parts of the supply chain in the short term, partially due to this policy uncertainty. Yet, the fundamentals of the industry remain strong with the expectation that the market will create new opportunities as current and new manufacturers develop domestic supply chains, and other states establish wind energy generation targets.

As of March 2014, there was 106 MW of installed wind energy capacity in Massachusetts, providing 0.6% of the state's electricity. Governor Patrick has set a goal of installing 2,000 MW of wind capacity by 2020. Since only 5% of that capacity was in place by mid-2013, the demand for wind energy is likely to continue based upon this policy goal. In addition, federal studies rank Massachusetts' wind resources as excellent around Cape Cod, Martha's Vineyard and Nantucket. Some ridge crests in the Berkshire Mountains in western Massachusetts have also been found to have good potential. In total, NREL data shows that there is 1,028 MW of onshore wind potential in Massachusetts. However, the state's offshore regions have the highest wind resource potential with 199,987 MW of technical capacity. In fact, these locations are currently being considered for offshore wind projects. Cape Wind, which is the nation's first-ever offshore wind project proposed for ocean waters off Cape Cod, is progressing in its financing by also securing U.S. Department of Energy loan guarantees. Massachusetts is also planning the construction of the New Bedford Marine Commerce Terminal, the first facility in the nation built specifically to support the assembly, construction, and deployment of offshore wind projects.

In 2011 Massachusetts opened the first U.S. facility capable of testing large-scale wind turbine blades up to 90 meters in length. The MassCEC's Wind Technology Testing Center (WTTC) in Charlestown serves as a critical element in the wind energy industry, speeding deployment of the next generation of wind blades, attracting companies to design, manufacture and test their blades in the U.S. and catalyzing growth in the American wind turbine supply chain.

Growth of offshore wind turbines is anticipated to drive larger component sizes and make it increasingly difficult to move turbine components over land. Coastal manufacturing for blades and nacelle assembly, as well as tower, foundation, and substructure fabrication, may therefore be an industry requirement in the near future. It may be for these reasons that many blade and tower manufacturers have recently sought locations in southeastern Massachusetts.

As described in the Wind Energy section, there is a lack of wind in the range required to produce utility scale wind power, at a useful capacity, in the Montachusett and Northern Middlesex regions. However, smaller industrial or mid-sized turbines, as well as residential and community-scale turbines that can be applied to the electrical grid, may be feasible. As a result, there may potentially be more regional demand for smaller scale wind turbine production or components to be manufactured.

Hydro-energy related manufacturing

According to the NHA, there are 2,200 hydropower plants in the United States, which provide 100,000 MW of hydro-energy capacity[155]. Hydropower plants are by far the largest supplier of renewable energy in the nation. The industry is supported by more than 2,500 supply chain companies. In Massachusetts there are approximately 78 firms involved in the hydro-energy industry. These companies range from project developers to construction firms; architecture and engineering firms to electricians; and component manufacturers. Figure 40 below shows a snapshot of the hydropower industry in the region.

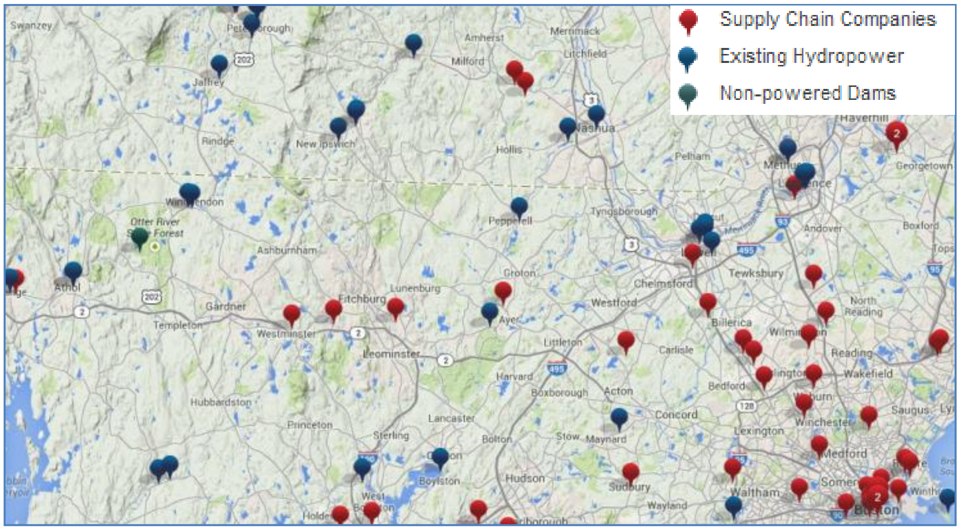


Figure 34: Snapshot of the Hydropower Industry

Source: NHA, http://www.hydro.org/why-hydro/available/industrysnapshot/

In 2012 the U.S. Department of Energy determined that there are approximately 54,000 existing non-powered dams across the country that could be powered and add 12,000 MW of new hydropower capacity to the nation's electricity grid. In Massachusetts, existing non-powered dams have 67 MW of potential capacity[156]. Additionally, Navigant Consulting, on behalf of the NHA, identified several tens of thousands of additional megawatts from other forms of development, such as expanding and upgrading existing hydropower plants and building new pumped storage. Recently, the Oak Ridge National Laboratory undertook an assessment of undeveloped stream-reaches to determine further hydropower energy potential in the U.S. The estimated technical resource capacity for new stream-reach development across the nation was found to be 65.5 GW, with 194 MW of potential in Massachusetts[157].

The Northern Middlesex and Montachusett regions have the potential to develop a number of existing dams (Refer to Hydropower Chapter). Powering these facilities is a way to increase the state's supply of renewable energy by maximizing existing infrastructure and avoiding the need to build new dams. Consequently, the potential to support additional hydro-related supply chain manufacturing could expand in both regions based upon the potential state demand.

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155 NHA, Hydropower Industry Snapshot, http://www.hydro.org/why-hydro/available/industrysnapshot/ (accessed July 25, 2014)

156 ORNL, *An Assessment of Energy Potential at Non-Powered Dams in the United States*, 2012

157 ORNL, *New Stream-reach Development: A Comprehensive Assessment of Hydropower Energy Potential in the United States*, 2014

Geothermal manufacturing

Since the 1960s the United States has been a world leader in the geothermal industry. Installed geothermal power capacity in 2012 grew by 5% or 147 MW to a total of 3,386 MW of geothermal power[158]. This represents the highest installed geothermal capacity in the world. The majority of geothermal installed capacity in the nation is concentrated in California and Nevada where geothermal resources are abundant. Several geothermal power plants are also operating or under construction in Alaska, Hawaii, Idaho, Oregon, Utah, Washington and Wyoming. It is forecast that emerging technologies, including enhanced geothermal systems, engineered hydrothermal reservoirs, geo-pressured resources, low temperature resources, and co-production from oil and gas wells, could expand the geothermal resource potential in the nation by more than 500 GW[159].

The Geothermal energy chapter found limited potential in the Montachusett and Northern Middlesex regions to generate large-scale geothermal electricity due to temperatures at the low end of binary cycle capability, as well as the high cost of implementing geothermal systems. Given the limited application in both regions and the absence of an existing supply chain, there may be limited opportunities for geothermal manufacturing to be established in the region. However, geothermal components, equipment and devices could still be manufactured in the Northern Middlesex and Montachusett regions and shipped to western states or overseas, where more geothermal capacity is generated. In addition, the analysis in Chapter X found that ground source heating has major potential for growth in Massachusetts and the Montachusett and Northern Middlesex regions. Therefore, manufacturing and installing small-scale, geothermal systems, such as heat pumps, may be a potential niche sector servicing this growing local residential market.

Biomass manufacturing

While biomass represents a very interesting renewable energy source, it is often considered controversial due to environmental impacts from greenhouse gas emissions, high water use, low energy efficiency and forest harvesting associated with woody biomass. However, the use of biomass energy is growing and will likely continue in the future as the nation seeks to increase use of renewable energy and decrease carbon emissions associated with fossil fuel use. According to a Pike Research study, "Biopower Markets and Technologies", global biomass power capacity will reach at least 86 GW globally by 2021, increasing by almost 50% from 58 GW in 2011. This growth in capacity will be the result of a total investment of $104 billion in the biomass sector between 2008 and 2021

The U.S. Department of Energy projects an estimates 696 to 1,184 million annual dry tons of biomass inventory potential by 2030[160]. The estimated biomass feedstock corresponds to roughly 100 GW of dedicated biopower capacity in the nation. In Massachusetts the NREL estimates that between 150,000 and 250,000 annual dry tons of biomass resources is technically available in Middlesex and Worcester counties[161]. While demand for biomass production is expected to increase, environmental

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[158] Geothermal Energy Association, *2013 Annual US Geothermal Power Production and Development Report, April 2014*

[159] NREL, *Renewable Electricity Futures Study,* 2012

[160] Department of Energy, *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry,* 2011.

[161] NREL, *Biomass Maps, 2009*, http://www.nrel.gov/gis/biomass.html (accessed July 24, 2014).

concerns with this energy source, combined with limited application and supply chain activities in the region, may mean that biomass manufacturing is not an industry sector that is directly targeted by communities in the region. However, similar to geothermal manufacturing, there are no constraints to the manufacturing of biomass components, equipment or machinery in the Northern Middlesex and Montachusett regions.

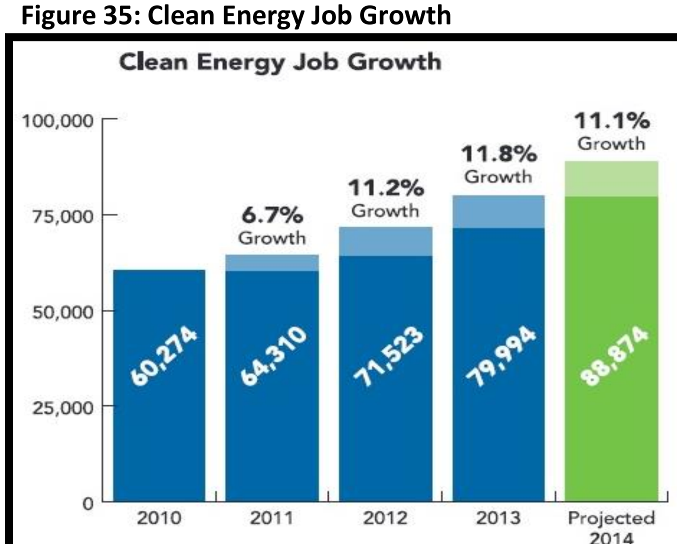
As summarized in this section, the renewable energy manufacturing industry currently has a modest presence in the Montachusett and Northern Middlesex regions. Solar supply chain activities, particularly those of Tier 2 manufactures, are clustered in the Northern Middlesex region. In the Montachusett region, there are a number of hydropower-related and wind-energy related supply chain manufacturing facilities, including several Tier 1 suppliers. Furthermore, the renewable energy industry, primarily solar and wind, is a growing sector in the nation and the state. Given the relatively recent emergence of this industry, forecasts about future growth must be tempered with a degree of caution as the long term performance of the industry in the United States remains unknown due to the uncertainty about as federal incentives and tax breaks. Yet, the outlook for renewable energy manufacturing is fairly positive due to growing customer demand and overall concerns about the environment.

While deployment of certain renewable energies may have limited potential in the region, this does not preclude the manufacturing of components, machinery and equipment associated with these sectors. However, transportation costs will be an important factor, depending on where the equipment is ultimately deployed. As described in further detail in the following sections, the region is well served by rail and road networks making transportation of most large scale machinery, components and equipment relatively easy. There are also many other manufacturing, workforce and locational strengths that make the Montachusett and Northern Middlesex regions attractive locations for renewable energy manufacturers.

Demand for Renewable Energy Manufacturing Employment

According to the U.S. Bureau of Labor Statistics, renewable energy, such as solar power and wind power, is expected to be a key piece of the growing "green economy," and jobs in these industries show great potential for growth. As growth and interest in renewable energy continues, demand for more trained workers, including those involved in the manufacturing supply chain, will also increase. Renewable energy manufacturing is also typically more labor intensive than current fossil fuel energy. Both the solar-related and wind energy sectors have more than two-thirds of their jobs in manufacturing, with the remaining third consisting of research and development, construction and operation,

Figure 35: Clean Energy Job Growth

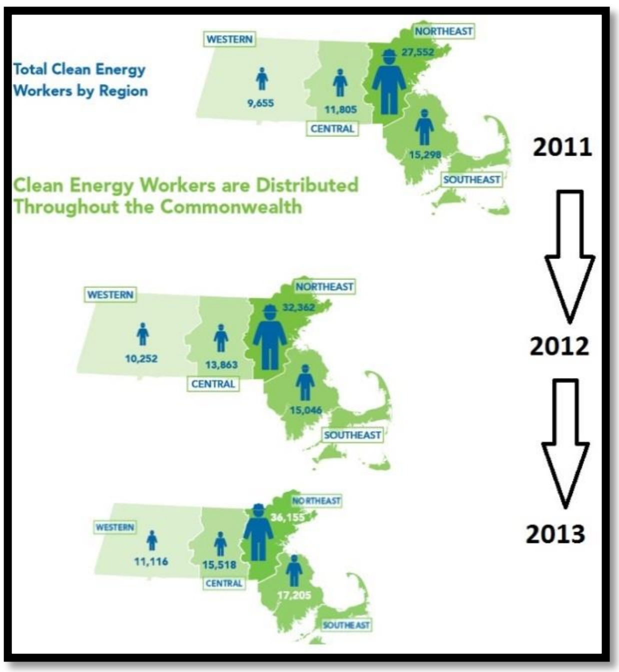


and installation and maintenance.[162]. Thus, the number of manufacturing jobs is expected to increase proportionately with the amount of renewable energy created. Peripheral jobs are also likely to be created in related sectors that develop and maintain associated systems, technology and equipment.

In its most recent report, the MassCEC found that there were 79,994 workers employed in the clean energy industry at the end of 2013[163]. Approximately 30,537 workers are associated with the renewable energy sector and it is estimated that 13,458, or 44.1%, of these workers were employed in manufacturing. The 2013 Massachusetts Clean Energy Industry Report also shows that all clean energy jobs grew by 11.8% from 2012 to 2013, following an 11.2% growth the year before and a 6.7% increase in 2011. Between 2012 and 2013, clean energy manufacturing employment in Massachusetts grew by 20.6%. The Clean Energy Job Growth is summarized in the chart below. It is expected that there will be an 11.1% growth between 2013 and 2014. The future for clean energy jobs in Massachusetts is quite positive based upon the figures from MassCEC.

The image to the left shows the Massachusetts map and depicts the regional changes in the labor force; it augments the data from the table above. Clean energy employs the highest amount of people in the northeastern region of Massachusetts. This is to be expected considering that Boston and the majority of its suburbs fall within this region. Since 2011 the number of clean energy jobs within the northeast region of Massachusetts increased by 9,000 or 31.2%. Central Massachusetts experienced a 31.5% increase in clean energy jobs with a total of 3,713 new jobs between 2011 and 2013. There has been a resilient upward trend of workforce expansion for all clean energy jobs throughout the Commonwealth since 2011.

Figure 36: Total Green Energy Workers By Region



To reduce greenhouse gas emissions at the state level, Executive Order No. 484[164] is an environmental initiative titled Leading by Example Program, which mandates that state agencies reduce their environmental impact by aggressively setting energy use goals and by targeting reductions in greenhouse gas emissions. The Executive Order dictates numerical percentages and years by which state-owned buildings must reduce their energy consumption and reduce their level of greenhouse gas emissions. In a further effort to facilitate renewable energy production, and reduce fossil fuel emissions

[162] The Brookings Institution - Metropolitan Policy Program, *Sizing the Clean Economy a National and Regional Green Jobs Assessment*, 2011

[163] The study's definition of a clean energy worker is any worker that spends *any* portion of his or her time supporting their firm's clean energy business.

[164] http://www.mass.gov/governor/legislationeexecorder/executiveorder/executive-order-no-484.html

of greenhouse gases - the Commonwealth has enacted the Green Communities Act, Global Warming Solutions Act, Clean Energy Biofuels Act, and the Green Jobs Act[165].

Massachusetts has been successful in stimulating the clean energy economy throughout the past seven years. Moreover, this economy has been booming in the past three years – as seen in the table on the next page. This table illustrates the increases in various sectors of the economy's clean energy labor force over the past three years. Installations and maintenance firms are the only sector of the economy where job growth was not consistently increasing. The reason for this is that installation jobs are seasonal and part-time; once the installation is complete the installers are no longer required. Since 2011, the clean energy sales and distribution labor force has increased by 3,000 or 15.79%. Engineering and research jobs grew by 58.44% and manufacturing jobs grew by 64.66%. Massachusetts has 13.2% more clean energy firms in 2013 compared with 2011.

Table 18: Growth in Energy Sectors

Work Force Sector	2011	2012	2013	% Growth
Installations and Maintenance Firms	20,709	18,280	19,031	↓ 8.10 %
Sales and Distribution	18,686	20,671	21,637	↑ 15.79 %
Engineering and Research	11,019	13,182	17,458	↑ 58.44 %
Manufacturers	8,173	11,162	13,458	↑ 64.66 %
Other (legal, policy making, finance, etc.	5,723	8,229	8,409	↑ 46.93 %
Total	64,310	71,524	79,993	↑ 24.39 %
Employers/ Firms	4,909	4,995	5,557	↑ 13.20 %
Locational Division of Workforce				
Northeast	27,552	32,362	36,155	↑ 31.23 %
Southeast	15,298	15,046	17,205	↑ 12.47 %
Central	11,805	13,863	15,518	↑ 31.45 %
Western	9,655	10,252	11,116	↑ 15.13 %
Total	64,310	71,523	79,994	↑ 24.39 %

Determining the exact number of employees working to support the clean energy economy is difficult because different data sources use slightly different parameters to define the green economy or green goods and services. It is important to note that the positive trend of more jobs relating to the green economy is consistent across an array of sources. The U.S. Bureau of Labor Statistics shows the number of employees supporting green goods and services within Massachusetts private sector. Data from BLS indicates that in 2010 there were roughly 70,000 people employed in Massachusetts who spend at least a part of their time supporting the green goods and services industry. In 2011 this number grew to 75,000. According to the Massachusetts Clean Energy Center, in 2010 there were about 60,000 clean energy workers. This inconsistency is due to the varying definition of clean energy worker or green

[165] http://www.mass.gov/governor/legislationeexecorder/executiveorder/executive-order-no-515.html
Table 2: 2011-2013 Massachusetts Clean Energy Industry Report - http://www.masscec.com/content/2013-clean-energy-industry-report

goods and service used to collect data; there is no one definition for this and therefore variations in statistical data do occur.

Table 19: Green Goods and Services (GGS) private sector employment by state and industry sector with over-the-year change and annual averages

		2010			2011			change	
	Industry	GGS Employed	Total Employed	GGS %	GGS Employed	Total Employed	GGS %	GGS Employed	GGS %
Massachusetts	Total	70,720	2,733,361	2.6	75,071	2,778,429	2.7	4,351	0.1
	Natural resources and mining	-	7,783	-	-	7,877	-	-	-
	Utilities	1,263	10,434	11.1	958	10,453	9.2	-305	-2.9
	Construction	8,029	107,103	7.4	8,582	110,752	7.7	553	0.2
	Manufacturing	9,457	256,493	5.8	9,299	253,948	3.7	-158	0.0
	Trade	3,074	462,054	1.0	3,048	466,636	0.7	-26	0.0
	Transportation and warehousing	10,782	68,840	9.1	11,067	69,667	15.9	285	0.2
	Information	-	85,118	-	3,674	84,251	4.4	-	-
	Financial Activities	-	207,883	-	-	207,409	-	-	-
	Professional, scientific, and technical services	11,840	248,546	5.7	14,736	256,923	5.7	2,896	0.9
	Management of companies and enterprises	-	57,442	-	-	58,628	-	-	-
	Administrative and waste services	9,538	156,279	5.6	8,917	161,564	5.5	-621	-0.6
	Education and health services	8,112	626,851	-	7,351	638,878	1.2	-761	-0.1
	Leisure and hospitality	-	307,011	-	708	314,883	0.2	-	-
	Other services, except public administration	2,052	113,528	0.9	2,426	136,559	1.8	374	0.3

Source: U.S. Bureau of Labor Statistics; http://www.bls.gov/web/ggqcew/ggqcew_supple_table6.pdf
[Note: Data is missing when statistics do not meet BLS disclosure standards.]

Solar energy jobs

According to the Solar Energy Industry Association, America's solar industry now employs more than 142,000 workers – more than doubling since 2009, of which 8,400 are

Figure 37: Worker in Solar Factory
Source: www.seia.org

located in Massachusetts[166]. This growth in the solar power industry is evidenced by the rapid increase in solar capacity over the past several years, leading to the increased demand for skilled workers. The U.S. Bureau of Labor Statistics anticipates that as solar technology evolves and new uses for solar power are discovered, occupations in the industry will continue to grow and develop. The Solar Foundation, in its Annual Review of the U.S. Solar Workforce, found that there are 29,851 workers employed in solar manufacturing in the U.S. in 2013[167]. This is expected to rise by 8.9% in 2014 to approximately 32,429 workers[168].

It is also important to note that solar manufacturers are the most diverse of all solar sectors. Firms in this category are an important employer of U.S. veterans and Latino/Hispanic workers. Additionally, manufacturers on the whole have the largest proportion of female workers of all of the solar industry sectors.[169]

Wind energy jobs

As of the end of 2013, the U.S. wind energy industry supported 50,500 full-time equivalent jobs directly associated with wind energy project planning, siting, development, construction, manufacturing and supply chain, and operations[170]. Wind energy development supports long-term, high-paying jobs in fields such as wind turbine component manufacturing, construction and installation, maintenance and operations, legal and marketing services, transportation and logistical services.

Historically, the wind industry's manufacturing sector has grown significantly in the U.S. Employment in the manufacturing sector increased from 2,500 jobs in 2004 to 20,000 in 2010.[171] However, in recent years, the wind energy industry has declined due to uncertainties associated with the federal Production Tax Credit and Investment Tax Credit extension. Manufacturing and supply-chain-related employment dropped from 30,000 jobs to 25,500 jobs in 2012, according to the AWEA. Furthermore, in 2013 there was a 92 percent drop in wind installations across the nation and 30,000 wind energy jobs were lost.

Hydropower jobs

Being the largest supplier of renewable energy in the United States, the national hydropower industry employs approximately 300,000 workers. In 2009 the National Hydropower Association commissioned a study examining the hydropower industry's job-creation and growth potential. The results demonstrate that with the right policies in place, hydropower could create 1.4 million cumulative jobs and add 60,000 MW of affordable, domestic, renewable energy by 2025[172].

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166 SEIA, *Solar Energy Facts: 2013 Year in Review*, March 2014, http://www.seia.org/research-resources/solar-industry-data (accessed May 22, 2014)

167 http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF%20Solar%20Jobs%20Census%202013.pdf (Accessed May 21, 2014)

168 Ibid.

169 Ibid.

170 AWEA, *Wind Energy Facts at a Glance*, http://www.awea.org/Resources/Content.aspx?ItemNumber=5059

171 NREL, *Renewable Electricity Futures Study,* 2012

172 Navigant Consulting, *U.S. Offshore Wind Manufacturing and Supply Chain Development,* 2009

Location and Siting Considerations

Attracting renewable energy manufacturers to a region requires an understanding of the decision-making process and variables that determine where new manufacturing facilities are located. Facility location is a strategic decision that firms make based on the whole environment in which they operate. This section examines the location and siting considerations of renewable energy manufacturing facilities and the typical siting strategy that guides private sector decision-makers.

In general, much of the background material focuses on locations that are supportive of the renewable energy manufacturing in terms of Renewable Portfolio Standards (RPS) and incentives, site and building readiness, transportation, and the presence of existing supply chains and suppliers. However, it is important to note that location and siting needs vary for renewable energy manufacturers. For example, wind-energy manufacturing facilities have more specific transportation requirements and are generally located near valuable wind resources in comparison to the other energy sectors. Many other variables may guide a firm's decision-making process, as outlined in the summary list included in this section.

Economics

The economic development tools used to attract renewable energy manufacturers have historically focused on financial incentives.[173] Many states have sought to influence siting decisions with property tax rebates, income tax credits, grants, loans, and sales tax exemptions. The success of these financial incentives is often debated and, as a result, other approaches are often recommended by economists, including investing in human capital, workforce development and modernizing infrastructure[174]. This section briefly summarizes some of the key national and state manufacturing incentives and initiatives available in the Northern Middlesex and Montachusett regions.

Federal incentives and initiatives

Manufacturing Tax Credits (48C)

In order to foster investment and job creation in clean energy manufacturing, the *American Recovery* and *Reinvestment Act of 2009* included a tax credit for investments in manufacturing facilities for renewable energy technologies. The Section 48C Advanced Manufacturing Tax Credit originally provided a 30% investment tax credit to 183 domestic clean energy manufacturing facilities valued at $2.3 billion. On February 7, 2013, the IRS announced the availability of additional 48C allocations, releasing $150 million remaining tax credits that were never fully utilized by previous awardees.

Production Tax Credit for Renewable Energy

The Production Tax Credit (PTC) is a federal incentive that provides financial support for the development of renewable energy facilities. Companies that generate electricity from wind, geothermal, and "closed-loop" bioenergy (using dedicated energy crops) are eligible for a federal PTC, which provides a 2.3-cent per kilowatt-hour (kWh) incentive for the first ten years of a renewable energy facility's operation.

[173] NREL, *State Clean Energy Policies Analysis (SCEPA):*February 2010.

[174] Ibid.

The PTC for renewable energy technologies expired at the end of 2013. A new provision was included in the American Taxpayer Relief Act of 2012 (enacted in January 2014) permitting only projects that were under construction before January 1, 2014 to qualify for the PTC.

Clean Energy Manufacturing Initiative

The Clean Energy Manufacturing Initiative strategically focuses the Office of Energy Efficiency & Renewable Energy's (EERE) clean energy technology offices and its Advanced Manufacturing Office around the competitive opportunity for the United States to be the leader in the clean energy manufacturing industries and jobs of today and tomorrow. The objectives of this initiative are to:

- Increase U.S. competitiveness in the production of clean energy products.
- Increase U.S. manufacturing competitiveness across the board by increasing energy productivity.

State incentives and initiatives

Massachusetts consistently ranks high as a renewable energy leader among other states. Growth of the renewable energy industry is a clear economic development priority, with strong results to date in leading-edge policies, industry expansion, job creation, and increased investment and deployment.[175]

Advanced Manufacturing Collaborative

On November 28, 2011, Governor Patrick announced the launch of the Massachusetts Advanced Manufacturing Collaborative (AMC) – a group comprised of leaders from industry, academia and government that has come together to enhance the competitiveness of Massachusetts manufacturing and lead the national effort to revitalize the U.S. as a manufacturing center. The industry-led AMC is focused on improving the competitive conditions in which our manufacturers can compete and thrive.

MassCEC's IncubateMass program

The MassCEC's IncubateMass program was recently announced and provides funding to incubators that catalyze and support startup companies to create jobs and promote the commercialization of new clean energy technology. By providing their client companies with targeted business support services and resources, such as mentors, specialized equipment, educational series and networks, these incubators work to accelerate the development of clean energy startups and increase the success rate of member companies.

Commonwealth Solar II

Commonwealth Solar II provides rebates for homeowners and businesses in Massachusetts, who install solar PV at residential, commercial, industrial, institutional and public facilities. In addition to the base incentive, additional incentives are available for installations using components manufactured in Massachusetts, for individuals with moderate income or home values, and for those who are rebuilding as a result of a natural disaster.

[175] Clean Edge, *A Future of Innovation and Growth: Advancing Massachusetts' Clean Energy Leadership,* April 2010

Working Capital Loan Guaranty for Manufacturers

MassDevelopment's newest loan guaranty product allows banks to make larger working capital loans to manufacturing companies than they would normally make under their existing advance rates. Eligible borrowers are manufacturers that conduct their primary operations in Massachusetts. A fixed guaranty to the lender of up to $1 million will cover advances up to 25% above the lender's maximum allowable advance rate under its current formula. The guaranty terminates with the maturity of the line of credit and will be considered for renewal on the same cycle as the bank, but no less frequently than every three years.

Local government

While states normally establish industry wide programs and incentives for renewable energy, local governments can also play a role in attracting renewable energy investment to their municipalities. Local governments unable to finance programs specifically for the renewable energy manufacturing industry can prioritize the industry as one of the targeted sectors of its economic development efforts. Miami-Dade County, Florida, for example, provides financial incentives for specific industries, including renewable energy, looking to relocate or expand within the county. Specifically, the County provides qualifying companies a property tax credit up to 1.7% of total real property capital investment or 1.15% of the tangible personal property capital investment. Additional incentive opportunities for eligible real property and tangible personal property include:

> *Some firms assert that incentives are temporary "band-aids" and that the success of the solar market depends on its ability to function without them. The temporary nature of incentives is aggravated by the fact that many state and local incentives are constantly in flux. One respondent noted that if incentives were guaranteed for four or five years, solar companies (particularly manufacturers) could plan investment with much more certainty (IEDC).*

- 17.5% of capital investment bonus for each new job if the company is located in a Designated Priority Area.
- 17.5% of capital investment bonus for each new job if the company is a "Green Certified" business in Miami-Dade County.
- 5% of capital investment bonus for companies that operate their businesses out of buildings or facilities that qualify as "green construction" or that incorporate an alternative energy system.
- 5% of capital investment bonus, if the company manufactures, installs or repairs solar thermal or PV systems.

Municipalities can also commit to purchasing a specified amount of renewable energy (solar) equipment from manufacturers locating in a community as a recruitment tool. Municipalities that operate their own local electric utilities have additional options to attract solar firms to the area. For example, Columbia, Missouri, established a solar portfolio goal as a target to generate or procure a portion of the municipal utility's electrical load with PV generation. Austin Energy, in Texas, and the Los Angeles Department of Water & Power offer higher incentives for installing locally-manufactured solar equipment as part of their solar incentive programs.

Within the Northern Middlesex and Montachusett regions there are no known local incentives or initiatives that specifically target renewable energy manufacturing at the municipal level. However, the traditional economic development tools available for other manufacturers, such as the Economic Development Incentive Program (EDIP), can be used for renewable energy firms as a means to reduce their property taxes for a specific period of time, as well as their personal property taxes.

While traditional economic development activities have focused on providing various forms of financial and other incentives to attract new renewable energy facilities, there appears to be a move away from these costly tools. A growing national trend focuses on maintaining, retooling and diversifying the existing manufacturing base to support emerging industries. This is evidenced in the recent development of several national and state collaboratives and partnerships, as well as workforce development grants (discussed in Section 7). Coupling incentives with broad-based programs will ultimately support long-term economic development[176].

Zoning and Permitting

"Building" or "site-readiness" is also identified as key site determining factors. A fundamental aspect of 'site readiness' is related to zoning. Zoning has the potential to either facilitate economic development or prohibit it. In general, zoning should encourage the specific uses a municipality is seeking to attract in specific locations. This means that sites are readily available for economic development, and that a developer or end user has one less regulatory step to go through. As such, this section examines the zoning of each community within the Northern Middlesex and Montachusett regions.

Zoning

Generally, renewable energy manufacturing would fall under the definition of light manufacturing, manufacturing, laboratory/office park, and research & development when combined with these other uses as an accessory use, rather than 'heavy' manufacturing. Locations that either allow manufacturing by right, or with a special permit are considered most supportive of renewable energy manufacturing. The tables in Appendices J.1 and J.2 identify the Northern Middlesex and Montachusett communities that currently facilitate renewable energy manufacturing through their bylaws.

Permitting

The ease and speed of permitting is also very important to the renewable energy sector and assists with site readiness. The faster a community signs off on permitting, the quicker a manufacturing facility can be built or retrofitted. According to the International Economic Development Council (IEDC), based on a survey of solar industry firms, the most important local asset for growing renewable energy is the permitting process. Studies comparing the U.S. and German solar markets have shown that "soft costs", such as permitting, are 80% lower in Germany. Similarly, wind farm developers have identified the State's complicated permitting process, which involves multiples agencies and levels of government, as a barrier to wind energy development.

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[176] NREL, *State Clean Energy Policies Analysis (SCEPA):*February 2010

Massachusetts Chapter 43D - Expedited Local Permitting

In August 2006 Chapter 43D Permitting was enacted into Massachusetts law, establishing an inventory of Priority Development Sites (PDS) on which municipalities offer a maximum of 180 day local permitting process. Cities and towns that opt into the Chapter 43D Program are able to target and promote specific areas, through a streamlined local permitting process, for economic development and housing production. As of February 2014, the Chapter 43D Program has been adopted by sixteen (16) municipalities for thirty (30) sites within the Northern Middlesex and Montachusett regions.

Table 19: Expedited Permitting – Chapter 43D

Municipality	# of Sites	IPB Approval Date	Site(s)	Municipal Contact
Athol	3	9/13/2007	North Quabbin Business Park District; Mohawk Plaza EOA; 134 Chestnut Hill Street	Shaun Suhoski, Town Manager, (978) 249-2496
Ayer	1	1/9/2008	40 Groton School Road	Robert Pontbriand, Town Administrator, (978)-772-8210
Billerica	1	12/13/2007	45 Middlesex Turnpike	Stephanie Cronin, Economic Development Coordinator, (978) 808-5281
Chelmsford	1	12/17/2008	25 Katrina Road	Evan Belansky, Community Dev. Director,(978) 244-3341
Clinton	1	3/11/2009	460-530R Main St.	Philip M. Duffy, Director Community and Economic Development, (978) 365-4113 pduffy@clintonma.gov
Fitchburg	2	3/13/2008	0 Airport Road and 135 Intervale Road; 0 Princeton Road	Michael J O'Hara, Principle Planner,(978) 345-1018 x18
Gardner	3	9/24/2008	Rear Main St.;Mill St.; Summit Industrial Park	Trevor Beauregard, Dir. Dept. of Comm. Dev. & Planning, (978) 630-4014
Groton	2	12/13/2007	Station Avenue Overlay District; 134 Main Street (6/21/11)	Michelle Collette, Town Planner, (978-448-1105
Lancaster	4	3/11/2009	Lancaster Technology Park; Ascetic Hill Park; Chisholm Property; Hill Property	Noreen Piazza, Planning Director, (978) 368-4007
Leominster	1	4/11/2007	Southgate Business Park	Lisa Vallee, Economic Development Coordinator, (978) 534-7525 ext. 257
Lowell	2	5/24/2007	Hamilton Canal District; 38 Prince Avenue	Diane Tradd, Asst City Manager, (978) 446-7200
Lunenburg	1	8/12/2009	100 Summer Street	Planning Director, (978) 582-4147
Orange	3	5/14/2008	Putnam Hall Block; South Main Street Block; West River Street Block	Richard Kwiatkowski, Town Administrator, (978) 544-1100 x107

Municipality	# of Sites	IPB Approval Date	Site(s)	Municipal Contact
Pepperell	1	12/17/2008	128 Main Street	Ken Kalinowski, DPW Director/Town Engineer, (978) 433-0327
Tewksbury	1	9/24/2008	Simon Properties/RJ Kelly	Steven J. Sadwick, Dir. of Comm. Dev., (978) 640-4370
Westminster	3	3/11/2009	Fitchburg Road; Simplex Drive; Westminster Business Park	Steven Wallace, 978-874-7414

Barriers

There are several planning barriers to locating renewable energy manufacturing facilities in the Montachusett and Northern Middlesex regions. Most notably, there is a lack of 'as-of-right' zoning in many communities, which may reduce the attractiveness of the region when manufacturers are making location decisions. Lengthy and costly siting processes can also be barriers to the siting of renewable energy manufacturing facilities. The process for securing permits and community approvals for renewable projects can be both costly and time-consuming without municipal support.

Infrastructure

Like any manufacturing industry, renewable energy manufacturing facilities require land to be fully serviced with infrastructure and services. Firms, especially those serving regional markets, will evaluate the infrastructure available within a region. Water and sewer is usually required. While energy use in the manufacturing sector has declined over recent years[177], the industry has high electricity consumption rates, therefore power supply and gas requirements are essential factors. Given today's high-tech workplace, telecommunications are also essential. Within the Northern Middlesex and Montachusett regions, there are some industrial districts with limited access to sewerage, which would limit their consideration as viable sites.

Access and Transportation

The efficient movement of goods, machinery, people and finished products is a key component of any manufacturing activity. Easy access to development sites can be vital when it comes to executing business strategies, saving time and money, and creating an attractive environment for both employees and customers. The same can be said for the specific renewable energy segment, however, some additional parameters must be considered as large components, machinery and devices are manufactured in the wind and hydro sectors. Notably, transportation of wind turbine equipment, such as blades and towers, requires specific local and regional infrastructure. (Attached in Appendix J.3 and J.4 are the analyses of the access and transportation issues in the Montachusett and Northern Middlesex regions completed by the MRPC and NMCOG staff. These analyses were completed to help identify those potential locations for renewable energy facilities within each region, taking into

[177] Total energy consumption in the manufacturing sector decreased by 17 percent from 2002 to 2010 (US EIA, http://www.eia.gov/consumption/manufacturing/reports/2010/decrease_use.cfm?src=%E2%80%B9%20Consumption%20%20%20%20%20%20Manufacturing%20Energy%20Consumption%20Survey%20(MECS)-f2)

consideration the barriers that need to be addressed for each site. The maps for each region reflect the conclusions reached by each RPA staff as a result of the analyses.)

Goods and Freight Movement

Clean Energy executives recognized the cost to their businesses caused by inefficient transportation. One employer said, "Improving public transit would allow us to connect regionally, and would prevent wasting money on travel and transportation …traffic kills our productivity but we need better and more options for people to reliably get to and from work." MassCEC 2013

Ensuring that the regional transportation network is capable of transporting equipment is an important consideration in renewable energy development. Locations near major transportation facilities that enable the efficient movement of freight, and movement and storage of goods are fundamental to a region's economy and also very important to the renewable energy manufacturing industry.

Figure 38: Transporting a Wind Turbine Blade over Highway

Transporting wind turbine components, due to their physical dimensions and weight, from the factory floor to the project site is a significant challenge for the wind industry. It involves handling sensitive and valuable components that can weigh up to 80 tons and be up to 145 feet in length. Such dimensions exceed standard truck trailer parameters, which carry 28 tons and are 53 feet long, and require closure to traffic of one side of an Interstate highway while it passes. Blade lengths are also expected to grow in the future, particularly for offshore wind projects, which further complicates road transportation.

As a result of these logistical issues and transportation costs, original equipment manufacturers (OEMs) often seek locations close to regions with valuable wind resources. In contrast, renewable energy component suppliers may be less constrained by resource areas or transportation infrastructure, but often require more engineering and machining production expertise. These suppliers are likely to be more interested in workforce characteristics, local government dynamics, overall operations costs, and incentive packages (NREL, 2010).

Transportation costs and issues have been a lesser concern for the solar energy manufacturing industry. This may change as the industry develops. Moving large volumes of glass can be challenging and manufacturers may ultimately decide to locate close to high-value markets to overcome this barrier. Nevertheless, the solar energy manufacturing industry, like the wind energy manufacturing sector, involves many component and material suppliers for which proximity to demand is less important. The solar energy industry prioritizes the ability to leverage existing assets, including R&D capabilities, as well as a skilled labor force and infrastructure with pre-existing silicon refining and production capacity[178] .

[178] NREL, Assessment of Offshore Wind Energy Resources for the United States, 2010

Public transit

While the highway and road network is highly important for large scale goods, freight and machinery movement to and from renewable energy manufacturing facilities, the MassCEC 2013 Clean Energy report emphasized that employers want more public transit options to make it easier for employees to travel to work without driving. One key reason cited in the report is that an effective transportation system can help to mitigate Greater Boston's high real estate prices in two key ways. First, it enables additional, lower-cost alternatives by providing access for people and goods to be connected to the marketplace. It also permits workers to commute from farther, lower cost areas, which allows for wage-growth containment as it less frequently needs to be linked to cost of living standards of Greater Boston[179].

Transportation Barriers

In the wind energy manufacturing sector, the blade and turbine transportation challenge is associated with the difficulty of transporting long wide loads around turns, through narrow passages, and beneath overhead obstructions on roads and railways. Thus, road weight limits and clearances, as well as bridge clearances and weight capacities, have the potential to limit the easy and efficient transportation of large-scale wind energy (and to a certain extent hydro energy) components and machinery.

Clustering

According to the Brookings Institution, clusters are a key organizational unit for understanding and improving the performance of regional economies. Firms cluster together within a region because each firm benefits from being located near other similar firms. The firms in a cluster have common competitive strengths and needs, and draw an advantage from their mutual proximity and connections. Consequentially, renewable energy manufacturers may look at the existing supply chain and ascertain which suppliers are present or absent in a region. These locational attributes are an important consideration for renewable energy firms looking to invest capital in a new location and are considered fundamental building blocks to establishing a successful enterprise.[180]

More detailed considerations

The National Renewable Energy Laboratory (NREL) has identified the following specific attributes that may also be attractive to renewable energy manufacturers when determining facility location:

- **Immediate local infrastructure:** A well-designed industrial park or existing facility may help finalize an individual firm's siting decision.

- **Business and government relations:** Courteous and transparent relations between government and business create a stable and clearly defined future, which is a vital business interest.

[179] MassCEC, *Massachusetts Clean Energy Industry Report*, 2013

[180] NREL, *State Clean Energy Policies Analysis (SCEPA): State Policy and the Pursuit of Renewable Energy Manufacturing*, Technical Report, February 2010

- **Quality of life variables:** Companies are often concerned with local public services (e.g., primary and secondary school systems), culture, and recreational opportunities. Such attributes are important when executives, management, staff, and families are expected to relocate.

- **Public investment in the broader community:** Public support for parks, recreation, and public spaces may be viewed as indicators of community values or local government values.

- **Community enthusiasm:** Company representatives sometimes mention community support for projects as drivers in the decision-making process. In addition, supportive communities may help simplify the permitting and approval processes, thereby reducing costs.

Potential Land Supply

Based on the location and siting considerations described above, locations suitable for renewable energy manufacturing have been defined as industrial and commercial districts that allow manufacturing by right or special permit. These districts have been mapped in the Northern Middlesex and Montachusett regions to determine the preferred locations for the siting of renewable energy manufacturing facilities. In addition, major transportation infrastructure, industrial parks, and road and bridge capacity restrictions are also mapped.

A more detailed analysis of potential sites at the local level would involve identifying several other factors associated with providing a realistic opportunity to construct a renewable energy manufacturing facility, site readiness, as well as the more specific transportation requirements. The analysis might include:

- Within the zoning districts, identification of zones that allow manufacturing by right.

- Identification of available vacant and developable land that can accommodate a facility or facilities of 50,000 square feet or larger in the aggregate. Due to the scale of products being manufactured, renewable energy manufacturers often require large floor space areas and high ceilings. As was seen at American Superconductor in Devens, the facility has a floor area of 345,000 square feet. A rule of thumb that could be used for this assessment is the Green Communities Criterion 1 guidance, which includes determining if there is enough available land or vacant space in existing buildings to provide for a facility at least 50,000 square feet or larger. To undertake this assessment basic yield calculations considering height, floor area ratio, setback, parking, and other limits on building size can be undertaken to determine available land for new renewable energy manufacturing facilities.

- Locations within 2.5 miles of entries, exits or stations associated with major transportation routes (major roadways, highways and active freight and rail lines).

a. Available land in the Northern Middlesex Region

See map in Appendix J.5.a

b. Available land in the Montachusett Region

See map in Appendix J.5.b

Education and Workforce Development

Many renewable energy manufacturers also seek out locations with a highly educated and skilled workforce. As renewable energy manufacturing is a relatively new industry, a highly trained workforce with renewable energy technology-specific knowledge and skills is required. This workforce is needed to support innovative, large-scale manufacturing facilities that can produce renewable energy products that are required now and into the future. As such, some regions may be overlooked because of workforce skill deficiencies.[181] States and regions with a highly skilled manufacturing workforce are likely to have an advantage in attracting new renewable energy manufacturing investment. Available training programs at public and private universities, colleges, and other educational facilities throughout the region, coupled with the ability to develop new training programs, as the need arises, are key considerations.

In the Montachusett and Northern Middlesex regions, energy-related training is provided at a number of universities, colleges, technical schools and organizations, including UMass Lowell, Fitchburg State University, and Middlesex and Mount Wachusett Community Colleges. These programs are summarized in Appendix J.6. In order to capitalize on the growth of renewable energy, the Montachusett and Northern Middlesex regions need to ensure that the existing manufacturing workforce is ready to adapt to this industry. This will be possible through enhanced communication and partnerships with educational institutions and the Workforce Development Boards.

In addition, MassCEC's Workforce Capacity Building program provides funding for renewable energy-centered science, technology, engineering and math (STEM) for students throughout the state. The initiative targets Massachusetts vocational-technical high schools, colleges, universities and community-based non-profit groups to help train students for careers in the rapidly-growing clean energy sector. Programs funded under this program aim to boost the number of high school graduates pursuing STEM majors in college and include curriculum and course development, professional development, internship and apprenticeship programs, hands-on instruction training and dual enrollment programs, in which high school students are able to take college courses.

Additional information on the workforce development and training programs in the Northern Middlesex and Montachusett regions are included in Appendix J.6. Potential careers in renewable energy are highlighted in Appendices J.7.a – J.7.e.

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[181] Ibid.

Regional Potential

The renewable energy industry provides economic development opportunities for regions and local communities. The direct economic benefits of renewable energy include the creation of jobs in construction and operation of new facilities, payments to the state and localities, payments for fuel and land leases, and in-state purchase of materials and services.

In order to gain an understanding of the potential in the Northern Middlesex and Montachusett regions to attract renewable energy manufacturing, a self-assessment of the regions' strengths, weaknesses, opportunities, and threats (SWOT) has been undertaken. There is benefit from evaluating the region's strengths and examining its abilities to meet the needs of renewable energy industries.

a. Strengths

- Both the Northern Middlesex and Montachusett regions possess a highly educated workforce.
- High-tech manufacturing expertise, which can meet the needs for engineers, manufacturing technicians, and design professionals, that are required in the renewable energy manufacturing sector (Northeast Energy Sector Partnership)
- There is a relatively large cluster of solar energy manufacturing firms in both regions, a small cluster of hydro manufacturing industries in each region and a small cluster associated with the wind energy industry in the Montachusett region.

Several state workforce training grants have been awarded to firms in the Montachusett and Northern Middlesex Region. In 2013, the Executive Office of Labor and Workforce Development's Workforce Training Fund awarded grants to two renewable energy manufacturers in the region. Entegris Inc., of Billerica, was a recipient of a $128,000 to train 55 employees (in collaboration with Middlesex Community College) and hire five new workers. Ranor, Inc Westminster was awarded $73,692 to train 140 employees and create five additional jobs.

- Both regions have a history of manufacturing and an existing manufacturing base that could be diversified to support emerging renewable energy industries.
- The Montachusett and Northern Middlesex regions have good quality road and rail infrastructure.
- The Northern Middlesex region is home to the UMass Lowell Wind Energy Research Group and is close to the MassCEC Wind Technology Testing Center (WTTC) in Charlestown.
- Both regions are recognized for their high quality of life and attractiveness.

- Both regions have four-year and two-year colleges (UMass Lowell, Fitchburg State University, Middlesex and Mount Wachusett Community Colleges), as well as technical and vocational schools (Montachusett Regional Vocational Technical School, Nashoba Valley Technical High School, Greater Lowell Technical High School, and Shawsheen Valley Technical High School).

- UMass Lowell has clean energy technical assets and expertise. The university provides 120 degree and certificate programs in a wide variety of fields, and works closely with employers engaged in manufacturing, plastics engineering, design and quality control through its Corporate Training Department. In addition, UMass Lowell has a growing wind energy research group and thus potential synergies, clustering and business development opportunities are possible[182].

- Fitchburg State University offers more than 30 undergraduate and 22 graduate programs, including an industrial technology program, with concentrations in energy management and manufacturing technology.

b. Weaknesses

- There is a lack of skilled workers in certain manufacturing sectors and in certain locations within the region.

- New industry with unknown future in region.

- Some towns have infrastructure limitations, such as lack of sewer, while other communities do not actively support manufacturing initiatives.

c. Opportunities

- Renewable energy manufacturing is a growing sector in the State, which builds upon the emphasis on green communities and sustainability in the region.

- Expanding renewable energy production in the region can broaden and diversify the regions' existing industrial base.

- Manufacturing jobs in the renewable energy industry are often well paid jobs. According to the Brookings Institution, the clean economy offers more opportunities and better pay for low- and middle-skilled workers than the national economy as a whole.

[182] The UMass Lowell Wind Energy Research Group (WERG) has expertise and capabilities to conduct research in the advancement of wind turbine science and systems. The group consists of thirteen interdisciplinary faculty members whose research focuses on wind turbine manufacturing, reliability, energy storage, and design.

- Partnerships with UMass Lowell, Fitchburg State University, Middlesex and Mount Wachusett Community Colleges and regional technical schools are readily available.

d. Threats (or Barriers)

- Loss of incentives and subsidies for renewable energy, and changing policies and programs at the federal and state levels may limit future renewable energy development opportunities.

- Market demand for renewable energy manufacturing is unknown over long term and manufacturing has cyclical history.

- Expanding and cheaper industrial markets in China and other foreign countries.

1. Recommendations

The Northern Middlesex Council of Governments and the Montachusett Regional Planning Commission are committed to facilitating the growth and expansion of the renewable energy manufacturing sector in their region. Having the right siting and planning policies in place, as well as economic and workforce development actions that support renewable energy manufacturing, will ensure the region is well positioned to capitalize on the potential of this emerging industry and attract and grow jobs associated with the renewable energy supply chain. The following recommendations are steps that NMCOG and MRPC can take to create the right conditions that make the region attractive for renewable energy manufacturers.

Siting and Planning

- Encourage local communities in the region to review their zoning bylaws and ordinances to consider introducing laboratory R&D, light manufacturing and manufacturing zones by right, in appropriate locations.

- For those communities without expedited permitting, encourage the introduction of expedited and streamlined permitting process for renewable energy manufacturing faculties. Cutting the timeline and paperwork for permitting at the municipal level would remove a barrier to renewable energy manufacturing growth.

- Encourage local communities in the region to consider waiving or reducing permit fees for renewable energy manufacturing as part of an incentives package.

- Work with local communities in the region to investigate the potential of establishing a comprehensive inventory of development-ready large industrial sites that could be utilized by renewable energy manufacturing facilities.

- Undertake a comprehensive assessment of road and bridge infrastructure to determine where limitations exist and what mitigation is needed to establish large scale renewable energy manufacturing in the region.

- Better understand the regional strengths through a detailed cluster analysis of the renewable energy industry, including the range of other industries associated with the energy sector, such as manufacturing, R&D, installation and maintenance. Identify ways to support the entire industry by attracting suppliers and manufacturers to locate in the region.

Attracting renewable energy manufacturers

- Ensure that the Northern Middlesex and Montachusett Comprehensive Economic Development Strategies (CEDS) prioritize renewable energy manufacturing.

- Assist municipalities through economic development activities and strategies to help determine if engaging in the renewable energy manufacturing supply chain is a good fit for their community, and if so, through which avenues.[183]

- Encourage municipalities to address renewable energy manufacturing in their comprehensive master plans.

- Work with economic development stakeholders and organizations to promote the Montachusett and Northern Middlesex regions as a friendly place for renewable energy manufacturing.

- Recognize the need to educate existing manufacturers and suppliers on the opportunities available in the renewable energy manufacturing supply chain and provide assistance to enter these markets.

- Work with economic development stakeholders to develop and grow the cluster of solar firms in the region seeking synergies with other nearby firms and research facilities.

- Assist interested communities to meet with renewable energy manufacturers in the region in order to establish a comprehensive understanding of their needs and to entice suppliers to locate in the region.

- Encourage interested communities to adopt incentive programs such as property tax credits for renewable energy manufacturers, like the Miami-Dade County, Florida example cited in Section 5(a) or offer other incentives to renewable energy facilities utilizing equipment and components made in the regions.

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[183] U.S. Department of Energy, Spurring Local Economic Development with Clean Energy Investments: Lessons from the Field, November 2013

Education and workforce development

In order to capitalize on growth of the renewable energy sector locally, it is important to ensure the local workforce has the right skills to engage in this sector. As such, the Northern Middlesex Council of Governments and the Montachusett Regional Planning Commission should assist the Greater Lowell and North Central Workforce Investment Boards to:

- Enhance the amount and quality of science and math taken at the secondary level so that students are able to take advantage of both current and future employment in areas of occupational growth.

- Increase the amount of hands-on instruction related to renewable energy in the regions' vocational schools through closer partnerships with businesses and suppliers in the industry.

- The regions' community colleges should explore the development of manufacturing technician Associate Degree programs that meet the needs of companies and those workers seeking middle skill positions in the industry.

- Work with local education providers to ensure that renewable energy training curricula aligns with the workforce needs of the industry.

- Identify ways to market the regions' labor force, particularly in advanced manufacturing, to clean energy companies looking for a U.S.-based location to establish and conduct their manufacturing operations.

- Consider the development of on-the-job (OJT) training programs at the regions' critical Clean Energy manufacturing businesses to give potential workers the sector-specific work experience necessary to gaining employment in these growing middle-skill occupations.

- Work closely with companies in the sector to develop short-term training and OJT opportunities to transition experienced manufacturing workers to new opportunities in the Clean Energy industry.

- Continue to advocate for policies that support the development of a skilled regional workforce, particularly in the areas of engineering and manufacturing technicians.

- Work with unions providing training and apprenticeships in the critical Clean Energy trades to ensure that workers have the skills required in the fastest growing sectors of the Clean Energy economy.

- Work with economic development stakeholders to enhance connections between the region's small and medium sized manufacturing firms and emerging Clean Energy companies that will require manufacturing expertise as they come to scale.

(The above education and workforce development recommendations are from the Northeast Energy Sector Partnership's *Clean Energy Labor Market Blueprint*, 2012)

FINAL RECOMMENDATIONS

Solar

- To help promote solar throughout the region, NMCOG and MRPC will help communities clarify goals and priorities related to solar energy use. In particular, the agencies will help incorporate solar energy into the community's master plan and/or comprehensive plan and work to create a regional clean energy plan that prioritizes solar. NMCOG will continue to incorporate solar into the Northern Middlesex Region's Comprehensive Economic Development Strategy (CEDS), and will work on obtaining funding to create a regional energy plan, which will also prioritize solar. MRPC's Regional Energy Plan currently prioritizes solar, and MRPC will work to ensure that the recommendations outlined in the plan are implemented.[184]

- NMCOG and MRPC will also help communities write zoning bylaws to eliminate uncertainty around where solar energy systems may or may not be allowed, ensure that installations are placed in appropriate locations, and mitigate any potential negative impacts. Utilizing DOER's *Model Zoning for the Regulation of Solar Energy Systems*, NMCOG and MRPC can adapt the model bylaw to suit the needs of local municipalities.

- Clear standards can also help communities avoid conflicts over competing values, such as tree cover or historic character of protected districts or structures. The RPAs will work with communities to ensure zoning ordinances do not restrict the types of districts in which solar facilities are allowed and to ensure there are no height restrictions, lot coverage limitations, or setback requirements that do not allow for the placement of solar panels on existing rooftops or building sites. The RPAs will work with communities to ensure expedited permitting for solar projects and to ensure homeowners' association covenants do not restrict solar. The RPAs could work to create additional unique incentives for solar such as waiving permit fees and allowing density bonuses for developments that use solar power.

Education

- NMCOG and MRPC will help educate residents about solar at the regional and community level. As learned through this grant, community workshops can help educate residents and business owners about the local solar market through workshops and outreach events. Community outreach can also be conducted through site visits, via booths/tables at local events, or even within the school system. Education is a crucial component of renewable energy siting because residents who are educated about the importance of renewable energy may be more likely to install solar on their own property, and may be more accepting to large-scale solar installations.

- NMCOG and MROPC will also educate land-owners, developers and business owners about solar siting. Documents can be developed that includes a step-by-step process for public and private sector developers and business owners to site solar facilities. The document could include

[184] Montachusett Region Regional Energy Plan

information on zoning regulations, permitting and financing. The RPAs will particularly reach out to those land-owners who have been pre-sited through the EPA RE-mapping technology as especially suitable for solar power.

Capacity Building

- MRPC and NMCOG will encourage communities to hire an energy manager to help advocate for solar development and can help quantify energy and cost-savings. As previously mentioned, Chelmsford and Lowell recently received funding for a full time Energy Manager through the state's Energy Manager Grant Program. The RPAs can assist their communities with Energy Manager Grant Program applications and, in particular, can bring together smaller municipalities to discuss the possibility of a "shared" Energy Manager. A shared Energy Manager may be an option for communities we do not have the capacity for a full time position. The RPAs can also encourage communities to take advantage of various state-run green programs by assisting with SolarizeMass and Green Community applications, and by assisting with group procurement for solar installation.

Financing and Affordability

- NMCOG and MRPC can partner with banks to create specialized green loans as a way to reduce costs of solar installations for homeowners. The RPAs could work to promote low-interest loans and group purchasing. As described in the *Implementing Residential Solar Energy in the Montachusett Region,* MRPC and NMCOG could create a group-purchasing program at the regional level (e.g. Solarize NMCOG/MRPC), which would work with energy and installation companies to encourage solar adoption in the region. NMCOG and MRPC could pre-site viable locations on contaminated lands, assist in obtaining competitive bids for solar installation, and partner with the state to maximize additional incentives and financing options.

Solar Siting

- As discussed, less than 20% of homes are suitable for residential solar. NMCOG and MRPC will promote community solar for those homes that are not suitable for residential solar. We will work to pre-site locations for solar farms/community solar gardens on contaminated land, and could conduct outreach to recruit shareholders to participate in the community solar program. The program could be designed specifically for those who do not qualify for residential solar. NMCOG and MRPC should conduct a detailed, site-specific analysis of EPA's RE-mapping sites, to identify or prioritize the best sites for developing renewable energy facilities based on the technical and economic potential. This will involve visiting each site to determine its true suitability for solar and to conduct prioritize locations for installations.

Job Development

- NMCOG and MRPC will work closely with the local Workforce Investment Boards to encourage training for solar industry-related jobs throughout the region. Promoting solar throughout the region will help create jobs in installation, manufacturing and development. It will also indirectly help create jobs in the research and development. For example, in June 2010 the Greater Lowell Workforce Investment Board received funding from the United States Department of Labor to create an integrated system of education and training to promote skill attainment and career development benefiting business, incumbent workers and job-seekers. Using a portion of this funding, 37 incumbent workers and 36 unemployed individuals received solar related training and HVAC, BPI and LEED; obtained industry recognized credentials. NMCOG and MRPC should continue to work with the local Workforce Investment Boards to encourage job training throughout the regions.[185]

Wind:

- Wind power potential within the Northern Middlesex and Montachusett regions is limited. Wind speeds in the area are generally not fast enough for current wind turbine technology for utility scale wind turbines. There are more possibilities with residential and commercial sized turbines which require lower wind speeds.

- Continuing to encourage municipalities to consider wind energy development in their comprehensive plans, including identifying locations where the municipality encourages wind energy systems to be located or not, will provide a basis for the growth of wind energy in Massachusetts and our regions.

- In order to promote the installation of wind turbines, it is suggested that cities and towns within the Northern Middlesex and Montachusett regions create zoning bylaws specifically for wind turbines. The bylaws could include siting requirements or zoning overlay districts. The town of Ashby has a Wind Energy Facility Zoning Overlay District which identifies locations were wind turbines can be built with special permits.[186] Samples of cities and towns within the Northern Middlesex and Montachusett regions can be found in Appendices C.3, C.4 and C.5.

Geothermal:

- Geothermal electricity production in the Northern Middlesex and Montachusett regions is limited by the low temperature of the Earth. A Binary Cycle power plant works by pulling a lower temperature geothermal fluid from the ground and using it to flash a fluid (generally a refrigerant of some form) with a low critical point. This type of geothermal plant can work with lower temperatures around about 57^{O}C or 134.6^{O}F and could possibly be used in our area. A Binary Cycle system is recommended for geothermal electricity production in the area.

- Geothermal heating and cooling has better potential than electricity production as it can work on lower temperatures. There are different systems depending on site requirements that are explained in the Geothermal section of this report. Geothermal heating would be great for district heating or heating of individual buildings.

- Regulations for geothermal differ between cities and towns. Groton is the only town in the Northern Middlesex and Montachusett area that has a set of bylaws for geothermal heating. The regulation pertains to boreholes which are part of a ground source heat pump system also

[185] Solar siting workshop, Gail Brown presentation
[186] http://www.ci.ashby.ma.us/document/planbd/Wind%20Energy%20Facility%20Zoning%20Overlay%20District%20Map.pdf

known as a geothermal heating system. The Groton regulations include setback requirements, regulations for drilling, as well as regulations for reporting closed-loop geothermal boreholes.

Hydro:

- Within the Northern Middlesex and Montachusett regions there are 330 dams, some of which produce electricity. Many of the dams in the region are low head and low flow. The dam in Pepperell is a great example of the potential for low head dams in the area and is discussed thoroughly in the Hydropower section.

- Currently, there are no zoning bylaws for hydropower in any city or town in Massachusetts. The permitting process is lengthy compared to other sources of renewable energy. It is recommended that current dams in the Northern Middlesex and Montachusett region be evaluated for the potential to convert the dam to a hydroelectric dam. Due to environmental regulations and other restrictions, it may be difficult to have a new dam permitted.

Biomass:

- Biomass is a form of renewable energy that covers a number of different types of energy production. Landfill gas, anaerobic digestion, and woody biomass all have potential in the region. It is recommended that landfills within the Northern Middlesex and Montachusett regions be evaluated to see if there is potential to capture the methane gas that is released during the decomposition of the landfill. Anaerobic digestion has potential on farms using animal waste, in areas with a large amount of food waste, or in waste water treatment plants that use anaerobic digestion to help with treating sewage. Woody biomass can be used to heat individual homes and even larger buildings.

Manufacturing and Jobs:

Siting and Planning

- Encourage the region's communities to review their zoning bylaw to consider introducing laboratory R&D, light manufacturing and heavy manufacturing zones by right in appropriate locations. Also, consider solar access ordinances to protect access to sunlight for photovoltaic systems.

- Encourage the regions' communities to consider introducing expedited and streamlined permitting process for renewable energy manufacturing faculties. Cutting the timeline and paperwork for permitting at the municipal level would remove a barrier to renewable energy manufacturing growth.

- Encourage the regions' communities to consider waiving or reducing permit fees for renewable energy manufacturing as part of an incentives package.

- Work with the regions' communities to investigate the potential of establishing an inventory of development-ready large industrial sites that could be utilized by renewable energy manufacturing facilities.

- Undertake a comprehensive assessment of road and bridge infrastructure to determine where limitations exist and what mitigation may be needed to establish large scale renewable energy manufacturing in the region.

- Better understand the strengths of the regions through a detailed cluster analysis of the renewable energy industry, including the range of other industries associated with the sector, such as manufacturing, R&D, installation and maintenance. Identify ways to support the entire industry and entice suppliers and manufacturers to locate in these regions.

Attracting Renewable Energy Manufacturers

- Ensure that the Northern Middlesex and Montachusett Comprehensive Economic Development Strategy (CEDS) prioritize renewable energy manufacturing.

- Work with economic development stakeholders and organizations to promote the Montachusett and Northern Middlesex regions as a friendly place for renewable energy manufacturing.

- Recognize the need to educate existing manufacturers and suppliers on the opportunities available in the renewable energy manufacturing supply chain and provide assistance to enter these markets.

- Work with economic development stakeholders to develop and grow the cluster of solar firms in the region seeking synergies with other nearby firms and research facilities.

- Assist interested communities to meet with renewable energy manufacturers in the region in order to establish a comprehensive understanding of their needs and to entice suppliers to locate in the region.

Education and Workforce Development

Assist the Greater Lowell and Montachusett Workforce Investment Boards to:

- Enhance the amount and quality of science and math taken at the secondary level so that students are able to take advantage of both current and future employment in areas of occupational growth.

- Increase the amount of hands-on instruction related to renewable energy in the regions' vocational schools through closer partnerships with businesses and suppliers in the industry.

- The regions' community colleges should explore the development of manufacturing technician Associate's degree programs that meet the needs of companies and those workers seeking middle skill positions in the industry.

- Work with local education providers to ensure that renewable energy training curricula aligns with the workforce needs of the industry.

- Identify ways to market the regions' labor force skill sets, particularly in advanced manufacturing, to clean energy companies looking for a U.S.-based location to establish and conduct their manufacturing operations.
- Consider the development of on-the-job (OJT) training programs at the regions' critical Clean Energy manufacturing businesses to give potential workers the sector-specific work experience necessary to gaining employment in these growing middle-skill occupations.
- Work closely with companies in the sector to develop short-term training and OJT opportunities to transition experienced manufacturing workers to new opportunities in the Clean Energy industry.
- Continue to advocate for policies that support the development of a skilled regional workforce, particularly in the areas of engineering and manufacturing technicians.
- Work with unions providing training and apprenticeships in the critical Clean Energy trades to ensure that workers have the skills required in the fastest growing sectors of the Clean Energy economy.
- Work with economic development stakeholders to enhance connections between the region's small and medium sized manufacturing firms and emerging Clean Energy companies that will require manufacturing expertise as they come to scale.
- Support the establishment of educational programs in the regions elementary schools to expose children to the benefits of sustainable energy practices.
- Work with RPA affiliates such as green building commissions, sustainable organizations, conservation commissions, environmental groups and neighborhood groups to develop energy outreach and education programs.

(The education and workforce development recommendations are from the Northeast Energy Sector Partnership's *Clean Energy Labor Market Blueprint*, 2012)