Siting Renewable Energy on Brownfields

An Interactive Qualifying Project
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WORCESTER POLYTECHNIC INSTITUTE
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Abstract

This Interactive Qualifying Project (IQP) focuses on siting renewable energy on brownfield sites in the Montachusett region in response to the grant given by the Economic Development Administration. Assessment of renewable energy is conducted in terms of site characteristics, including area and available resources. Implementation on brownfield sites is scrutinized with regards to incentives, policies, social impacts, environmental impacts, and cost. The final product provides a tool to assist with and encourage siting renewable energy on brownfields.

Acknowledgments

We would like to dedicate special thanks to Profess Suzanne LePage and Professor Derren Rosbach for leading this IQP. We are grateful for the support and guidance that the Montachusett Regional Planning Commission and Boreal Renewable Energy Development have given throughout the project. For all others involved with the project, thank you for the contributions and encouragement resulted in the success of this IQP.

Authorship

All members of this IQP group contributed equally to the project. All members collaborated to produce the Methodology and the Supporting Document, found in the Appendix. The rest of the project was divided equally, as follows:

Julia Lamontagne

Julia wrote the introduction, as well as sections of the Background focusing on the Montachusett region, EDA grant, brownfields, and brownfields redevelopment. She is also responsible for the "Possible Impacts" section of the Case Study and the Findings chapter.

Khanh Tran

Khanh was responsible for the "Solar Energy", "Wind Energy", and "Government Policy and Incentives" sections of the Background. Khanh and Chi worked together to produce the "Geothermal" section of the Background and the main section of the Case Study chapter, as well.

Chi Tran

Chi contributed the "Biomass Energy", "Hydropower Energy", and "Permitting" sections of the Background chapter. Chi, in collaboration with Khanh, worked to produce the "Geothermal" section of the Background and the main section of the Case Study chapter.

Each section was reviewed and revised by all members of the group before the final submission.

Executive Summary

With the increase in electrical usage in today's society, scarcity of fossil fuels has become a major issue that needs to be addressed and resolved. In response to the issue, the Economic Development Administration (EDA) awarded a grant to the Montachusett Regional Planning Commission (MRPC) to fund research on siting renewable energy. Consequently, this Interactive Qualifying Project, with the help from the MRPC, is focused on siting renewable energy on brownfields and providing a tool to assist with this process. The tool includes essential information about each type of renewable energy, such as land requirement, costs, incentives offered, and other aspects. It is designed for developers to determine which renewable energy is the most feasible at a preferred site.

Background Overview

A comprehensive background research on the Montachusett Region and the EDA grant was conducted. Aspects of each of the five renewable energies was then thoroughly explored, specifically the technologies, efficiency, and capacity factor, as well as the advantages and disadvantages. Moreover, governmental programs, incentives and permits pertaining to renewable energies were examined to deliver a literature review of regulations and motivations offered. Lastly, research on brownfields and their redevelopment, especially in the Montachusett Region, was carried out. The obtained information was incorporated all together and siting renewable energy on brownfields was determined to be a suitable option for the use of the EDA grant. This background research also provided a firm foundation for further progress of the IQP.

Methodology Overview

After the necessary information was acquired from the previous section, types of renewable energies to be included in the project were decided. The renewable energy screening process, which utilized the information from the background, led to the exclusion of hydropower and geothermal energy. The tool design process was then initiated. First, with inspiration from similar projects and suggestions from knowledgeable parties, criteria to be included in the tool were determined. These criteria included: permitting, land requirement, amount of available resources, cost and incentives/programs. Next, necessary data was obtained through research and other contacts. Based on previous study and

thorough scrutiny, the table format was selected to be the most appropriate for the final tool. All of the above steps were conducted to generate a complete product, which was then tested in a case study. In the case study, a brownfield was chosen, using various screening criteria determined from online national documents. An overview background of the brownfield was also obtained via research and site inspection, which helped to confirm the feasibility of renewable energy at the site. Afterwards, the tool was implemented on the site to conclude which of the three energies was the most feasible, followed by an impact analysis.

Case Study Overview

The effectiveness, practicality and validity of the tool was tested in the case study. The brownfield, located at 110 Burrage St, Lunenburg MA, was selected based on criteria described in the Methodology section. The tool was then implemented on this specific site, following the steps outlined in the Supporting Document. Detailed calculations and analysis were clearly presented. After much investigation, the two most suitable energies at the site were solar and biomass. Due to certain limitations, no further decision could be made; yet, developers should carefully assess the two options to choose the most fit. An analysis on environmental and social impacts that solar and biomass power plants would create in the area was also created. Via the analysis, advantages and disadvantages of these two energies could be weighed, thus, helping developers to make the decision.

Findings Overview

In this final section of the report, accomplishments throughout the project were stated. The most recognizable achievement was the creation of the tool. Moreover, the implementation of the tool on a specific brownfield allowed the tool to be evaluated. As the case study progressed, certain changes were made in order to optimize the process and create a more logical flow between steps. In conclusion, it is hoped that this IQP, especially the tool, will further encourage the use of renewable energy in the Montachusett region.

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1. Introduction

Today's society relies heavily upon electricity, which is produced primarily by burning fossil fuel. As fossil fuel is a non-renewable resource that is drastically depleted, its price and the price of electricity have increased significantly in the past decades (Payne, Dutzik, & Figdor, 2009). Also, burning fossil fuel creates a lot of pollutants. Because of this increasing scarcity and pollution, there has been an inclination for an alternative option, which leads to renewable energy.

States laws have been passed encouraging the alternative option, one of which is the Massachusetts Renewable Energy Portfolio Standards requiring suppliers to increase the percentage of renewable energy generated. The law was established to encourage renewable energy in the state and also offers many incentives (Energy and Environmental Affairs (EEA), n.d.). In addition to state laws, many government organizations are also pushing for renewable energy by funding research and implementation; one such government organization is the Economic Development Administration (EDA).

The EDA has a general mission of promoting innovation and competitiveness, preparing regions for growth and success in the worldwide economy. They take interest in the renewable energy market because of the jobs and economic boost that it has the potential to create (U.S. Economic Development Administrator (EDA), n.d.). In 2010, the EDA awarded a grant to the Montachusett region, in northern central Massachusetts, to fund research on siting renewable energy, including wind, solar, hydro, geothermal, and biomass energy. The intent of the grant is to assess the potential for renewable energy to create a thriving job market around the new projects in the region (Montachusett Regional Planning Commission, 2011).

This Interactive Qualifying Project (IQP) is centered on siting renewable energy in the Montachusett region in response to the EDA grant. The project evaluated the feasibility of implementing commercial-scale, electrical renewable energy plants, as they are likely to have a larger impact than small or residential scale projects. This project also specifically assessed the redevelopment of underutilized brownfields for renewable energy plants; brownfields are abandoned sites that likely contain hazardous substances. In addition, it studied the requirements and characteristics that make renewable energy plants efficient.

Barriers that are specific to each type of energy and barriers for renewable energy as a whole were also analyzed. Information about efficiency, costs, environmental and social impacts, government policies and incentives, and site requirements of each type of energy is presented in the final product. The final product was then used to assess a brownfield in the area as a case study. The end result is that the final product is available and useful for utility companies in the Montachusett region, renewable energy developers, or other contracting groups looking to develop renewable energy in the area. They are supplied with the information needed in order to consider renewable energy options at contaminated sites in the region.

The expectation is that this IQP has impacts on many different levels. On a broader scale, it promoted the federal initiative "RE-Powering America's Land" in the area. This initiative was started to assist developers to realize the potential brownfields have for development in the energy business. On a state-wide level, this IQP provided developers with tools to help meet the quotas set forth by the state in the Renewable Energy Portfolio Standards. Lastly, this IQP helped the renewable energy market in the area get started and will hopefully draw more competition and business to the area. It also contributed to counteract the "not in my backyard" attitude that most communities have and informed the population on the benefits of developing renewable energy on brownfields. Renewable energy is a promising opportunity and this IQP helped the Montachusett region exploit this abundant resource.

2. Background

The following sections give general background knowledge on topics covered in this project, including:

- The Montachusett region and the EDA grant
- Solar, wind, biomass, hydropower, and geothermal energy
- Energy generation processes, technologies, efficiencies, costs, and impacts for each type of renewable energy
- Permitting required for implementation of each renewable energy
- Various government policies and incentives for renewable energy
- Brownfields, their redevelopment, and the implementation of renewable energy

2.1 Montachusett Region and EDA grant

The Montachusett region is comprised of 22 separate communities in both the Worcester and Middlesex counties. The cities of Fitchburg, Gardner, and Leominster are the urban areas in the region while the remaining cities are relatively rural. The total population of the region is 228,000 people in an area of approximately 685 total square miles (Montachusett Regional Planning Commission, 2011). Figures 1 and 2 depict the entirety of the Montachusett region.

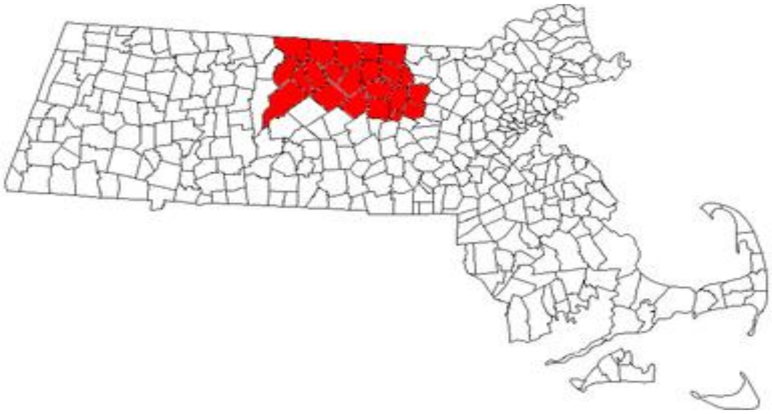


Figure 1. Map of Massachusetts with Montachusett region highlighted

(Schzmo, 2009)

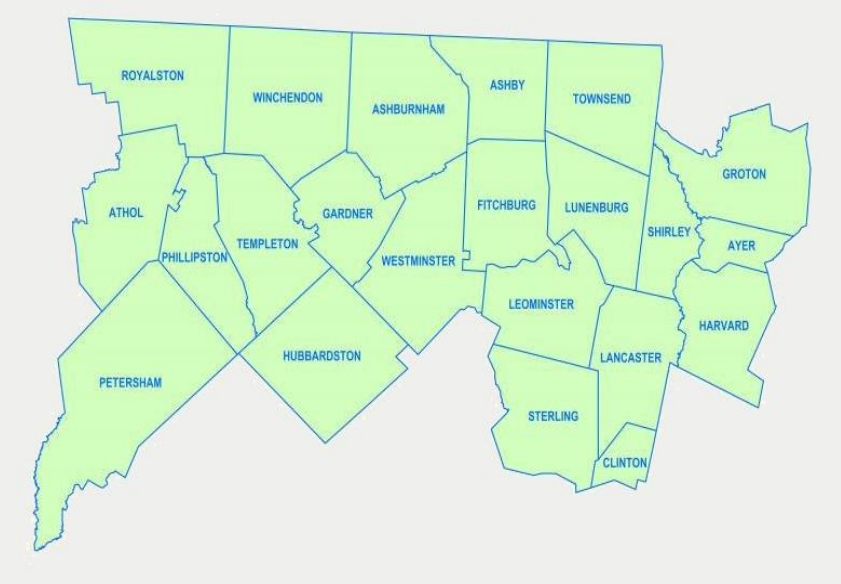


Figure 2. Map of Montachusett Region

(Montachusett Regional Planning Commission, n.d.)

The region acquires its energy from two main utility companies, National Grid and Unitil, along with a variety of municipally owned companies. National Grid provides electricity to 13 communities in the area, while Unitil provides to only four. The municipally owned utility companies include Ashburnham Municipal Light Plant, Groton Electric Light Department, Templeton Municipal Water & Light Department, Sterling Municipal Light Department, and Mass Development Devens. These companies serve five communities in the region. There are many renewable energy sources already implemented in the Montachusett region, including hydro, wind, biomass, and solar energy facilities. They are primarily located in the more rural areas of the region (Montachusett Regional Planning Commission, 2010).

Montachusett Regional Planning Commission (MRPC) is one of the 13 planning agencies in Massachusetts. The objective of the MRPC is to conduct comprehensive energy and land-use planning and resolve issues of boundary and zoning regulations in the Montachusett region. The MRPC works with the 22 communities under its discretion to create strategies for development, transportation, emergency situations, energy use, and remediation.

In 2010, the MRPC was awarded a grant from the Economic Development Administration (EDA) to fund research for renewable energy in the area. The grant was divided up into ten tasks, five of which include different forms of outreach and community education. The other five deal with the analysis of solar, wind, hydro, biomass, geothermal energy. The grant will cover research for an overview of each type of energy, along with a study to determine if the resources for each type of renewable energy are available and abundant in the region. Other areas funded by the grant include planning and zoning, permitting and regulations inquiry, incentive research, and an analysis of regional potential for each energy type (Montachusett Regional Planning Commission, 2011).

2.2 Solar Energy

According to the U.S. Department of Energy, solar energy is the most abundant resource on earth, as “173,000 terawatts of energy strike the Earth continuously,” which is “more than 10,000 times the world’s total energy use” (Chandler, 2011). Distribution of solar radiation in the United States.

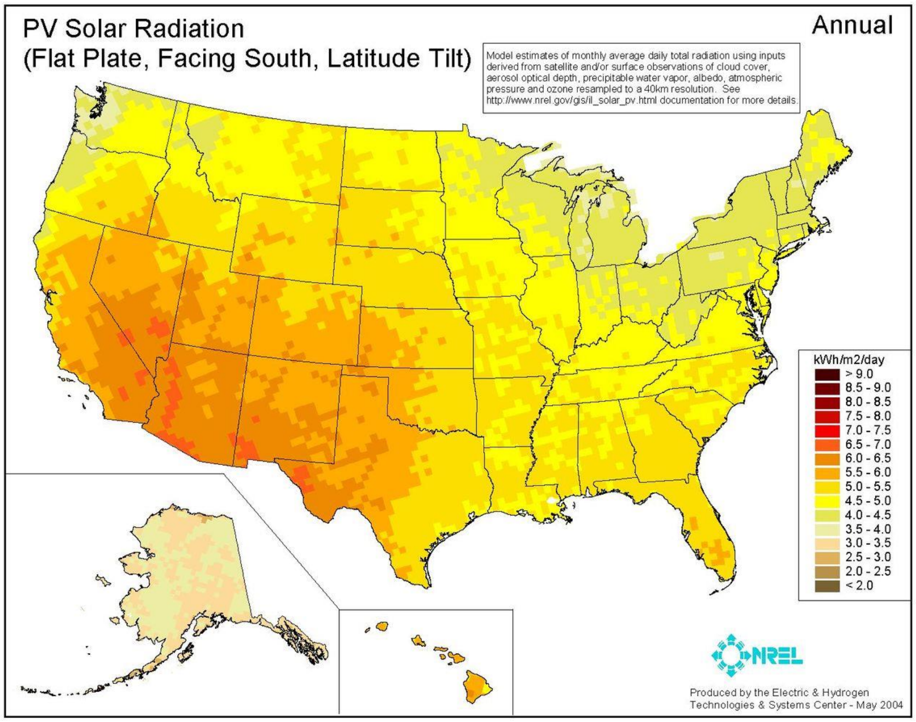


Figure 3. Solar power in the United States.

(National Renewable Energy Laboratory, 2013)

Energy from sunlight is generated via the use of photovoltaic panels. A photovoltaic cell (also called solar cell or PV cell) converts energy directly into electricity using two semiconductors, generally composed of silicon crystals. The bottom layer of a PV cell holds a positive charge while the top layer holds a negative charge. When sunlight strikes the cell, electrons are knocked loose in both layers. The electrons will flow from the negative layer to the positive layer due to the opposite charges of the layers. This movement creates a current and the energy is harnessed by an external circuit. Solar cells are generally grouped together as modules and modules can then be arranged in larger arrays (Gratzel, 2005).

The two most common types of solar panels are silicon and thin-film. The efficiency of a solar panel is determined by the material used. Silicon solar panels have the highest conversion efficiencies of all solar panels. They convert, on average, between 15% and 20% of the light that hits them (National Energy Education Development Project, 2006). On the other hand, thin-film solar panels cost much less to manufacture than crystalline silicon panels. As of yet, thin-film cannot equal silicon in conversion effectiveness. Cadmium telluride (CdTe) and cadmium-indium-gallium-selenide (CIGS) solar panels are the current champions of thin-film solar technologies, averaging around 11% efficiency. Most thin-film solar cells convert about 4-10% of sunlight (Zweibel, 1998). The solar panel system also affects the productivity. Ground mounted solar panel systems have the highest efficiency in capturing sunlight and turning that sunlight into energy because the system allows for more air circulation around the panels, which perform best when in cooler conditions. The efficiency of solar panels also varies day to day depending on weather condition. If weather conditions block the source of sunlight, solar panels will decrease in productivity. Air pollution and other environmental factors can negatively affect the efficiency of the cells.

Moreover, rated capacity is also a crucial factor to be considered when planning for a solar energy facility. Rated capacity is defined as the maximum power that the unit is designed to provide to the grid. Capacity factor is the ratio of a unit's actual output to its maximum possible output at its rated capacity (U.S. Energy Information Administration, 2013). The capacity factor determines which percentage of that rated capacity will actually produce electricity. Actual output of a solar unit can be calculated using the capacity factor as follows:

$$Actual\ Ouput = Capacity\ Factor * Rated\ Capacity$$

According to the National Renewable Energy Laboratory, the capacity factor of solar energy is 15% (National Renewable Energy Laboratory, 2013).

Along with efficiency, there are many other reasons why solar energy is a good alternative to coal-fired energy. It is available in the most remote areas of the world and produces almost no pollution. There are also many drawbacks to solar energy. The initial cost of buying and installing solar panels is very high. Maintenance and replacement costs can become costly over the years as the systems start to degrade also (European Photovoltaic Industry Association, 2011). Building a solar power plant requires sufficient land usage and will destroy the aesthetic values of the land on which it is built. Many people have complained that solar panels are an “eyesore” (Navarro, 2011). Developers need to be aware of the cost, environmental impacts and social reactions of solar energy in order to get a good picture of the impacts that their projects will have.

2.3 Wind Power

Wind energy is generated by wind turbines that convert kinetic energy from the wind into mechanical power. Electricity is generated when the wind passes over the blades creating lift. The lift then causes a rotor to turn and spins a shaft which connects to a generator that produces electricity. The generator’s electrical output flows to a transformer that converts it to the right voltage for the larger electrical grid (Office of Energy Efficiency & Renewable Energy, 2013).

Figure 4. Wind turbines in Boston, MA

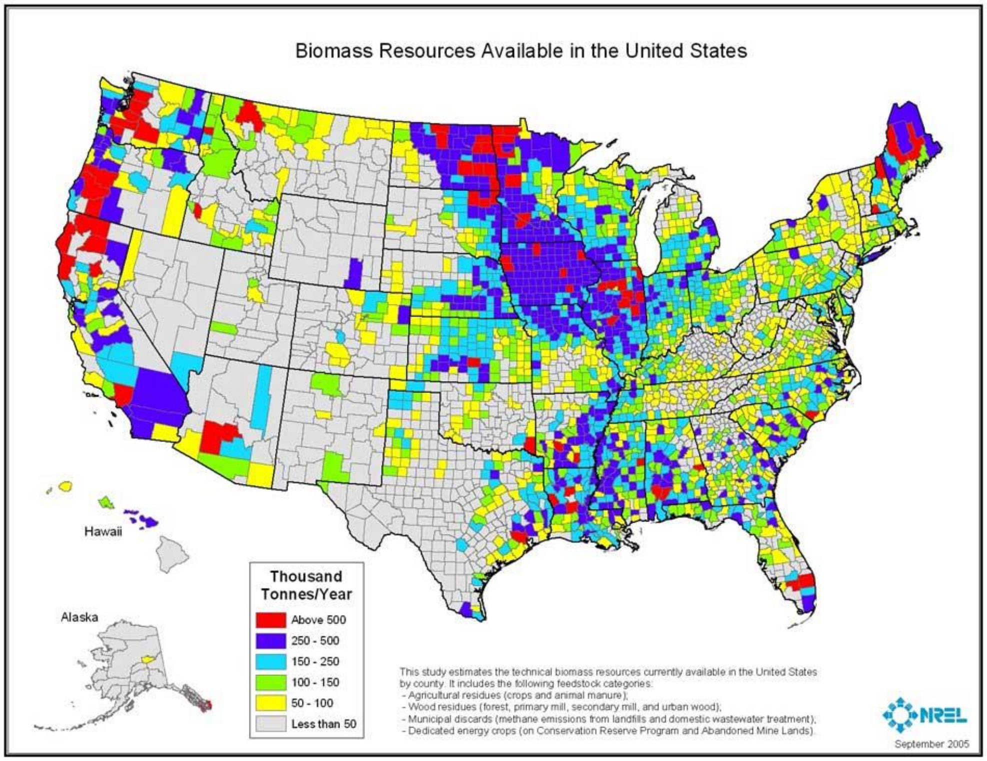
(United States Environmental Protection Agency, 2013)

There are three main variables that determine the efficiency of a turbine. The first factor is wind speed; wind turbines generate energy at wind speeds of 4-25 meters per second. If the wind reaches a speed of over 25 meters per second, the turbine stops because it can be damaged (Paraschivoiu, 2009). Secondly, the larger the radius of the blades, the more energy can be produced. If the blade radius is doubled, four times energy can be produced. Moreover, the height of the turbine also plays an important factor in determining the efficiency. The higher the elevation of the blades, the higher the wind speed is, which leads to higher efficiency. Lastly, heavier air exerts more lift on the rotor. Air density is a function of pressure, altitude and temperature. High-altitude locations have lower air pressure and "lighter" air so they are less productive turbine locations. The dense "heavy" air near sea level drives rotors more effectively. The maximum theoretical efficiency of wind energy is 59% (Smith, 2008). This efficiency is higher than most alternative renewable energy sources. Also, the capacity factor of a typical wind farm is 27% (National Renewable Energy Laboratory, 2013).

There are many aspects of wind energy that are crucial for an energy source and its impact on the future. Wind energy will produce jobs, while producing almost no pollution (Lynch, 2013). However, wind energy also has some drawbacks. First of all, even though wind can be found anywhere, it is only consistently strong enough to sustain a wind turbine in certain areas. Wind farms can also be extremely expensive to build and maintain properly. Wind turbines can create noise and vibrations, which negatively impact the health and social life of households in the area, therefore, wind farms are not usually built near residential areas (Keane, 2010). Because wind turbines have large, spinning blades, they pose a threat to the migration and flight patterns of birds and bats. Research shows that about 45,000 birds have been killed over the past 20 years from flying over wind turbines (Oconnor, 2013).

2.4 Biomass Energy

Biomass is derived from living, or recently living organisms, based in oxygen, carbon and hydrogen (Truini, 2012) . There are several sources of biomass such as woods, plants, and waste (industrial and agriculture waste). Figure 5 shows biomass resources available throughout the United States.



Biomass Resources Available in the United States

This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:
- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and domestic wastewater treatment);
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands).

September 2005

Figure 5. Biomass resources in the United States

(National Renewable Energy Laboratory, 2014)

The most common conversion technologies for utilizing biomass are: direct combustion and chemical decomposition (Dermirbas, 2001). Direct combustion is when biomass is burned to create high-pressure steam, which drives a turbine generator to produce electricity. According to EPA, typical boilers and steam turbines provide approximately 10 MW electric output from 100 MBtu/hr. The efficiency of biomass combustion is dependent of the moisture content of the biomass, the amount of excess air presented in the boiler and the amount of uncombusted or partially combusted biomass. Moreover, the type of biomass also has a substantial effect on the overall system efficiency as biomass with high specific heats and low moisture content can yield efficiencies up to 25% higher than biomasses having the opposite characteristics (U.S. Environmental Protection Agency (EPA), 2007).

Biomass can also be burned simultaneously in combination with coal in the coal-fired processes. This technique is considered a favorable option for biomass use because of the higher conversion efficiencies of the coal power plants (Dermirbas, 2001). In this co-firing process, up to 20% of the coal used in the boiler can be replaced by biomass, resulting in the reduction of fuel costs and harmful by-product gases emission (U.S. Department of Energy (DOE), n.d.)

Accordind to Dermirbas, another technique of converting biomass to electricity is chemical decomposition, which is done on a commercial-scale through the process of gasification. Biomass gasification occurs when biomass is decomposed by heating it in the presence of a catalyst and without air. Biomass is then decomposed into a combination of carbon monoxide, hydrogen, methane, carbon dioxide and nitrogen (Dermirbas, 2001). This mixture of gases is often called syngas and can be combusted in order to produce steam, which can be used to turn a turbine generator and produce electricity. The average energy conversion efficiency of wood gasifiers is about 60% - 70% and is calculated as the ratio of calorific value of gas per kilogram of fuel divided by the average calorific value of 1 kilogram of fuel. For gasifiers, the overall system efficiency is estimated to range from 10% to 13% (Rajvanshi, 1986). Generally, agricultural and forestry waste such as corn straw, wheat straw, rice husks and wood waste are commonly utilized for gasification. Even though the efficiencies of different processes vary, the capacity factor of a biomass power plant remains at 75%.

Biomass has a relatively high efficiency and various advantages. As reported by the Natural Resources Defense Council (NRDC), burning biomass releases ash which can be used as fertilizer on farms. No harmful sulfur or mercury emissions are produced during the combustion of biomass. Moreover, the burning process produces significantly less nitrogen emission compared to coal-fired processes. From an economic perspective, biomass energy helps to reduce agriculture waste as it utilizes a great deal of residue remaining after the plantation. There are also many disadvantages to biomass energy. The biomass industry competes for the lands that would commonly be used for food and fiber production (Natural Resources Defense Council (NRDC), n.d.). Potential environmental effects include nutrient depletion, impaired water and air quality at the sites where biomass is produced. Indeed, the feedstock, combustion technology, and types of installed pollution controls all contribute to the level of air emission. The most common pollutants include nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide, and particulate matter. Specifically, NO_x emissions causes ground-level ozone, or smog. This gas burns lung tissue and imposes health problems such as bronchitis, asthma, and other chronic respiratory diseases. Both SO_2 and NO_x contribute to the formation of acid rain and harmful particulate matter (PM) (Massachusetts Environmental Energy Alliance, n.d.). According to Massachusetts Environmental Energy Alliance, 135MW of biomass energy generation in Massachusetts is estimated to create:

- 492 tons of NO_x
- 98 tons of hazardous air pollutants (HAPs)
- 617 tons of CO
- 165 tons of PM
- 2.2 million tons of CO_2

The level of impact is vastly dependent on the site and must be assessed regionally (Natural Resources Defense Council (NRDC), n.d.). Installing and operating costs of a biomass-fueled power plant depends on interrelated subsystems, such as: the boiler, handling equipment, water treatment systems, etc. It also depends on the methods used to convert biomass to electricity and the amount of biomass supply (U.S. Environmental Protection Agency (EPA), 2007). No matter what equipment or method is used, the installation and maintenance process of biomass systems is expected to be extremely costly.

2.5 Hydropower Energy

Hydropower can be generated from both falling and running water. The process utilizes turbines to collect and transform potential and kinetic energy of the water into electrical energy (U.S. Department of the Interior, 2005). There are three common types of hydropower dams: conventional dams, pumped-storage dams and run-of-the-river dams (Office of Energy Efficiency & Renewable Energy, n.d.). A conventional hydropower plant is when water used for the plant is stored in a dam. A run-of- the river hydropower plant is when no dam is built to create water storage and the power plant is subject to the seasonal flows of the river. A pumped-storage plant is when water is pumped from a reservoir at low elevation to a reservoir at higher elevation. When energy is needed, the water stored in the higher reservoir will fall into the lower reservoir through turbines, which generates electricity. This type of plant is ideal for streams and rivers with a limited dry weather flow or that are regulated by larger dams and reservoirs upstream. Overall, pumped-storage plants consume more energy than it produces (Raja, Srivastava, & Dwivedi, 2006). Figure 6 demonstrates typical components of a conventional hydropower facility.

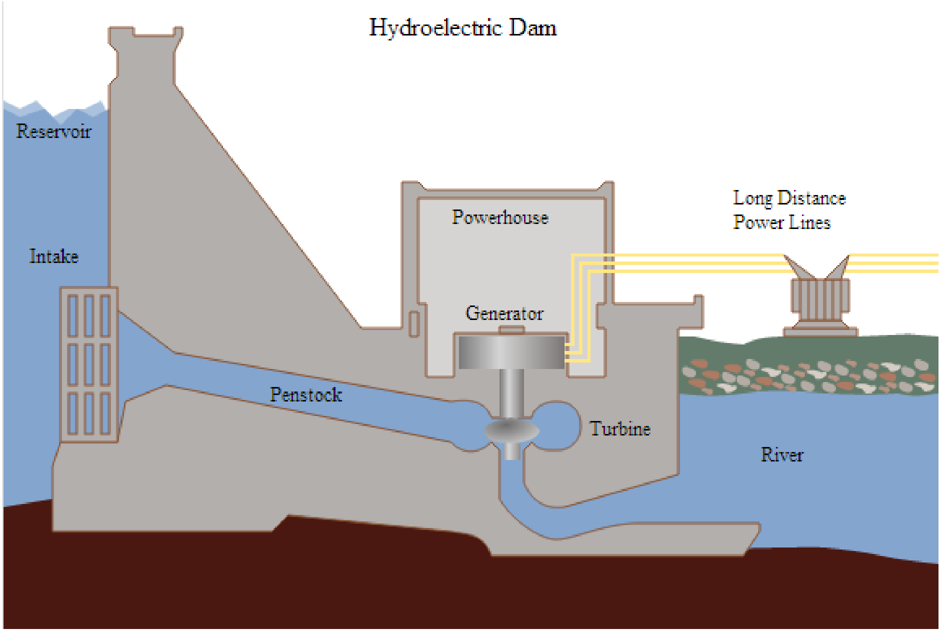


Figure 6. A conventional dammed-hydro facility.

(Tomia, 2007)

The amount of power generated from a conventional hydropower plant depends on many factors. The principal requirement of a dam is that it must be located close to a water source with specific characteristics to generate power. In order to determine the feasibility of a hydropower site, the amount of power that can be generated is calculated using this formula:

$$Power = Gross\ Head * Flow * System\ Efficiency * C$$

Where: Gross Head is the difference in height between the source and the water's outflow

Flow is the velocity of the water stream

System Efficiency is usually in the range between 40% and 70%; a well-designed system will have an efficiency of 55%

C is a constant representing gravitational acceleration, C = 9.81 in metric unit (Natural Resources Canada, 2005).

Hydropower sites are generally classified as high and low-head sites. "Low-head" indicates a change in elevation of no more than 10 feet, but the change in elevation of the water should be at least 2 feet for the system to be feasible (Oregon Department of Energy, n.d.). Generally, the higher the dam is, the more costly it is to construct. A low head when being combined with a high flow is still able to produce a reasonable electricity capacity, however, this method requires larger and more costly turbines (New, 2012). The capacity factor of a hydro power plant is 38% (National Renewable Energy Laboratory, 2013).

Most investors shy away from hydropower because of the tremendous cost of building a dam. Around 300-450 million dollars is required to build a hydroelectric plant, depending on the circumstances. The dam slows down the water, as a result, causing silt to build up (U.S. Department of the Interior, 2005). Silt build-up will require maintenance on the dam, which can become costly. The dam will change the habitat and landscape up-stream, as more land will be submersed. Marine populations will also be directly harmed. New technology has been developed to prevent the death of marine life, but this technology is extremely costly, therefore investors tend to use old technology instead. The land below the dam is also affected as the flow of water is reduced. The lakes that form behind the dam can be used for water sports and leisure activities. The lake's water can be used for irrigation purposes as well (U.S. Department of the Interior, 2005). An economic advantage of hydropower is that the production level can be adjusted based on the demand, as water can be stored and utilized at peak demand times. This IQP weighs the advantages and disadvantages of hydropower to determine its potential benefit to the region.

2.6 Geothermal Energy

Geothermal energy is generated from the heat within the Earth. It can be harnessed from hot water and hot rock found anywhere beneath the Earth's surface (Union of Concerned Scientists, 2009). According to the U.S. Department of Energy, electricity can be generated from geothermal energy through three different processes: dry steam power plants, flash steam power plants, and binary cycle power plants. In dry steam plants model, hot steam from geothermal reservoirs is pumped into the generators located inside the power plant. Electricity is generated as the steam spins the turbines. Flash steam plants utilizes hot water to produce electricity. Specifically, hot water, between 300 and 700 degrees Fahrenheit, is pumped in to a tank, and some of which turns to steam, which drives the turbines. When cooling, the steam condenses back into water and is returned to the ground. Binary cycle plants pump moderately hot geothermal water into a tank. It is then passed through a heat exchanger, where its heat is transferred to a liquid that boils at a lower temperature than water. When that fluid is heated it turns to steam, which spins the turbines (U.S Department of Energy, 2012). Figure 7 depicts a typical design of a flash steam power plant.

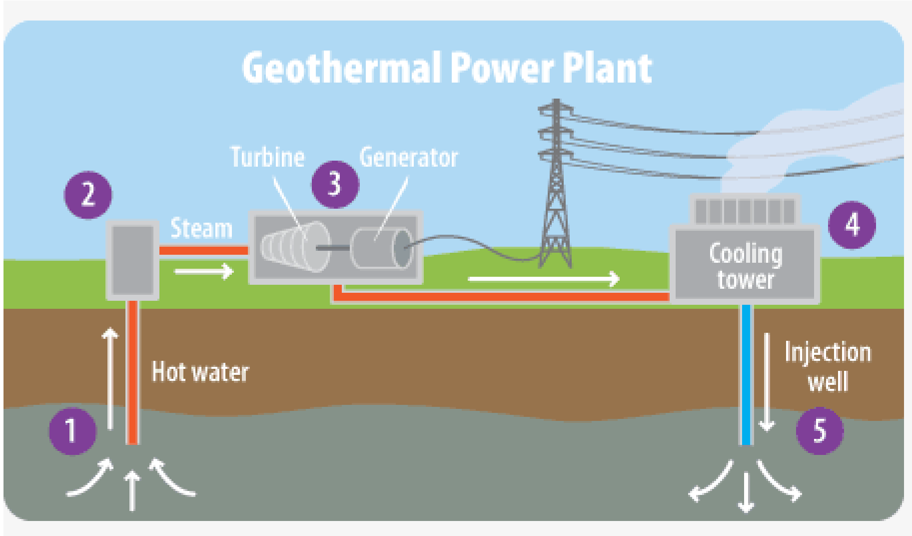


Figure 7. Geothermal Power Plant

(United States Environmental Protection Agency, 2013)

The efficiency of a geothermal power plant is mainly dependent upon the temperature of the geothermal fluid. The higher the temperature is, the more efficient the plant is. The use of low temperature fluids allows the efficiency to be typically between 7-12%. For higher temperatures, efficiencies of over 20% can be achieved. Geothermal energy is not popular on the commercial scale; therefore, more research needs to be conducted in order to have a thorough understanding of the efficiency (Bertani, 2010). The capacity factor of a geothermal unit is 58% (National Renewable Energy Laboratory, 2013).

Evaluating a potential site for a geothermal power plant is a very complicated and expensive process. The typical procedure of assessing feasibility of a geothermal site includes 4 phases (Geothermal Energy Association, 2012):

- Phase I: Resource Procurement and Identification
- Phase II: Resource Exploration and Confirmation
- Phase III: Permitting and Initial Development
- Phase IV: Resource Production and Power Plant Construction

In phase I, research is conducted to identify a suitable source of geothermal energy that meets all the requirements for the plant. In phase II, exploration is carried out to confirm the quality and availability of the source, which is a very complex procedure. The initial site inspection for geothermal energy consists of the following steps: determining the temperature, the depth of the water stream, the size of the aquifer, and other properties. These activities require advanced and expensive technologies. Moreover, this particular step takes place over a long period of time to assure the feasibility of the site, resulting in significant research cost. In the next phase, permissions from various authorities need to be obtained so that the plan can be initially developed. The last step is to exploit the geothermal resource and to construct the power plant (Geothermal Energy Association, 2012).

Geothermal is a non-polluting and environmentally-friendly renewable energy source. Geothermal energy produces no waste or by-products and the processes used are independent of weather conditions. In addition, geothermal power plants don't occupy much space and they require no fuel or transportation of resources (Lund, 2007). There are disadvantages to geothermal energy, too. Initial build costs of geothermal power plants can be high, as it requires preliminary research and experimental drilling, followed by more drilling to put pipes in place. The drilling can sometimes result in seismic activity; some geothermal projects have been stopped mid-build because of the seismic activity that occurred. Geothermal sites also run of risk of releasing harmful gases and toxins that would have otherwise been trapped in the Earth (Conserve Energy Future, n.d.)

2.7 Permitting

In order to construct a renewable energy facility on a brownfield, an investor needs to go through a permitting process in order to ensure the practicality of the facility. The permits obtained from these authorities are meant to ensure that the potential power plants meet certain requirements of a commercial-scale project. These requirements concern mainly the environment and the well-being of the surrounding neighborhoods. Permitting agencies also review the cost-benefit tradeoffs associated with impact mitigation strategies. The overall process will maintain the balance between making a project acceptable to the community and preserving the project’s economic capability in a competitive electricity market.

Generally, a power plant is required to obtain permits from the three governmental levels simultaneously. State and federal permits are commonly acknowledged and applicable for different towns while the local permitting process will depend on specific town or city requirements. Local permits will mainly involve local grading or building permits to ensure compliance with structural, mechanical and electrical codes. The process is not only costly, but also time-consuming, since many investigations and inspections need to be conducted to ensure regulations are being met. There are some common regulations that apply to all renewable energies; however, there are also various policies that pertain specifically to each type. Moreover, as brownfields are abandoned lands due to contamination, approvals must be acquired in order to guarantee that construction on the lands will neither create hazards to the community nor increase the level of contamination.

According to the National Wind Coordinating Committee (NWCC), most permitting processes for energy facilities consist of five basic steps: Pre-application, Application Review, Decision Making, Administrative and Judicial Review and Permit Compliance. During the pre-application phase, a project developer and permitting agency meets to help ensure that both understand the project concept, permitting process and possible issues. Application Review begins when the project developer files a permit application. The agencies review the application to ensure that it contains the necessary information. Any needed inspections would take place during this phase. The permitting agency then enters the decision making stage. During this stage, the agency not only determines whether or not to allow a proposed facility to be constructed or operated, but whether environmental mitigation and other construction or operation constraints are needed. The project developer then has the chance to appeal the decision in the administrative appeals and judicial review stage. The developer is then responsible for permit compliance, which extends throughout a facility's lifetime. This stage may include inspection or monitoring to ensure that the project is constructed, operated and decommissioned in compliance with the terms and conditions of its permit and all applicable laws (National Wind Coordinating Committee (NWCC), 2002).

Prior to the construction of the facility, in addition to the permitting process, the investor also need to obtain a Power Purchase Agreement (PPA) with the local electrical provider or the company that operates the electrical grid in the area. A PPA is a contract between the facility, usually addressed as the seller and the electrical provider, the buyer. All of the commercial terms regarding the sale of electricity between the two sides were defined in the PPA. These terms will include the commercial operation starting time, schedule for electricity delivery, payment terms, charges for under delivery, and contract termination. There are many forms of PPA in use today, which vary according to the needs of the buyer, seller, and financing counterparties. The validation of the agreement is expected in the range between 5 years and 20 years (Thurman & Woodroof, 2009).

PPAs are typically subjected to regulation at the state and federal level to varying degrees depending on the nature of the PPA and the extent to which the sale of electricity is regulated. The Federal Energy Regulatory Commission determines which facilities are considered to be exempt wholesale generators or qualifying facilities and are applicable for PPAs under the Energy Policy Act of 2005.

2.8 Government Programs & Incentives

The United States and Massachusetts governments strongly encourage the use of renewable energy by offering appealing incentives. The state and local incentive programs may provide low cost loans along with grants or tax incentives to cut down the initial as well as operating and maintenance costs of utility scale renewable energy installations. According to the National Association of Local Government Environmental Professionals, the Renewable Electricity Production Tax Credit (PTC) and the Business Energy Investment Tax Credit (ITC) are the two most recognized tax incentives for renewable energy production. The PTC provides a 2.2¢/kWh payment for wind, geothermal, and closed-loop biomass and a 1.1¢/kWh payment for other eligible technologies. Moreover, this tax credit also applies to the first ten years of operation, with some exceptions (National Association of Local Government Environmental Professionals, 2012). The ITC provides a corporate tax credit depending on the value of the qualifying property: 30% for solar, small wind turbines, or fuel cells, 10% for geothermal systems, and combined heat and power systems (Database of State Incentives for Renewables & Efficiency, 2013).

Moreover, the Renewable Energy Production Incentive (REPI) provides incentive payments for electricity generated and sold by new qualifying renewable energy facilities. Qualifying systems must utilize solar, wind, geothermal, biomass to generate electricity

(U.S. Environmental Protection Agency, 2014). New Clean Renewable Energy Bonds ("New CREBs") and Qualified Energy Conservation Bonds ("QECBs") are federal tax credit bonds available for the financing of a variety of renewable energy projects, including photovoltaic, wind, biomass, and hydroelectric. Interest on the bonds (100% in the case of CREBs and 70% in the case of QECBs) is paid by the federal government through tax credits to bondholders, significantly reducing borrowing costs for bond issuers (U.S. Department of Energy).

The federal government also provides several tax incentive programs to promote redevelopment. These programs serve as means to support brownfield-sited renewable energy projects. For example, the Brownfields Expensing Tax Incentive allows federal taxpaying owners of qualifying brownfield properties to reduce their taxable income by the costs of cleanup expenses. The New Markets Tax Credit allocates tax credits to certified Community Development Entities (CDEs). CDEs offer these tax credits to private-sector investors and use the investors' equity to make investments in low-income communities. More information on federal tax incentives that can support brownfield investments can be found in EPA's comprehensive guide (United States Environmental Protection Agency, 2011).

In addition to tax incentives, there are federal government loan and grant programs available to assist in brownfields redevelopment activities and support development of renewable energy projects. The EPA manages a number of key brownfields redevelopment programs, including grants to cover the assessment of brownfield sites, grants for the cleanup of such sites, revolving loan fund grants, and brownfields-related job training grants. These grants and assistance programs can provide substantial help to local governments throughout the brownfield redevelopment process, including, critically, at the outset, when local governments are looking to assess the feasibility of renewable energy projects in their communities. Businesses also have the opportunity to recover investments via the Modified Accelerated Cost Recovery System (MACRS). MACRS is a method of depreciation in which a business' investments in certain tangible property are recovered, of tax purposes, over a specified time period through annual deductions (Solar Energy Industries Association).

Furthermore, the Massachusetts commonwealth has many financing and ownership options for the installation and operation of renewable energy technology. Table 1, obtained from the Database of State Incentives for Renewables & Efficiency, lists fundamental incentives offered by the Massachusetts government.

Table 1. Summary of Renewable Energy Incentives in Massachusetts

(U.S. Department of Energy, n.d.)

Name	Incentive type	Eligible Renewable	Summary
Excise Tax Exemption for Solar- or Wind-Powered Systems	Corporate Exemption	Solar and Wind	"Massachusetts law exempts any solar or wind powered system that qualifies for the state's excise tax deduction for these systems from the tangible property measure of the state's corporate excise tax."
Local Option – Energy Revolving Loan Fund	PACE Financing	Solar, locally determined	"Property-Assessed Clean Energy (PACE) financing effectively allows property owners to borrow money to pay for energy improvements. The amount borrowed is typically repaid via a special assessment on the property over a period of years. "
Renewable Energy Property Tax Exemption	Property Tax Incentive	Solar, Wind and Hydro	"Massachusetts law provides that solar-energy systems and wind-energy systems used as a primary source of energy needs of ***taxable property*** are exempt from local property tax for a 20-year period. Hydropower facilities are also exempt from local property tax for a 20-year period if a system owner enters into an agreement with the city or town to make a payment (in lieu of taxes) of at least 5% of its gross income in the preceding calendar year."

Solar Renewable Energy Credits (SRECs)	Performance-Based Incentive		“Solar Renewable Energy Certificates (SRECs) represent the renewable attributes of solar generation, bundled in minimum denominations of one megawatt-hour (MWh) of production. Massachusetts' Solar Carve-Out provides a means for SRECs to be created and verified, and allows electric suppliers to buy these certificates in order to meet their solar RPS requirements. All electric suppliers must use SRECs to demonstrate compliance with the RPS. Only solar-electric facilities built after January 1, 2008, may be qualified to generate SRECs. Generators must apply in order to participate in this program. Facilities that received funding prior to the effective date of the Solar Carve-Out from the Massachusetts Renewable Energy Trust or the Massachusetts Clean Energy Center, or received more than 67% of project funding from the American Recovery and Reinvestment Act of 2009, are ineligible.”

In addition to these incentives, there are also many programs which encourage the usage of renewable energy. Some of the principal programs that are most relevant to this IQP are summarized in Table 2.

Table 2. Summary of Renewable Energy Programs in Massachusetts

(U.S. Department of Energy, n.d.)

Program	Eligible Renewable	Summary
Commonwealth Commercial Wind Program	Wind energy	"Through the Commonwealth Wind Incentive Program – Commercial Wind Initiative the Massachusetts Clean Energy Center (MassCEC) offers site assessment grants of services, feasibility study grants, and development grants and loans for commercial wind projects 2 MW or greater that will serve the whole-sale energy markets or for projects that do not qualify for net metering but provide on-site use."
Commonwealth Wind Incentive Program – Micro Wind Initiative	Wind energy	"Through the Commonwealth Wind Incentive Program – Micro Wind Initiative the Massachusetts Clean Energy Center (MassCEC) offers rebates of up to $4/W with a maximum of $130,000 for design and construction of customer-sited small wind public projects and rebates of up to $5.20/W with a maximum of $100,000 for non-public projects."
Renewable Energy Portfolio Standard (RPS) Class I	Solar photovoltaic, Wind energy, geothermal energy	"The RPS proposes that all retail electricity suppliers must provide a minimum percentage of kilowatt-hours (kWh) sales to end-use customers in Massachusetts. The 2010 RPS Class I requirement is 5%, and is set to increase by one percent each year. It is met through electricity production from qualified New Renewable Generation Units. New Renewable Generation Units are facilities that began commercial operation after 1997 and generate electricity using any of the mentioned technologies."
RPS Class II		"RPS Class II mandates that a minimum percentage of electricity sales come from each of two sources, renewable

		energy and waste energy. The current RPS Class II Renewable Generation obligation is 3.6%, and the Waste Energy Generation obligation is 3.5%. The obligation does not increase annually. A Supplier must comply with both the minimum percentage of Renewable and Waste Energy obligations.”
RPS Class II Renewables	Solar, Wind, Geothermal	“Similar to RPS Class I, this class pertains to generation units that use eligible resources such as sunlight, wind, ocean, landfill methane gas, small hydropower, and geothermal, but have an operation date prior to January 1st,1998. Therefore, RPS Class II provides financial incentives for the continued operation of qualified pre-1998 renewable generation units.”

On the other hand, many policies set regulations for the installation and operation of renewable energy technology. For example, a solar access provision allows for the creation of voluntary solar easements to protect solar exposure and authorizes zoning rules that prohibit unreasonable infringements on solar access. There are also a few other minor regulations listed on the Database of State Incentives for Renewables & Efficiency website that are relevant to this IQP. These rules and policies set requirements that a commercial-scale renewable energy facility has to meet in order to ensure the well-being of the community.

2.9 Brownfields

A brownfield is a portion of abandoned land that is challenging to expand upon, redevelop, or reuse because of the presence or potential presence of a hazardous substance, pollutant, or contaminant (U.S. Environmental Proctection Agency (EPA), n.d.). Most commonly, brownfields were previously used for industrial or commercial purposes and the previous owners could not fund remediation for the site. Generally, brownfields do not contain a high enough level of contamination to pose a serious health or environmental threat. Sites that do cause a serious threat are referred to as superfund sites and are governed under a completely separate set of legislation from brownfields (Corona, 2004). For the purposes of this IQP, superfund sites will not be considered as feasible sites for renewable energy.

Brownfields do not induce an immediate health or environmental threat, but they do create a social and economic threat to the area in which they reside. They are often considered "eyesores" and hinder redevelopment as well as economic growth in the area. Investors are often turned away by worries about liability as described under the Comprehensive Environmental Response, Compensation, Liability Act of 1980 (CERCLA). If additional contamination is found on the site, the investor will be held liable for cleanup. If this process if not completed correctly, the redevelopment will run into problems and result in heavy losses (Corona, 2004).

From an investor's point of view, initially brownfields may not be favorable choice, but their properties are most often inexpensive real estate in prime locations. Many brownfields have access to roads, electricity, heating, and plumbing already, as they were probably parts of the industrial sections of a city. Investors may also be able to integrate existing buildings, plumbing, or other infrastructure into construction, cutting back on costs. Redeveloping brownfields can bring jobs back to the area and increase the value of surrounding properties as well. The main advantage of redeveloping a brownfield is the tax incentives and funds encouraging the redevelopment of brownfields (U.S. EPA). The Small Business Liability Relief and Brownfields Revitalization (SBLRBR) Act, also called the "Brownfields Law", encourages private investment in brownfield properties. The Brownfields Law amended CERCLA by providing funds to assess and clean up brownfields, thereby taking some of the pressure off of the investor. The Brownfields Program, hosted by the EPA, gives an extensive framework of policies regarding brownfield cleanup and provides extensive grants and funding opportunities for assessment, cleanup, workforce training and technical assistance.

2.10 Brownfields Development and Renewable Energy

Many renewable energy projects have been met with objections from the public, especially in the Northeast. Much of the population has a “not in my backyard” or NIMBY attitude and believe that large renewable energy projects are an “eyesore”. NIMBY implies opposition of residents to a proposal for a new development because it is too close to them, often with the connotation that such residents believe that the developments are needed in society but should be further away. Hence, developers encounter more difficulties in obtaining permits, and therefore many competitors are driven out of the area. Sequentially, suppliers find it hard to meet quotas set forth by the Renewable Energy Portfolio Standards (Bowles, 2010).

The public also has a similar opinion about brownfields and expects them to be redeveloped and utilized. A renewable energy project might even be considered more acceptable than a brownfield by some people. A renewable energy project on green land may be seen as unnecessary, but an energy project on a brownfield can be considered as making good use out of otherwise unusable land. It is a land revitalization effort instead of degradation and helps with problems related to urban sprawl (U.S. Environmental Protection Agency, 2013). Redevelopment of brownfields with renewable energy can increase the public image of renewable energy.

The EPA has also realized the benefits of repurposing brownfields for green energy purposes. In 2008, the RE-Powering America’s Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites initiative was put into effect. The purpose of this initiative is to promote siting renewable energy generation facilities on brownfields by providing technical and financial assistance. The EPA has partnered with the National Renewable Energy Laboratory (NREL) in order to better assist investors. The EPA offers expertise on brownfields revitalization, while the NREL specializes in assessing the best renewable energy technology for a site, the potential electricity generating capacity of the technology used and the economic feasibility of the project (U.S. Environmental Protection Agency, 2011). The initiative offers many resources for siting renewable energy on brownfields and even pre-screens site for renewable energy potential.

In addition to technical and financial support from government agencies, repurposing brownfields to generate green energy has various advantages for the developer to consider as well. A brownfield will most likely have existing infrastructure on the site that can be incorporated into the new site plan. It will also most likely be connected to the grid already and not require new transmission lines to be installed. Brownfields clean-up regulations are also less strict with commercial and industrial uses than with residential uses as well.

With all of these advantages, implementing renewable energy on brownfields is a very important initiative. It will improve the public image of renewable energy and help to build a thriving, competitive renewable energy market in the Northeast.

3. Methodology

The critical goal of this IQP is to develop a selection tool that summarizes the characteristics and site requirements for power facilities using different types of renewable energy including solar, wind, biomass, hydro and geothermal energy. This tool will be used to analyze the feasibility of implementing renewable energy facilities on brownfields in the area. In order to achieve the principle goal, the following objectives need to be accomplished:

- Research different types of renewable energy and their characteristics
- Conduct a preliminary screening of data to better focus our project
- Develop a product outlining site criteria for renewable energy
- Conduct a case study

3.1 Background research and inquiry on the region

This project is designed to meet the principal expectations of both the Economic Development Administration (EDA) and the Montachusett Regional Planning Commission (MRPC), which is to "provide a framework of the specific actions needed to achieve a reliable, affordable and environmentally sound future desired by the region" (Montachusett Regional Planning Commission, 2011). In order to obtain a better understanding of the specific actions needed, online and literature researches were conducted, as well as interviews with related professional parties.

Initially, online research was conducted to identify basic information about the Montachusett region, the EDA grant, each type of renewable energy, various site selection criteria, brownfields and brownfield redevelopment. The information obtained on renewable energy included the energy source, different technologies used to generate electricity, their specifications and efficiency. Moreover, we also inquired about the social and environmental impacts of each type of energy, along with the cost, governmental policies and incentives. As online research alone did not supply us with in-depth knowledge needed for our project, we sought out professional articles and papers. The research tools that we used consisted of Google Scholar and WPI library resources. Notably, WPI library resources also provided us the opportunity to find references from previous related IQPs. With these resources, we were able to complete our background chapter, as well as gather some of the necessary information for our final tool.

As we progressed with the project, we encountered difficulties in obtaining certain pieces of data. Hence, we contacted the consulting group hired by the MRPC, Boreal Renewable Energy Development. Via email and conference call, we discussed our project with Robert Shatten and Tom Michelman, the co-founders of Boreal Renewable Energy Development. Through our conservation with the consultants, we were able to obtain the information needed to proceed with our project. Some of the conclusions drawn as a result of our conversation are highlighted in the next section.

3.2 Preliminary Renewable Energy Screening

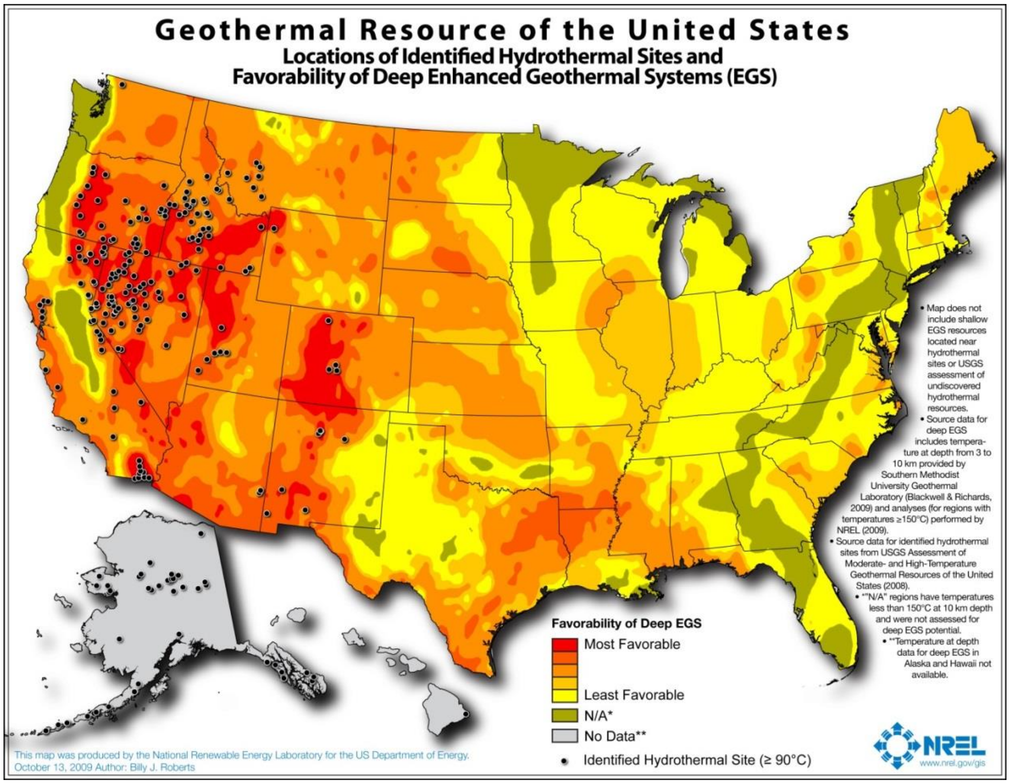
While gathering all necessary data, decisions had to be made as to which renewable energies to include in the project. After much consideration and analysis, hydropower and geothermal were excluded from the remaining research based on various criteria.

3.2.1 Exclusion of Hydro Power

As a part of our research, we attended a seminar on hydropower in the region held in Pepperell Town Hall on November 7, 2013. At the seminar, recent hydropower projects were discussed in detail and a tour of Pepperell Hydro Power Plant was given. We learned that in the past 50 years, the region has not seen any new hydropower dams built based on the factor of cost alone. An analysis of cost together with a review of environmental impacts is also provided in section 2.5 of the Background Chapter (page 18 and 19). Instead of building new dams, the region has seen many dams and mills being renovated and turned into working power plants. According to MRPC officials, there are no brownfields in the area that are both located near a water source and have a mill or dam that could potentially be renovated. Consequently, we made the decision to exclude hydropower from further analysis.

3.2.2 Exclusion of Geothermal Energy

Our research on geothermal energy led us to a similar conclusion as with hydropower, but for different reasons. Through our online research, we learned that geothermal resources in the New England area, and especially in Massachusetts, are not sufficient for commercial level electricity generation.



Geothermal Resource of the United States
Locations of Identified Hydrothermal Sites and
Favorability of Deep Enhanced Geothermal Systems (EGS)

- Map does not include shallow EGS resources located near hydrothermal sites or USGS assessment of undiscovered hydrothermal resources.
- Source data for deep EGS includes temperature at depth from 3 to 10 km provided by Southern Methodist University Geothermal Laboratory (Blackwell & Richards, 2009) and analyses (for regions with temperatures ≥150°C) performed by NREL (2009).
- Source data for identified hydrothermal sites from USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the United States (2008).
- *"N/A" regions have temperatures less than 150°C at 10 km depth and were not assessed for deep EGS potential.
- **Temperature at depth data for deep EGS in Alaska and Hawaii not available.

This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
October 13, 2009 Author: Billy J. Roberts

Figure 8. Geothermal Resources in the United States.
(National Renewable Energy Laboratory, 2013)

As shown in the figure above, Massachusetts is colored with yellow, which indicates that this area is one of the least favorable locations for geothermal energy. This project is focused on commercial-level electricity production and the amount of energy needed for the process to be feasible cannot be obtained in New England very easily. This conclusion was also confirmed by the Boreal consultants in the conference call.

Due to the lack of resources in the area, the complicated process to find a feasible site as described in section 2.6 of the Background Chapter, as well as the cost factor, we chose to exclude geothermal from the renewable energies that will be in our final tool.

3.3 Tool Design

The major goal of this project is to develop a tool that developers can use when siting renewable energy options. This tool is expected to provide a guide for investors to determine which type of energy among the three—solar, wind and biomass—is the most feasible at a site. Prior to creating a design for our tool, we researched tools that had been previously generated for similar purposes. We found many resources for developing renewable energy on brownfield sites, but the tool provided by the Re-Powering America's Land initiative was the most helpful (United States Environmental Protection Agency, 2013). After reading through this document, we decided to use this tool as inspiration for our own design (United States Environmental Protection Agency, 2013). However, this tool was very complex and comprehensive for the purposes of our project, so we wanted to construct a more simplified and user-friendly version. The following process was used in designing the tool.

3.3.1 Determining Site Criteria

The first step in designing the tool was to determine which criteria developers would look for in a site. Through our research and conference call with the Boreal consultants, we learned that there are certain characteristics of the site that are crucial to the feasibility of power facilities. These characteristics include:

- Land requirement
- Amount of resources
- Cost
- Incentives/ Programs
- Permitting
- Extra considerations

A brief explanation of each criteria can be found in the Supporting Document in the Appendix. We believe these criteria provide a comprehensive basis from which to pre-screen sites for renewable energy feasibility. It gives the developer a glimpse into the physical requirements of the sites and the responsibilities and opportunities associated with them.

3.3.2 Gathering Chart Data

Through our research and conference call, we were able to gather most of the necessary information in order to complete the tool. Since we knew neither the generation capacity, nor the area of the potential power plant, it was necessary to obtain land requirement and cost per unit area or unit capacity. In order to acquire these numbers, we manipulated data found through online research by dividing the total cost and land requirement by the total area or the total capacity. These calculations can be found in the supporting document in the Appendix. Most of the information for amount of resources, permitting and extra considerations was obtained from the consultants via conference call. The incentives and programs for each type of renewable energy can be found in section 2.8 of the background chapter. In order to obtain information regarding biomass energy, which could not be found through our online research, we contacted Michael Buckman, the plant manager of Pinetree Power Fitchburg via e-mail. He was able to provide us with all of the necessary data to complete the chart.

3.3.3 Tool Development

The next step was to determine the appropriate format for our final product. Initially, we considered three options: flowchart, interactive application and table. After much review, the final design for this tool will take the form of a table, with renewable energies in rows and site characteristics in columns.

We came to this decision for several reasons. A flowchart consists of a sequence of questions, where the answer to the preceding question will lead to the next one. Even though the Re-Powering America's Land tool, created by the EPA, used a flowchart, we determined this was not a suitable format for our purposes (United States Environmental Protection Agency, 2013). The EPA created a separate tool for each type of renewable energy. We wanted to create a tool that included all three energies in one product. At a meeting with MRPC and Boreal consultants, the idea of an interactive application for our tool was mentioned. We took this into consideration, however, this option would require a lot of time and expertise in computer programming. Due to our lack of knowledge on the matter and tight schedule, this option was eliminated as well. Moreover, as we scrutinized the screening criteria used to evaluate renewable energy potential approved by EPA and NREL (United States Environmental Protection Agency, 2013), it was determined that the most suitable layout for our tool is a table, as pictured below:

Table 3. Proposed Chart Layout

	Permitting	Land requirement	Amount of Resources	Extra Considerations	Cost	Incentives/ Programs
SOLAR						
WIND						
BIOMASS						

The table provides a general overview of site requirements. Moreover, it allows developers to compare and contrast requirements for different energies easily and effectively.

3.4 Brownfield Case Study

The next objective for this project was the application of the tool to the special case of a brownfield. With a completed chart, we executed a case study to serve as an example of how to use our product.

3.4.1 Brownfield Screening

In order to implement our final product, we chose a brownfield to apply our tool to as our case study. The initial step was to obtain a list of brownfields from Renee Marion, a GIS analyst at the MRPC. The list was sent to us first in GIS format and then later in an excel spreadsheet. The list included 81 sites from the 22 communities within the Montachusett region and contained a brief description of the site, street location and a link to its file in the MassDEP searchable sites online database. It also provided a MassDEP tracking number, region number and a tier classification; however, this information was not used in our analysis.

From the 81 sites on the list, we were able to narrow down our search fairly quickly, using siting guidelines provided by the U.S. Department of the Interior (U.S.Department of the Interior, 2013) and additional recommendations from the MRPC. To begin, we did not consider any sites labeled as “residential” in the description for three reasons:

1. Any energy development in a residential area would more than likely illicit a negative reaction from the neighbors.
2. Most residential sites would not be large enough for an investor to make profit on any energy implemented on the site.
3. Contamination at residential brownfield sites normally means that there was a small spill of heating oil, but that the site may still be in use.

Next, we narrowed down the list further by looking at the current development in the area. Brownfield sites that were near commercial businesses or generally high traffic areas were not considered because an energy project in that area would most likely be met with objections from the public. A renewable energy project could also affect the surrounding businesses because of noise, shadow flicker, glare and pollution problems.

The final aspect that we looked at when narrowing down the list of brownfields was acreage. Wind and solar farms require much more land, but through our research, we found that the minimum land requirement for a biomass plant was five to six acres. Hence, any sites smaller than five to six acres were not considered.

After eliminating sites due to the restrictions described above, the list of 81 sites was narrowed down to approximately ten. The next step in identifying a brownfield for our case study was to conduct research on each site. For each site, we looked at specific location details including proximity to highways, hospitals, schools or any other populated areas. We also looked to see if a business was operating at each site, if so, then it was not considered. With these further conditions, we were able to identify three appropriate sites for a case study.

3.4.2 Brownfield Historical Research and Site Visit

After selecting the three brownfields, we then visited them to conduct a site inspection. Via these visits, we gained first-hand knowledge of the site and were able to evaluate the terrain for shade, neighboring buildings, landscaping and the economic status of the area, etc. Furthermore, being aware of existing infrastructure at the site would allow us to evaluate its benefits. For example, an abandoned warehouse could be renovated to satisfy the requirements of a biomass plant. Hence, we would have to take into account the cost to either repair or demolish the existing facility. The site visits served as an important part of testing our final product

3.4.3 Table Implementation

After gathering all necessary data for our brownfield case study, the next step in our project was to apply our tool in the evaluation of the brownfield to identify the renewable energy facility most feasible for the site. The steps for applying the table and all other details can be found in the supporting document located in the Appendix. After interpreting the best renewable energy for the site, our selection process identifies information on costs, incentives, governmental policies, and other considerations.

3.4.4 Impact Analysis

Another important aspect of any energy development project is the environmental, social and economic impacts that it will cause on the surrounding area. As a part of our case study, we outlined and analyzed the predicted effects that the proposed project will have, drawing from information gathered throughout our research.

While looking at environmental impacts and utilizing knowledge gained while completing our background research, we predicted how the existing environment and landscape at the site will be affected. We also predicted any air, land or water pollution that may result. Existing contamination at the site was also be taken into account. An energy project may also affect the economic status of an area by creating new jobs. Our analysis predicted the impact of these new jobs. Lastly, we predicted possible social reactions from the neighboring community. These reactions may be dependent on the environmental and economic impacts, but may also be a result of any inconveniences caused by the project, such as solar glare, shadow flicker, decrease in land value and noise complaints.

4. Case Study

In order to test the viability of our chart and supporting document, we conducted a test case. We used the process described in our Methodology to choose a suitable brownfield in the Montachusett region. We then followed the steps provided in our supporting document to apply the tool. This process is described in the following sections.

4.1 Site selection

The initial list of brownfields provided by MRPC consisted of 81 brownfields, but only three satisfied the requirements of our project: Coolidge Park, 1537 Central St, and 110 Burrage St. Next, we conducted background research on each brownfield to obtain basic information such as an address, past usage, level of contamination, and other relevant features. After the research, we visited the sites to acquire a visual perspective as well as to gather further information. Via the site inspection, we were able to eliminate two out of the three brownfields.

1. <u>Coolidge Park, 0 Pearl Street Fitchburg MA</u>:

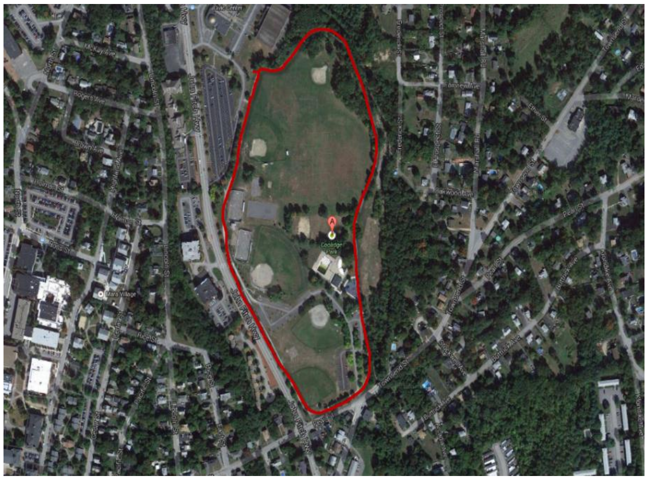


Figure 9. Satellite view of Coolidge Park

(Google Maps)

Figure 10. The Swimming Complex at Coolidge Park.

When researching Coolidge Park, it was considered the best candidate for our project because it was large enough to accommodate any type of renewable energy facility and was set apart from any residential areas. However, upon visiting the site in person, we realized that it had already been redeveloped.

Figure 12. Playground at Coolidge Park.

Figure 11. Baseball field at Coolidge Park.

Figures 10, 11, and 12 demonstrate that this location has been renovated to a recreation area, including a playground, a swimming complex, three baseball fields, two softball fields and one basketball court. Since the brownfield had already been redeveloped, it was eliminated from our list.

2. <u>1537 Central St, Leominster:</u>

Although the brownfield located at 1537 Central St, Leominster had sufficient land for the construction of a renewable energy facility, there were others factors that caused us to eliminate it from our list. First, as shown in Figure 16, the land is very hilly; consequently, it would be costly and challenging to level out the area in order to build a new facility.

Figure 14. Satellite view of 1537 Central St.

(Google Maps)

Figure 13. Business near 1537 Central St.

Moreover, there is an operating business across the street from the site, as pictured in Figure 14. Developing a power plant next to a business could potentially have a negative impact on the area.

Figure 16. View of the site.

Figure 15. Another view of the site.

3. <u>110 Burrage St, Lunenburg:</u>

After eliminating the above two sites, we were able to select one suitable site for our purposes. The chosen site was the S Penniman Sewer Service located at 110 Burrage St, Lunenburg, MA.

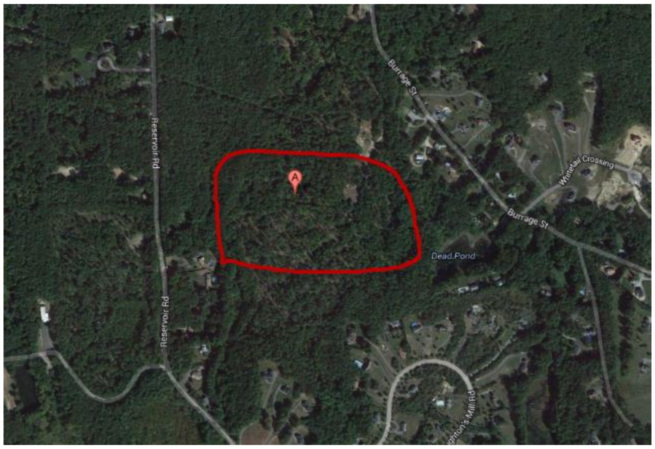


Figure 17. Satellite view of 110 Burrage St.

(Google Maps)

Figure 19. Picture 1 taken at 110 Burrage St.

Figure 18. Picture 2 taken at 110 Burrage St.

The site consists of approximately 50 acres, which is adequate for our purposes. We obtained this information from the Hearthstone Agency, whose phone number was provided at the site (Figure 18). The location was considered the best fit as it was not surrounded by residential area, as shown in Figure 17, and the nearby land seemed to be vacant, thus, making it possible for future expansion of the facility. The area was also relatively flat, making construction of the plant easier.

4.2 Chart Implementation

After selecting a brownfield site for our case study, we applied the steps given in the chart to determine which type of renewable energy was most feasible at the site. The steps can be found in the supporting document of the chart in the Appendix.

4.2.1 Calculate maximum output using area

The area of the site was approximately 50 acres. Using this number along with the land requirement ratios given in the tool, we were able to calculate maximum electricity capacity of the potential power plant. Next, applying this number to the equation mentioned in part 3.3.4 of the Methodology, the expected actual electrical output of the facility was determined. The calculations are shown below:

a. Solar:

- Maximum electricity capacity is in the range

$$\frac{50\ acres}{7.6\ acres/MW} = 6.6\ MW \sim \frac{50\ acres}{5\ acres/MW} = 10\ MW$$

The capacity factor of solar energy is 15%; hence, we have:

- Actual Capacity is in the range

$$(6.6\text{ MW} * 15\%) = 0.975\text{ MW} \approx 1\text{ MW} \sim (10\text{ MW} * 15\%) = 1.5\text{ MW}$$

- Annual output is in the range

$$1\text{ MW} * \frac{(365*24)hours}{1\ year} = 8{,}760\text{ MWh} \sim 1.5\text{ MW} * \frac{(365*24)hours}{1\ year} = 13{,}140\text{ MWh}$$

➔ As a result, the expected actual output of a solar power plant ranges from 8,760 MWh to 13,140 MWh.

b. Wind:

- Maximum electricity capacity is in the range

$$\frac{50\ acres}{44.7\ acres/MW} = 1.1\ MW \sim \frac{50\ acres}{30\ acres/MW} = 1.7\ MW$$

The capacity factor of wind energy is 27%; hence, we have:

- Actual Capacity is in the range

(1.1 MW * 27%) ≈ 0.3 MW ~ (1.7 MW * 27%) ≈ 0.5 MW

- Annual output is in the range

0.3 MW * $\frac{(365*24)hours}{1\ year}$ = 2,628 MWh ~ 0.5 MW * $\frac{(365*24)hours}{1\ year}$ = 4,380 MWh

➔ As a result, the expected actual output of a wind power plant ranges from 2,628 MWh to 4,380 MWh.

c. Biomass:

- Maximum electricity capacity = $\frac{50\ acres}{5\ acres/MW} = 10\ MW$

The capacity factor of biomass is 75%.

- Actual capacity = 10 MW * 75% = 7.5 MW
- Annual output = 7.5 MW * $\frac{(365*24)hours}{1\ year}$ = 65,700 MWh

➔ As a result, the actual output of a biomass power plant is estimated to be 65,700 MWh.

From the above calculations, a summary table was generated:

Table 4. Summary of estimated capacity and output corresponding to each type of energy

Type of energy technology	Maximum electricity capacity	Estimated actual output	Annual output
Solar	6.6 MW – 10 MW	1 MW – 1.5 MW	8,760 MWh - 13,140 MWh
Wind	1.1 MW – 1.7 MW	0.3 – 0.5 MW	2,628 MWh - 4,380 MWh.
Biomass	10MW	7.5 MW	65,700 MWh

4.2.2 Permitting

The permitting stage is one of the most important aspects of siting renewable energy since the construction of the power plant cannot be initiated without the necessary permits. A thorough analysis of specific requirements is probably beyond the scope of our project and expertise of our team. Hence, for the purposes of this case study, we only listed the general permits that are critically essential to the future project. Permits required for each type of renewable energy are listed below and a thorough description of each permit is provided in the Supporting Document presented in section 6, the Appendix.

General permits required for each type of renewable energy:

- Private or Federal Land Use permit: According to the MassDEP searchable site online database, the brownfield is located on a private land, therefore, any power plant proposed on the site must obtain the necessary approvals prior to construction from state and local agencies. Specifically in this case, the investor has to make sure that the project meets all the zoning and land use regulations of the town of Lunenburg.
- Environmental permit: Agencies working with an investor of a renewable energy power plant must follow Massachusetts Environmental Policy Act (MEPA). On the other hand, the investor must prove that the site is clear of endangered species, wetlands, and floodplains in order to gain the approval from the U.S. Department of Fish and Wildlife. Consulting with Army Corps of Engineers may be needed if wetlands are nearby. As observed in our site inspection, trees would need to be cleared before the actual construction of the facility. As a result, a National Pollutant Discharge Elimination System (NPDES) permit would also need to be obtained.

  For wind or biomass facility, the developer needs to follow the standards set by the Clean Water Act and obtain the NPDES permit from the EPA. In addition, the project must have a Storm Water Pollution Prevention Plan (SWPPP). The investor can contact the Massachusetts pollution control agencies to inquire about the process for formulating the SWPPP and obtaining a NPDES.

- Historic Land Use permit: The Massachusetts Historic Commission will conduct site investigation to ensure that renewable energy project is not sited on or near historical sites.

Permits required for each individual renewable energy:

- Solar: Solely based on our research, it appears that there may not be any issues obtaining the permits mentioned above. However, when the actual process is carried out, some additional permits may need to be obtained.
- Wind:
    - Determination of no hazards due to aviation obstruction (FAA)
    - Approval for transmission of microwaves (FCC)
    - MA noise Policy review
    - Shadow flicker review

The process of obtaining these permits is complicated and challenging because various investigations prior to the construction of the power plant are required. The permitting process could cause significant impacts on the design of the potential plant. Consequently, in the case that the developers face difficulties in obtaining these permits, the design may be modified in order to fulfill the governmental requirements.

- Biomass:
    - Spill Prevention and Control Countermeasures (SPCC)
    - State air permitting
    - MA noise policy review

Based on the listed permits, we expected the construction of a biomass unit on this specific brownfield to be fairly challenging. Most of the mentioned permits deal with environmental concerns, especially land, air and water pollutions. If a biomass power plant is constructed, it will likely emit pollutants which will worsen the air quality of the area and the surroundings. There is also a high possibility that a biomass plant will increase the contamination that already exists at the site. Because the site is relatively close to a residential neighborhood, we predict that the air quality and noise standards will become a huge obstacle for a biomass plant.

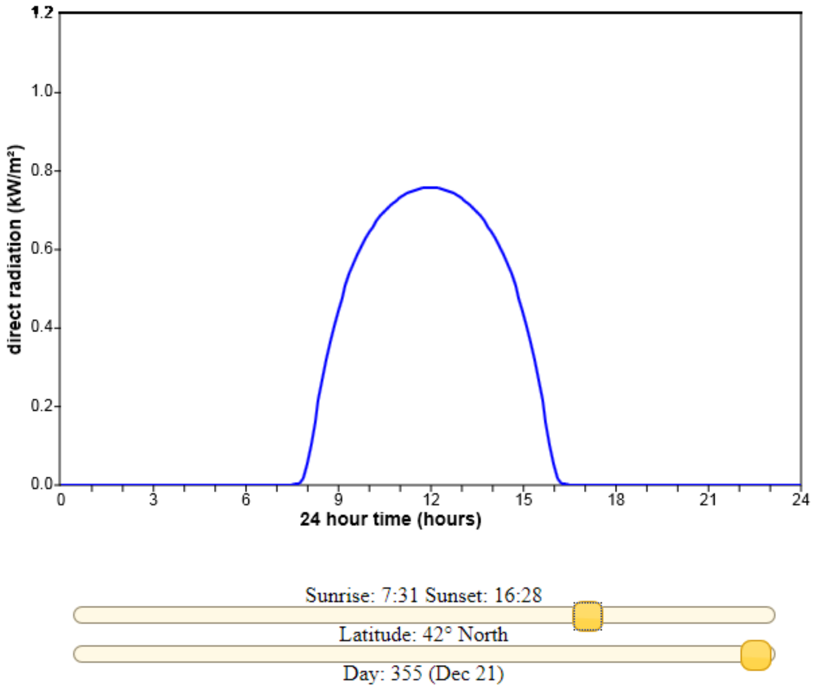
In addition to the permitting process, the investor also needs to obtain a Power Purchase Agreement (PPA) with the local electricity providers prior to the construction of the facility.

4.2.3 Find and compare available resources

The third step, as described in the supporting document, was to determine the amount of resources available at the site.

a. <u>Solar:</u>

Exploiting the website www.pveducation.org, a graph illustrating the hours of direct radiation that the town of Lunenburg received on December 21st was obtained. We chose this date because this is the day with the shortest daylength of the year; this information was also confirmed by the Borreal consultant. The town of Lunenburg is located at approximately 42.5° North; hence, we wanted to adjust the lattitude bar to match this number. Nevertheless, only integer numbers were accepted, thus, we investigated the graphs at both 42° North and 43° North on December 21st. Figure 20 and 21 showed nearly identical hours of direct radiation. The graphs are as follows:



Sunrise: 7:31 Sunset: 16:28

Latitude: 42° North

Day: 355 (Dec 21)

Figure 20. Direct Sunlight hours at 42°North lattitude on Dec 21st

(Photovoltaic Education Network)

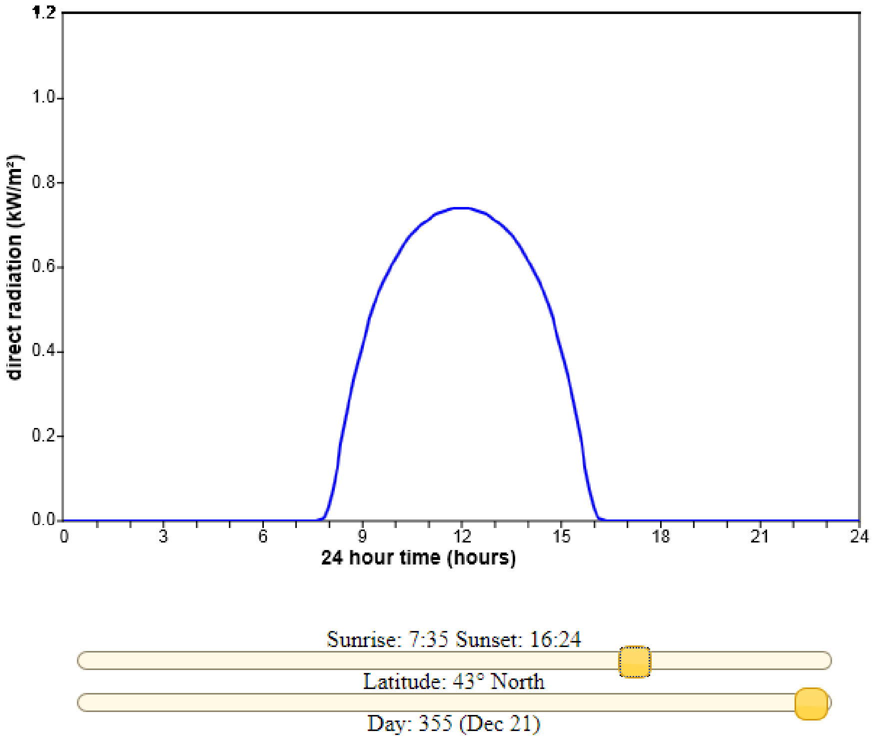


Figure 21. Direct Sunlight hours at 43°North latitude on Dec 21st.
(Photovoltaic Education Network)

Consequently, the site is expected to receive rougly 8 hours of direct sunlight.

According to our research, in order for a site to be feasible for commercial solar energy, it has to receive at least 5 hours of direct sunlight on December 21st. The above analysis proves that this specific site fulfills the available resource requirement.

b. Wind:

To test whether the wind speed at the brownfield site satisfies the requirement listed in the tool, we exploited the wind maps available on the MRPC website. Figure 22 shows the wind speed at 70m altitude at different communities in the Montachusett Region. A magnified portion of the wind map which focuses on the town of Lunenburg is shown in Figure 23.

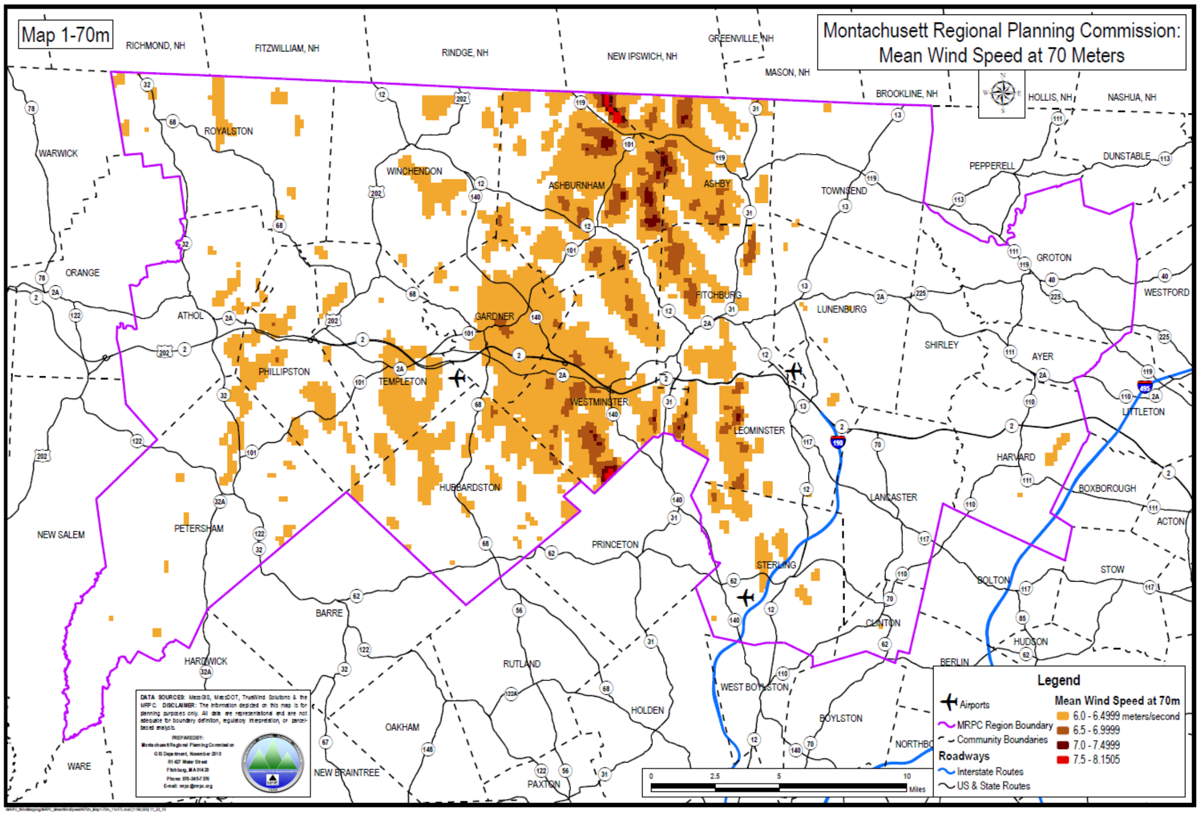


Figure 22. MRPC Regional wind speed at 70m altitude at Lunenburg

(Montachusett Regional Planning Commisison)

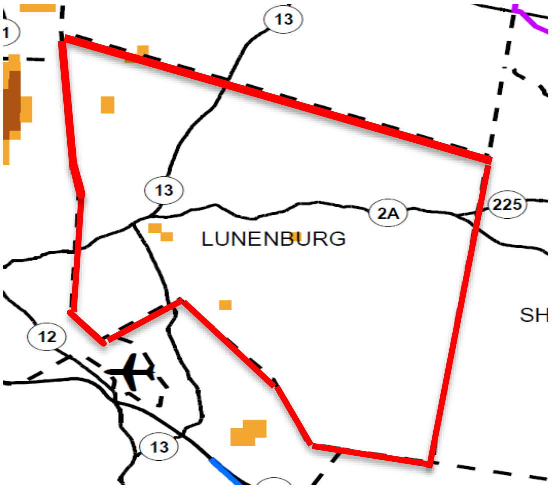


Figure 23. MRPC Regional wind speed at 70 meter altitude.

(Montachusett Regional Planning Commisison)

From the above figure, we can see that there are several orange dots within the boundary of Lunenburg, which indicates that there are a few locations in the town where the wind speed ranges from 6 to 6.5 m/s. Next, we utilized Google Maps in order to test whether the location of the selected brownfield lines up with the above spots.

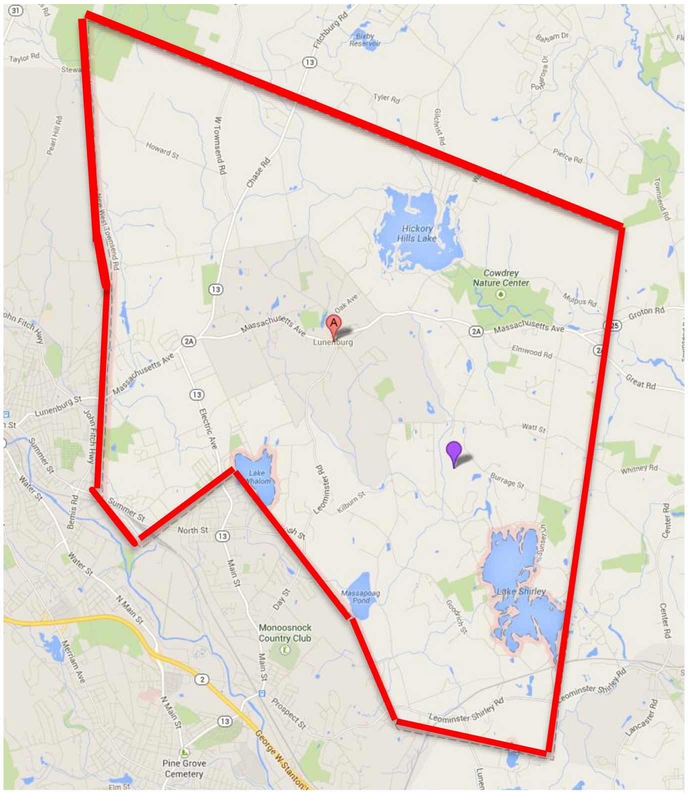


Figure 24. Town of Lunenburg.

(Google Maps)

The area bounded by the red lines is the town of Lunenburg and the purple mark represents our selected brownfield. From Figure 23 and 24, it is noticeable that the wind speed at the brownfield does not meet the requirement, which is 6m/s at 70m altitude. For this reason, wind energy is eliminated.

c. <u>Biomass</u>

As stated in the table, the amount of biomass needed for a commercial power plant is 8,500 tons/ MW. In order for a biomass power plant to be feasible at this site, the minimum amount of biomass required annually is:

$$7.5MW * \frac{8{,}500\ tons}{MW} = 63{,}750\ tons$$

However, due to our limitations, we were not able to determine whether the site meets this requirement. This evaluation would entail access to the list of available feedstock in the region and the specific amount of biomass provided by those feedstock. Because of the time constraint as well as our limited connections with authorized organizations and personnel, we decided to leave this research to the developer to conduct. Yet, a full analysis of a biomass power plant on the site is still presented in this case study.

4.2.4 Check considerations

a. <u>Solar</u>

Based on our site inspection, images gathered from Google Earth, and the brownfield database on the Massachusetts Department of Environmental Protection website, the chosen brownfield meets all the requirements listed under the "Considerations" column for solar energy. The land is located in a fairly undeveloped area; there are no tall buildings in the surrounding area and only a few residential homes. There are, however, tall trees in the area; most of which may need to be removed for a solar plant to achieve maximum efficiency. Further research needs to be conducted in order to fully examine the solar capabilities of the site.

b. <u>Biomass</u>

Other considerations that developers need to be aware of before constructing a biomass power plant are:

- The feedstock has to be within 50-mile radius of the site.

- The number of trucks coming in and out of the power plant needs to be minimized. Because the transportation of 63,750 tons of biomass would require a lot of trucks, without a logical arrangement, the traffic in the area could become a major issue.

- There needs to be fuel supply, water supply and electrical distribution capability at the site.

Though we are capable of determining if the site meets the third requirement, the first two aspects impose difficulties, as explained earlier. The developers, when exploring biomass feedstock in the area, should also make sure that those stocks are in 50-mile radius of the site. Moreover, a thorough plan for biomass transportation also needs to be designed.

4.2.5 Costs

Using the maximum capacity calculated in Table 6 and the cost ratios given in the tool, the following calculations were made:

a. Solar

Initial cost:

6.6 MW * \$2.85 M/MW = \$18.81 M = \$18,810,000

10 MW * \$3.85 M/MW = \$38.5 M ≈ \$38,500,000

Hence, the initial cost, including capital, equipment, facilities and permitting costs for a solar power plant ranges from \$18.81 to \$38.5 million.

Annual cost:

8,760 MWh/year * \$27.6/MWh ≈ \$242,000 /year

13,140 MWh/year * \$27.6/MWh ≈ \$363,000/year

Therefore, the annual operating and maintenance cost for the solar power plant is estimated to range from \$242,000 to \$363,000.

b. Biomass

Initial cost:

Similarly, with the maximum capacity of the biomass power plant being 10MW, which is equivalent to 10000 kW, the initial cost corresponding to different biomass technologies are presented below:

Table 5. Biomass technology initial costs

Technology	Initial cost
Stoker	$19 million– $41 million
BFB/CFB	$21 million – $45 million
Gasifier	$21 million - $59 million
Stoker CHP	$39 million - $70 million
Gasifier CHP	$58 million - $68 million
LFG	$20 million - $25 million
AD systems	$5 million - $10 million

Annual cost:

The annual cost of a biomass power plant includes fixed and variable operating and maintenance costs. The fixed O&M cost is expressed as percent of initial cost; the minimum fixed cost is calculated by multiplying the minimum initial cost with the smaller number of the two given values for the percent. Similarly, the maximum fixed cost is the maximum initial cost multiplied with the larger number of the percent. Hence, from values calculated in Table 5, different biomass technologies' fixed O&M costs can be calculated. With the annual output being 65,700 MWh, the variable O&M costs are shown in Table 6.

Table 6. Biomass technology annual costs

Technology	**Annual cost**	
	Fixed O&M	**Variable O&M**
Stoker	$600,000 - $1,700,000	$250,000 - $310,000
BFB/CFB	$700,000 - $1,900,000	$250,000 - $310,000
Gasifier	$600,000 - $3,500,000	$240,000
AD systems	$100,000 - $300,000	$276,000
LFG	$2,200,000 - $5,000,000	N/A

4.2.6 Incentives/Programs

a. Solar

In order to aid with financial obligations and encourage the use of renewable energy, many governmental, including federal and state, incentives and programs are offered. The 30% federal tax credit allows businesses to offset their tax liability. Additionally, for unused tax credits, each one can be carried back one year and forward 20 years, which to assure that all credits can be fully utilized. Moreover, businesses may also gain Investment Tax Credit which is equal to 30% of expenditures, with no maximum credit.

To help recover the cost of commercial solar, each business can depreciate the system over a 5 year period. The Modified Accelerated Cost Recovery System (MACRS) is a depreciation method that is used only for income tax purposes. The depreciation schedule follows the 5 year property half year convention:

Table 7. Depreciation schedule

Year	MACRS
1	20%
2	32%
3	19.20%
4	11.52%
5	11.52%
6	5.76%

Common Massachusetts Solar Rebates and Incentives of which the investors can take advantage are described below:

- Massachusetts Property Tax Exemption: Solar PV systems in Massachusetts are exempt from all local property taxes for the first 20 year of their lives.
- Massachusetts Sales Tax Exemption: Solar PV systems in Massachusetts are exempt from all state sales taxes.

b. Biomass

Besides federal incentives mentioned in the Background, there are other offers specific to biomass energy. First of all, tax incentives have been introduced up to a 30% Invest Tax Credit (ITC) for overall project costs of commercial biomass systems. Furthermore, the Biomass Thermal Utilization of 2013 would provide a two-tiered ITC of 15 or 30% depending on operating efficiencies of the system. Moreover, renewable energy credits (RECs) from renewable thermal energy are also recognized and established. Thermal RECs would incentivize the production of biomass thermal energy and other renewable, carbon-neutral sources of heat. Thermal RECs could also be incorporated into federal energy policy frameworks designed to increase generation of renewable and clean energy.

4.3 Possible Impacts

As concluded in the previous sections, solar is definitely feasible at the 50 acre brownfield located at 110 Burrage St, Lunenburg, MA. However, developers should also consider biomass energy as well. Our team, with the limitations of college students, do not have enough time and resources to further evaluate its potential. Before proceeding with any sort of development, an extensive impacts analysis must be conducted. An impacts analysis would look at environmental, social, economic, and other impacts. As we do not have the resources to conduct a thorough impacts analysis, we will briefly mention some of the aspects that would need to be evaluated further.

A solar farm needs uninterrupted access to solar light. At 110 Burrage St, there are no buildings or homes in the immediate area that would block out the sun, but there are trees; the 50 acres of land at the site is almost entirely forested. In order to build a power plant, all of the trees would have to be taken down. This action not only would cost a lot of money, but may also cause environmental problems and social concerns. Taking down 50 acres worth of trees could affect the storm water drainage of the area and cause flooding and erosion problems. It could disrupt wildlife in the area, causing all different kinds of problems, also. The neighbors might depend on the trees to provide shade for their backyard and taking them down would raise concern. Commercial-scale solar facility can also raise worries about land degradation and habitat loss. However, these land impacts are minimized because they are sited at a brownfield, which is a lower-quality location. Another issue is life-cycle global warming emissions. While there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement (Union of Concerned Scientists). Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of carbon dioxide equivalent per kilowatt-hour (Union of Concerned Scientists). Hence, with the annual output of 8,760 MWh - 13,140 MWh, this solar power plant is expected to produce 613,200 to 2,365,320 pounds of carbon dioxide per year.

Alternately, there are also concerns associated with building a biomass facility at the site as well. The process of converting biomass to energy creates a lot of air pollution and may also worsen with existing contamination at the site. Using the above data mentioned in section 2.4 of the Background with the actual maximum electricity capacity of 10MW, the amount of emitted pollutants for this specific biomass power plant is calculated as follows:

Table 8. Amount of estimated pollution emitted from the biomass power plant

Type of pollutant	**Amount (tons)**
NOx	36.4
HAPs	7.3
CO	45.7
PM	12.2
CO2	163,000

The tremendous emission of poisonous gas and contaminants will certainly face objections from the public. Readily available technologies, such as fluidized bed or gasification systems, and electrostatic precipitators, can help reduce NO_x, CO, and particulate emissions associated with biomass power. Moreover, a commercial-scale biomass plant wastes water and pollutes rivers. It requires close to a million gallons a day of water cooling, water that is often taken from nearby rivers and contaminants being discharged into rivers will contribute to impact water quality (Massachusetts Environmental Energy Alliance). With the surrounding area being mostly residential, we expect that there will be social opposition to this pollution in their neighborhood. There will also be increased traffic in this residential area, as biomass will have to be transported to the facility. The roads leading the site are narrow and do not have much traffic. We expect that there will also be social opposition to the increased traffic to the area when large trucks start transporting biomass several times a day.

With our limited resources, we were unable to tell if the land at 110 Burrage St has development restrictions due to the contamination at the site. However, it is common for brownfields to have certain restrictions, such as restrictions against residential development. Building a power plant on the site would not violate any of these restrictions and would be a productive use of the land. It would turn an unused lot into an asset. New Englanders sometimes have a “not in my backyard” approach to energy developments, but when the development is being placed on an area that is already unusable, they might be more inclined to support the endeavor.

On the other hand, a renewable energy development would bring jobs and money to the area. As observed during our site visit, the area of Lunenburg that contains our brownfield is not especially industrious and is not stricken with low-income communities, but bringing more jobs to the area would definitely help their economic situation. The potential site is also close to the road and power grid, making construction easier and cutting down on costs. Furthermore, generating electricity from solar or biomass energy helps to take advantage of redundant resources that are not being effectively utilized. Especially, biomass power plant will consume agricultural residues, industrial wood and logging residues, farm animal wastes, and the organic portion of municipal waste, which may have been unused otherwise (the Public Utilities Commission of Ohio).

4.4 Conclusion

After the thorough evaluation of the potential of solar and biomass facility at 110 Burrage Street, Lunenburg MA, a comparison between these two energies can be generated as follows:

Table 9. Comparison between solar and biomass power plants

		Solar	Biomass						
			Stoker	Stoker CHP	Gasifier	Gasifier CHP	BFB/CFB	LFG	AD systems
Actual Output (MW)		6.6 - 10	10						
Initial cost (million dollars)		18.81 - 38.5	19 - 41	39 -70	21 -59	58 -68	21 - 45	20 - 25	5 -10
Annual cost (million dollars)	**Fixed O&M**	0.242 - 0.363	0.6 - 1.7		0.6 - 3.5		0.7 - 1.9	2.2 - 5	0.1 - 0.3
	Variable O&M		0.25 - 0.31		0.24		0.25 -0.31	N/A	0.276

From Table 9, developers can obtain a generalized idea of the differences between the two potential power plants. Moreover, depending on financial situation as well as references, developers can make their own decision. On the other hand, our group recommends the construction of a solar facility at this site. First of all, solar plant has been determined to be absolutely practical at the site. Unlike solar, we cannot evaluate the amount of biomass resources available. Had it not been for limited access to authorized parties, this number could have been acquired; therefore, we do not assure that biomass is feasible. In addition, with the maximum actual output of both of the plants to be 10MW, there are significant differences in initial and annual costs. While the maximum initial cost of solar plant is estimated to be $38,500,000; it is averagely $45,000,000 for biomass technology. Similarly, maximum annual cost for solar is $363,000 and that of biomass is $2,800,000. It is clearly shown that the construction and maintenance costs for a biomass power plant is much more than those of a solar plant that generates the same amount of electricity. These values along with impacts analysis in section 4.3 leads to our decision of selecting solar as the most feasible energy at 110 Burage Street, Lunenburg MA.

5. Findings

The main goal of this IQP was to provide information about redeveloping brownfields and to create a tool to encourage developers to site brownfields for renewable energy in the Montachusett region. Throughout the course of the project, we accomplished the following:

- Researched different types of renewable energy, efficiencies, and technologies in depth
- Researched the benefits and advantages of redeveloping brownfields
- Researched impacts, costs, incentives, government programs, and permitting of renewable energy
- Developed a chart to help developers site renewable energy
- Provided general information in a supporting document
- Created steps of implementation for the chart
- Conducted a case study

While conducting research on the different renewable energies and all the legislation that goes with it, we decided to focus on large scale renewable energy projects. This decision was made after encountering the Massachusetts Portfolio Standards; we realized that large scale projects would have a larger impact on the area. We also decided that we didn’t want to just collect data to present in the project; however, we wanted to create something that would have a direct impact. The idea of a siting tool took form and evolved into a chart that developers could use to site areas in the region.

As we delved deeper into our research on impacts and permitting, we realized that New Englanders have a “not in my backyard” outlook for most renewable energy projects. They were considered “eyesores” and the public generally had a negative reaction to them. With our project, we wanted to address this issue and suggest an innovative ways to get the public to approve of renewable energy projects. Siting renewable energy on brownfields was a perfect solution! Brownfields are also “eyesores” and cannot be used for many residential or commercial uses because of their contamination. Energy plants will not violate any of the limitations placed on the brownfields and therefore, use the land for a good purpose that would otherwise sit abandoned. Brownfields are also typically located in low-income areas and redevelopment would bring money and jobs to the area. Siting on brownfields also brings more tax incentives and government programs to help developers. Because brownfields have been previously used, there may be existing building or electrical infrastructure that would benefit the developers too. All in all, siting renewable energy on brownfields solves some of the issues surrounding brownfields and some of the issues surrounding renewable energy developments.

Putting all of our ideas into motion, we developed the main product of our project, the chart and supporting document. We created a chart that developers can use to determine if a site is suitable for renewable energy development and which type of energy is the most feasible. In order to test the viability and usability of the chart, we conducted a case study, in which we applied the steps mentioned in the Supporting Document. However, during the process, changes were made as we noticed several flaws in our main product, the chart. We clarified description in the steps of implementation, as well as rearranged some of the steps in order to make the flow more logical. We added information about Power Purchasing Agreements, reordered the columns in the chart to match with the arranged steps. The capacity factors were also taken into account to solidify the calculations. After these changes were applied to the chart and the Supporting Document, we were capable of completing the case study without running into any more problems. The chart is organized and logically ordered. The supporting document provides all basic information for developers to site an area and the steps of implementation are detailed and easy to follow. Thus, the chart and the supporting document themselves can be combined together and serve as a stand-alone document. At the end of the case study, we managed to identify the most feasible energy at the site; therefore, the tool did fulfil its duty.

Although the chart passed the testing phase, several of its aspects could be improved for better use. Initially, we decided that table was the most appropriate form for our final product. As much information is condensed in the chart, yet, in a very limited space, it is fairly difficult to process all information. Therefore, the chart could have taken another form in order to provide a better user experience as well as a more appealing visual. For instance, we could have created three separate tables, each presenting information corresponding to one renewable energy. While delivering the same information, this format would create less confusion for the users as the details are not cramped all together in one chart. For the content aspect, the chart currently presented seven siting criteria of three types of energy. By conducting in-depth field researches as well as participating in various renewable energy workshops, we anticipated that further enhancement could have been made to the final product in order to deliver a broader and more detailed siting foundation for the investors. Due to the time limit and the scope of this IQP, we were unable to carry out these modifications.

Also for the possible extension of the project, the case study could have been carried out more meticulously. We could have prepared a more comprehensive list of permits, including the permit specific to the town Lunenburg by arranging interviews with the town authorities. In addition, concrete numbers could have been obtained to calculate the estimated amount of financial assistance that the investors could acquire from the government incentives. Combining these numbers with the costs analysis, we might be able to generate a thorough budget analysis for the project. Moreover, a detailed research for biomass could have been conducted to determine the amount of biomass resources available in the area. Thus, our evaluation as well as recommendation could have been more precise and subjective.

We believe that developers will be able to use the chart to aid them in siting brownfields for renewable energy projects in the Montachusett region. Having the information gathered and presented in an easy-to-use chart, will encourage more renewable energy development in the area. We also believe that these findings can have a larger impact as well. With fossil fuels becoming scarcer and Massachusetts Portfolio Standards becoming more demanding, developers will realize the many advantages of redeveloping brownfields to produce renewable energy. The information provided about redeveloping brownfields will help to counteract the “not in my backyard” attitude that the public has towards renewable energy. We hope that this IQP will help the Montachusett region to realize the potential that renewable energy has and to exploit this wonderful resource even more.

6. Appendix

6.1 The Final Product

Table 10. Final product

<table>
<tr><th></th><th>Permitting</th><th>Land requirement</th><th>Amount of resources</th><th>Considerations</th><th>Initial Cost</th><th>Annual Cost</th><th>Incentives/ Programs</th></tr>
<tr><td>Solar</td><td>• General permits mentioned in Supporting Document
• Power Purchase Agreement</td><td>~5 - 7.6 acres/MW</td><td>5 hours of direct sunlight on Dec 21st</td><td>• Avoid areas surrounded by shading, high buildings</td><td>~$2.85M-3.85M/ MW</td><td>$27.6/ MWh</td><td>Corporate Exemption, Industry Recruitment/ Support, PACE Financing, Sales Tax Incentive, Property Tax Incentive, Performance-Based Incentive.</td></tr>
<tr><td>Wind</td><td>• General permits mentioned in Supporting Document
• Avian collisions and electrocutions permit
• Air traffic permit
• Radio frequency interference permit
• Visual resource damage permit
• Noise permit
• Power Purchase Agreement</td><td>30 - 44.7 acres/MW</td><td>6m/s at 70m altitude or 5.5m/s at 80m altitude</td><td>• Firm foundation
• At least 1000ft from the nearest residence or office building.</td><td>$2.75M/MW</td><td>$50,000/ MW</td><td>Corporate Exemption, Industry Recruitment/ Support, Property Tax Incentive. Commonwealth Commercial Wind Program, Commonwealth Wind Incentive Program – Micro Wind Initiative.</td></tr>
<tr><td>Biomass</td><td>• General permits mentioned in Supporting Document
• Air pollution permit
• Wastewater discharge permit
• Noise permit
• Power Purchase Agreement</td><td>5 acres/MW</td><td>8,500 tons /MW</td><td>• Feed stock within 50-mile radius
• Minimize truck traffic
• Fuel supply, water supply and electrical distribution capability</td><td>• Stoker: 1.9K – 4.1K/kW
• BFB/CFB: 2.1K – 4.5K/kW
• Gasifier: 2.1K – 5.9K/kW
• Stoker CHP: 3.9K – 7K/kW
• Gasifier CHP: 5.8K – 6.8K/kW
• LFG: 2K – 2.5K/kW
• AD systems: 2.9K – 6.3K/kW
• Co-firing: 0.5 – 1K/kW</td><td><table>
<tr><th></th><th>Fixed O&M (% of installed cost)</th><th>Variable O&M (USD/MWh)</th></tr>
<tr><td>Stokers/ BFB/CFB boilers</td><td>3.2 – 4.2</td><td>3.8 – 4.7</td></tr>
<tr><td>Gasifier</td><td>3 - 6</td><td>3.7</td></tr>
<tr><td>AD systems</td><td>2.1 – 3.2</td><td>4.2</td></tr>
<tr><td>LFG</td><td>11 – 20</td><td>N/A</td></tr>
</table></td><td>Industry Recruitment/ Support.</td></tr>
</table>

Acronyms and abbreviations used in the tool:

BFB	Bubbling Fluidized Bed
CFB	Circulating Fluidized Bed
CHP	Combined Heat and Power
LFG	Landfill Gas
AD	Anaerobic Digestion
O&M	Operating & Maintenance

6.2 Supporting Document

The final product of this IQP takes the form of a table. The three rows in the table describe the renewable energy technologies and the six columns represent essential characteristics of those technologies. Based on our extensive research, the chart has now been fully developed with information for investors to reference when assessing feasibility of a site. This document contains supporting material for the table and consists of two main sections. The first section shows the development of the chart; calculations and decisions that led to the final product are included. The second section consists of step-by-step instructions on how to implement the chart to a potential site.

6.2.1 Calculations and Decisions

6.2.1.1 Permitting:

This is a crucial step to inform the investors the regulations and policies established for siting and operating renewable energy facilities. Since these policies are in place to protect and guarantee the well-being of the community and surrounding land, approvals are needed from authorized parties to ensure that the plant meets all of the expected requirements.

A thorough analysis of specific requirements is probably beyond the scope of our project and expertise of our team. Hence, for the purposes of the IQP, we only listed the general permits that are critically essential to the future project.

For solar and wind energy, the permitting process that an investor needs to go through was acquired from the Boreal consultants. For biomass, the information was provided by Michael Buckman – the plant manager of Pinetree Power Fitchburg.

General permits (permits common for all type of renewable energy) are described below:

- <u>Private or Federal land use</u>: If a power plant is proposed on private land, state and local agencies must grant the necessary approvals prior to construction. When power plants are proposed on federal land, the U.S. Bureau of Land Management or other governing body must authorize the development. (Solar Energy Industries Association (SEIA), n.d.)

- Environmental Issue: In Massachusetts, agencies working with an investor of a renewable energy power plant must follow Massachusetts Environmental Policy Act (MEPA), which requires them to be fully considerate of the environmental consequences of their actions, including permitting and financial assistance. In addition, MEPA requires these agencies to conduct corrective measures to mitigate as well as to avoid negative effects on the surroundings (Energy and Environmental Affairs (EEA), n.d.). According to the Boreal consultant, when proposing a power plant on wetlands or floodplains, the U.S. Department of Fish and Wildlife must grant approval. They will also make sure the area is clear of endangered species. If wetlands are nearby, the investor should consult with the Army Corps of Engineers to determine if the construction of the projects have any adverse effects, thus, coming up with the best practices to deal with them (Windustry, n.d.).

  For wind and biomass facilities, cooling water discharged to land or surface waters require a water discharge permit. Before the construction, the developer will need to obtain a National Pollutant Discharge Elimination System (NPDES) permit. Per the Clean Water Act and the NPDES mandated by EPA, industrial activities and the electrical generation facilities with the potential to generate storm water discharge are required to acquire a storm water discharge permit (Windustry, n.d.). The project must have a Storm Water Pollution Prevention Plan (SWPPP) which shows how storm water will be managed (Windustry, n.d.). The investor will need to contact the state pollution control agency to figure out the process for formulating the SWPPP and obtaining a NPDES.
- Historic land use: The Massachusetts Historic Commission will conduct site investigation to ensure that renewable energy project is not sited on or near historical sites.

In addition to the permits mentioned above, each renewable energy requires permits that are unique to that energy. These are described below:

- **Solar permit:** In addition to the general permits, actual construction process may require various additional permits.

- **Wind permits:** Wind energy facility siting processes are highly localized, as mentioned above, there is an enormous variation from town to town permitting process. Factors such as the need for transmission lines or access roads, facility size and location, and federal involvement may determine the number of agencies and the level of government involvement for a particular project.
  - Avian collisions and electrocutions: In the document prepared by NWCC, it has been stated that birds and bats can be hit by wind turbines due to the movement of the blades. Collisions can cause serious problems, especially the reduction of population of sensitive species. There is also a high opportunity that large birds can be electrocuted on distribution or transmission lines. As a result, the Avian Power Line Interaction Committee (APLIC) has set numerous standards for the wind facilities. If the project poses potential impacts on wildlife habitat or species protected under the Endangered Species Act, the Bald and Golden Eagle Protection Act, or the Migratory Bird Treaty Act, the permitting process will most likely involve coordination and consultation with the United States Fish and Wildlife Service (USFWS) (National Wind Coordinating Committee (NWCC), 2002).
  - Air traffic: The Federal Aviation Administration (FAA) requires a notification of at least 45 days before the initiation of construction from any organization that builds a structure 200 feet tall (Windpower Monthly, 2010). The FAA then conducts a study to determine whether the structure could impose any harms to aviation. Hazards might include potential collisions or conflicts with commercial aviation radars or military radars. The FAA regulations contain standards for determining obstructions to air navigation, Installation of lights on wind turbines along the border of a wind farm is also required if the turbines are 200 feet or taller and there must not be any unlit gap of more than half a mile between turbines. Projects must meet all lighting requirements and regulations for siting to receive a Determination of No Hazard to Air Navigation from the FAA. Tall cranes used during construction will also require FAA permits (National Wind Coordinating Committee (NWCC), 2002).

- Radio frequency interference: Tall steel wind turbines can interfere with radio transmissions jeopardizing navigational and defense radar signals. Approval must be obtained from the FAA and Federal Communication Commission (FCC), who work to avoid or mitigate electromagnetic signal interference (Rohde, 2008).
- Visual resource damage: By interrupting sunlight, rotating wind turbine blades can produce bright flickers which pass through closed eyelids and affect illumination inside buildings. These flicker can also lead to adverse human health effects, most likely involving with annoyance and stress. When planning the facility, the investor has to make sure that the flash frequency and the shadows formed by one turbine on another don't have the flash rate and cumulative flash rate, accordingly, more than three per second (The Society for Wind Vigilance, n.d.).
- Noise: Wind turbines create noise with low frequencies which is influenced by the ambient noise of the wind itself and decreases significantly with distance. Related noise concerns most likely focus on residences closest to the site. Normally, state agencies address these concerns by predicting and measuring noise levels, establishing noise standards, requiring noise setbacks, establishing zoning restrictions, and making turbine modifications (Natural Resources Defense Council (NRDC), n.d.). Hence, the investor should consult with Massachusetts Department of Energy Protection (MassDEP) for policy and regulations of wind turbine noise.

- **Biomass permits:**
  - Air pollution: Biomass electrical generation facilities create major air pollution. The processes emit particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), lead, mercury, and other hazardous air pollutants. Large-scale biomass burners are subject to the Clean Air Act and other regulations set forth by the Environmental Protection Agency. To reduce the amount of hazardous air pollutants emitted by commercial and industrial boilers, Environmental Protection Agency (EPA) sets limits for certain

pollutants under the “boiler rule”, which is part of the Clean Air Act (Holzman & Donovam, n.d.). In addition, the projects need to follow specific Massachusetts requirements and regulations on air pollution. The investor also have to obtain an Air Permit from Massachusetts Department of Environmental Protection (DEP).

- Wastewater Discharge: In addition to the permits mentioned above, according to the Boreal consultant, a biomass power plant developer has to obtain the Spill Prevention and Control Countermeasures (SPCC) and Waste Discharge Requirements (WDR) permits.
- Noise: Certain processes and machinery in a biomass facility could result in occupational noise that would exceed 8-hour noise limit of the Occupational Safety and Health Administration (OSHA). Workers in these areas are required to wear hearing protection as well as insulation of these areas would be needed to reduce noise level outside of these areas (Tribal Energy and Environmental Information Clearinghouse (TEEIC), n.d.). The facility also has to pass the specific Massachusetts noise review.
- The Massachusetts Department of Energy Resources (DOER) released a draft proposed regulation in 2010 to establish criteria that woody biomass facilities must meet under the Massachusetts Renewable Energy Portfolio Standard (RPS). This proposed regulation was a result of careful consideration of the Biomass Sustainability and Carbon Policy Study, subsequent public comments on that study and public comments generally on biomass policy. In August 2012, the final biomass regulation based on RPS was released (Energy and Environmental Affairs (EEA), 2012).

Prior to the construction of the facility, in addition to the permitting process, the investor also need to obtain a Power Purchase Agreement (PPA) with the local electrical provider or the company that operates the electrical grid in the area. A PPA is a contract between the facility, usually addressed as the seller and the electrical provider, the buyer. All of the commercial terms regarding the sale of electricity between the two sides were defined in the PPA. These terms will include the commercial operation starting time, schedule for electricity delivery, payment terms, charges for under delivery, and contract termination. There are many forms of PPA in use today, which vary according to the needs of the buyer, seller, and financing counterparties. The validation of the agreement is expected in the range between 5 years and 20 years (Thurman & Woodroof, 2009).

6.2.1.2 Land Requirements

This is the most vital aspect when choosing a site. Without sufficient land, it would be impossible to have the facility constructed. The facility for a renewable energy plant is most likely to include a power generator, power plant, storage, equipment to intake renewable energy, etc.

- **Solar Energy:**

  According to web research, the land requirement for solar energy is between the range from 5 to 7.6 acres/MW for fixed, small PV (>1MW, <20MW) panels. This number suggests that in order to produce 1 MW of electricity using a fixed, small photovoltaic system, about 5 to 7.6 acres of land is required. It was obtained directly from Table ES-1. *Summary of Land-Use Requirements for PV and CSP Projects in the United States* located on page 6 in the document named "Land-Use Requirements for Solar Power Plants in the United States" provided by the National Renewable Energy Laboratory (NREL) and via input from Boreal Renewable Energy Development (Ong, Campbell, Denholm, Margolis, & Heath, 2013).

- **Wind Energy:**

  The land requirement for a wind farm was found to range from 30 to 44.7 acres/MW. This information was obtained from the data given by the National Renewable Energy Laboratory (NREL). From the table provided by NREL, the area of a large scale wind farm ranges between 30 and 44.7 acres/MW (National Renewable Energy Laboratory (NREL), 2013).

- **Biomass:**

  The land requirement for a biomass power plant is 5 acres/MW. This number was obtained using Table. *Estimated Project Capacity and Screening Criteria* on page 5 in the document named "Data Documentation for Mapping and Screening Criteria for Renewable Energy Potential on EPA and State Tracked Sites RE-Powering America's Land Initiative" (U.S. Environmental Protection Agency (EPA), 2013). The calculation can be seen below:

$$\text{Land requirement } = \frac{50 \text{ acres}}{10 \text{ MW}} = \mathbf{5\ acres/MW}$$

6.2.1.3 Amount of Resources

Since renewable energy is the only source from which the electricity is generated, there must be an adequate amount of resources for the plant to operate effectively. The types of renewable energy are derived from various sources with different properties; hence, they are measured in their own unique ways.

- **Solar Energy:**

  During the conference call with the Boreal consultants, we were able to obatin the information that the area must receive at least five hours of direct sunlight on December 21st in order to be considered a feasible site for solar energy. Web research also confirmed this information.

- **Wind Energy:**

  In order for a wind farm to be efficient at a particular site, the speed wind at 70m altitude must be at least 6 m/s or 5.5 m/s at an altitude of 80m. This data was also acquired from the Boreal consultants and confirmed from the data given on Table. *Estimated Project Capacity and Screening Criteria* page 5 of the document "Data Documentation for Mapping and Screening Criteria for Renewable Energy Potential on EPA and State Tracked Sites RE-Powering America's Land Initiative" (U.S. Environmental Protection Agency (EPA), 2013).

- **Biomass:**

  For a typical biomass-fired power plant, 140-200 thousand tons of biomass per year is processed to produce 20 MW capacity. These numbers were obtained from “Biomass Conversion to Electricity” by John R. Shelly (Shelly, 2010). The calculation for the amount of biomass per MW capacity can be seen below:

$$\text{Amount of resources} = \frac{\frac{(140{,}000 + 200{,}000)\text{tons}}{2}}{20\text{ MW}} = \mathbf{8,500\ tons/MW}$$

  Some smaller biomass plants only have a 1MW capacity, therefore for a biomass plant to be feasible at a site, at least 8,500 tons of biomass must be available per year.

6.2.1.4 Considerations

In addition, there are other external factors not listed above, which will also influence the decision making of the investors. These external factors are certain characteristics or requirements that vary depending on the type of energy.

The extra considerations information was provided by the Boreal consultants. They include different factors for each type of energy. This information was included in the chart because these considerations are important factors that investors and developers must take into account when assessing feasibility of a site.

6.2.1.5 Costs

A proposal of the estimated costs of the plant should be available for an investor to determine the plausibility and the scale of the project. Before initiating the project, a thorough financial plan should be documented, taking into account all of the possible costs, including initial capital outlay, installation cost, operation and maintenance cost. Furthermore, the investors need to be prepared for unexpected costs that might arise during the build process.

- **Solar Energy:**

The initial cost was found to be \$2.85M to 3.85M/MW, which means that 2.85 million to 3.85 million U.S. Dollars is required to initially install a solar plant with a capacity of 1 MW. This number was obtained Bob Shatten, the principal of Boreal Renewable Energy Development.

For the annual operating and maintenance cost, the Annual O&M cost was divided by the Annual net electricity generation (MWh) for Wet-Cooled Design. These numbers are from Table 3. *Comparison of wet-cooled and dry-cooled parabolic trough plants in Daggett, CA, based on WorleyParsons Plant design* in the document "Parabolic Trough Reference Plant for Cost Modeling with the Solar Advisor Model (SAM)" (National Renewable Energy Laboratory (NREL), 2010). The calculation is shown below:

$$\text{Annual cost } = \frac{\$11.8\text{M}}{426{,}717\text{ MWh}} = \$\mathbf{27.6/MWh}$$

This number suggests that for every 1-MWh of electricity generated, 27.6 U.S. Dollars is spent to operate and maintain the solar power plant.

- **Wind Energy:**

The capital cost for a typical wind farm is 2,500 - 3,000 U.S. Dollars/ kW and the annual operating and maintenance cost is approximately 50,000 U.S. Dollars /MW. This information was given by the Boreal consultants; however, equipment prices are dropping with the decline in the U.S. based wind industry due to the expiration of tax incentives. The following conversions were calculated to provide consistency with units:

$$\text{Initial cost } = \frac{\frac{\$\,(2{,}500+3{,}000)}{2}}{1\text{ kW}} \text{ x } \frac{1000\text{ kW}}{1\text{ MW}} = \$\mathbf{2,750,000/MW}$$

- **Biomass:**

The capital cost as well as the operation and maintenance of a biomass power plant will vary with different types of technology. As the technology used for conversion depends on the available feedstock in the region, tables of the capital cost and annual cost for each technology are also included in the chart. The tables are retrieved from Figure 8.1.*Total Installed Capital Costs of Biomass-Fired Electricity Generation Technologies in OECD Countries* and Table 8.3.*Fixed and Variable Operations and Maintenance Costs for Biomass Energy* located on page 33 and 35, respectively in the document named "Renewable Power Generation Cost in 2012" provided by International Renewable Energy Agency (IRENA) (International Renewable Energy Agency (IRENA), 2013).

6.2.1.6 Incentives

The offered incentives and programs were obtained from the Database of State Incentives for Renewables & Efficiency (DSIRE) sponsored by U.S. Department of Energy. After sorting through the many that are offered, the chart was filled with the incentives and programs that particularly pertained to this IQP. Each row has incentives that pertain specifically to that energy. This information was included so that developers knew which incentives and programs would specifically apply to their project. Please refer to the U.S. Department of Energy database for more specifics.

Table 11. Incentives offered for renewable energy

(U.S. Department of Energy, n.d.)

Name	Incentive type	Eligible Renewable	Summary
Excise Tax Exemption for Solar- or Wind-Powered Systems	Corporate Exemption	Solar and Wind	"Massachusetts law exempts any solar or wind powered system that qualifies for the state's excise tax deduction for these systems from the tangible property measure of the state's corporate excise tax."
Local Option – Energy Revolving Loan Fund	PACE Financing	Solar, locally determined	"Property-Assessed Clean Energy (PACE) financing effectively allows property owners to borrow money to pay for energy improvements. The amount borrowed is typically repaid via a special assessment on the property over a period of years."
Renewable Energy Property Tax Exemption	Property Tax Incentive	Solar, Wind and Hydro	"Massachusetts law provides that solar-energy systems and wind-energy systems used as a primary source of energy needs of ***taxable property*** are exempt from local property tax for a 20-year period. Hydropower facilities are also exempt from local property tax for a 20-year period if a system owner enters into an agreement with the city or town to make a payment (in lieu of taxes) of at least 5% of its gross income in the preceding calendar year."
Solar Renewable Energy Credits (SRECs)	Performance-Based Incentive		"Solar Renewable Energy Certificates (SRECs) represent the renewable attributes of solar generation, bundled in minimum denominations of one megawatt-hour (MWh) of production. Massachusetts' Solar Carve-Out provides a means for SRECs to be created and verified, and allows electric suppliers to buy these certificates in order to

			meet their solar RPS requirements. All electric suppliers must use SRECs to demonstrate compliance with the RPS. Only solar-electric facilities built after January 1, 2008, may be qualified to generate SRECs. Generators must apply in order to participate in this program. Facilities that received funding prior to the effective date of the Solar Carve-Out from the Massachusetts Renewable Energy Trust or the Massachusetts Clean Energy Center, or received more than 67% of project funding from the American Recovery and Reinvestment Act of 2009, are ineligible.”

In addition to these incentives, there are also many programs which encourage the usage of renewable energy. These programs are categorized into four incentive types: State Grant Program, State Rebate Program, Utility Loan Program and Utility Rebate Program. Some of the principal programs that are most relevant to this IQP are summarized in Table 12.

Table 12. Programs offered for renewable energy

(U.S. Department of Energy, n.d.)

Program	Eligible Renewable	Summary
Commonwealth Commercial Wind Program	Wind energy	"Through the Commonwealth Wind Incentive Program – Commercial Wind Initiative the Massachusetts Clean Energy Center (MassCEC) offers site assessment grants of services, feasibility study grants, and development grants and loans for commercial wind projects 2 MW or greater that will serve the whole-sale energy markets or for projects that do not qualify for net metering but provide on-site use."
Commonwealth Wind Incentive Program – Micro Wind Initiative	Wind energy	"Through the Commonwealth Wind Incentive Program – Micro Wind Initiative the Massachusetts Clean Energy Center (MassCEC) offers rebates of up to $4/W with a maximum of $130,000 for design and construction of customer-sited small wind public projects and rebates of up to $5.20/W with a maximum of $100,000 for non-public projects."
Renewable Energy Portfolio Standard (RPS) Class I	Solar photovoltaic, Wind energy, geothermal energy	"The RPS proposes that all retail electricity suppliers must provide a minimum percentage of kilowatt-hours (kWh) sales to end-use customers in Massachusetts. The 2010 RPS Class I requirement is 5%, and is set to increase by one percent each year. It is met through electricity production from qualified New Renewable Generation Units. New Renewable Generation Units are facilities that began commercial operation after 1997 and generate electricity using any of the mentioned technologies."

RPS Class II		"RPS Class II mandates that a minimum percentage of electricity sales come from each of two sources, renewable energy and waste energy. The current RPS Class II Renewable Generation obligation is 3.6%, and the Waste Energy Generation obligation is 3.5%. The obligation does not increase annually. A Supplier must comply with both the minimum percentage of Renewable and Waste Energy obligations."
RPS Class II Renewables	Solar, Wind, Geothermal	"Similar to RPS Class I, this class pertains to generation units that use eligible resources such as sunlight, wind, ocean, landfill methane gas, small hydropower, and geothermal, but have an operation date prior to January 1 st,1998. Therefore, RPS Class II provides financial incentives for the continued operation of qualified pre-1998 renewable generation units."

6.2.2 Steps of Implementation

1) <u>Calculate expected actual electricity output of the power plant using area:</u> Divide the area of the potential site by the land requirement ratios given in the chart to get the maximum energy output of the site. Then, multiply this number by the capacity factor corresponding to each type of energy, mentioned in the Methodology, to get the expected capacity of the site. Please complete this calculation for each type of renewable energy.

2) <u>Permitting:</u> A list of permits that will need to be acquired for each renewable energy is given in the column entitled "Permitting". The information in the chart covers federal and state requirements, but local requirements are not included. Local permitting requirements will vary from town to town and depend on site conditions. This information is meant to make the developer aware of the permitting obligations of a project. Also, before the next steps are taken, contact the local energy provider about a power purchase agreement.

3) <u>Comparing capacities to usage:</u> Contact the local electrical provider or town manager to obtain information about the electricity usage of the area. Compare these numbers to the expected capacity of your potential site. This information is not necessary, but just for the developer to reference.

4) <u>Find available resources:</u> The next step is to determine if your potential site has enough renewable resource available.

+ For solar energy, the amount of available sunlight on December 21st can be obtained via online research.

+ For wind energy, wind map can be utilized to estimate the wind speed in the area at a certain altitude.

+ For biomass, further examination needs to be carried out to find out the amount of available biomass in the surrounding area and adequate water supply for cooling purposes.

5) <u>Compare amount of resources:</u> If the specifications in the table are met, then that particular renewable technology has enough available resource at the site to be considered feasible. If not, then do not consider that renewable technology in further steps. Please note that these specifications are for pre-screening purposes only and more information will be gathered if the site is deemed feasible for renewable energy.

6) <u>Check Extra Considerations:</u> Direct your attention to the next column in the table entitled "Extra Considerations". The requirements listed in this column are specific for each type of renewable energy. Please ensure that your potential site meets these specifications. If your potential site meets these requirements, then continue on to step 7.

7) <u>Calculate Estimated Costs:</u> Capital, maintenance and operating costs can be calculated using the calculated maximum capacity and the values given in the chart. If the estimated cost is too high for a renewable energy, please continue to the next step before eliminating it from your considerations.

8) <u>Incentives and Programs:</u> A list of government incentives and programs that pertain to each type of renewable energy is given in the column entitled "Incentives/Programs". The information is meant to make the developer cognizant of potential tax cuts, funding, and other opportunities that may help with costs.

<u>NOTE</u>: If your potential site met all of the criteria in steps 1-6 and the developer is aware and understands his obligations and opportunities as described in steps 7-9, your site is now considered feasible for renewable energy. Again, please note that this chart was intended for pre-screening purposes only and much more information must be gathered in order to propose a potential commercial-scale renewable energy project.

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