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Siting Renewable Energy Sources for the Montachusett Region

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Abstract

This project provided the Montachusett Regional Planning Committee with recommendations for residential renewable technologies to promote in the Montachusett area. The report analyzed current energy consumption patterns, the installation and running costs for renewable technologies, and developed a payback period analysis for a comparison. The project used climate and weather data, available cost data for renewable technologies, and historical energy utility costs to make these assessments. A method was devised to determine payback period for each device. Then, based on payback period and monthly savings, made recommendations for which technologies we feel that the MRPC should promote and try to develop in the area.

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Introduction

Throughout history, mankind has relied on renewable energy technologies in the forms of harnessing wind, biomass burning, and hydropower. It was only during the advent of the Industrial Revolution that coal and other fossil fuels began to outperform these renewable technologies in energy output, accessibility, and convenience. Nevertheless, concerns about peak coal and the limited capabilities of coal mining surfaced as early as 1870. French professor and inventor Augustin Mouchot voiced his concerns about the limitations of coal and the geopolitical constraints that a fossil fuel based economy could impose. "Eventually industry will no longer find in Europe the resources to satisfy its prodigious expansion... Coal will undoubtedly be used up. What will industry do then?" (Kovarik pg. 1, 2011) However, coal mining techniques would continue to improve, and the peak coal concerns of a generation would be alleviated.

Concerns on the limitation of fossil fuels never truly went away, but the infrastructure of the United States would develop to depend on coal, oil, and natural gas long before the repercussions of those actions were understood. By 1920, coal had replaced wood as the primary method of home heating in United States cities due to its widespread availability and lower price. Presently, a full half of all electricity produced in the United States is done via coal burning (EIA.gov, 2011). Oil comprises 93% of all energy in the United States used for transportation. Natural gas and oil make up the majority of home heating appliances, especially in the colder states (EIA.gov, 2012). These current consumption patterns cannot continue indefinitely.

Transitioning out of a fossil fuel based economy has long been a concern of both scholars and industrialists alike. Harold Hibbert, founder of the Division of Cellulose Chemistry of the American Chemical Society, was famous for his body of work relating to plastics and wary of unlimited sources of oil. After the founding of the Division of Cellulose Chemistry in 1922, Hibbert would devote much of the rest of his life to developing plastics from renewable sources (Wolfram, 1956). Famed industrialist Henry Ford was also a believer in the limited lifespan of an oil economy. By the early 1920's, Ford was outfitting Model Ts with plastic parts derived from soy plants. Model Ts and the newer Model As were designed to operate on both gasoline and biomass-derived ethanol but by 1927, Ford was losing market dominance and ethanol burning cars were phased out in order to compete with General Motors (Fekete, 2007). Once again, market forces continued to favor fossil fuel use and development over the alternatives.

The modern push for alternative energies can be traced back to 1956 and the publishing of Hubbert's Peak Theory. Initially ignored at the time, this theory has come to dominate our understanding of the limitations of fossil fuels. Hubbert's Peak Theory correctly predicted that the peak oil production in the United States would occur between 1966 and 1972, in actuality it occurred in 1970 (Heinburg, 2003). During the 1950's, the post-war boom in the United States allowed for the development of the expensive piping and infrastructure necessary to provide natural gas to residential homes. This decade also marked the first time oil eclipsed coal as the primary source of energy in the United States due to the growing use of the automobile (DOE.gov, 2007). By the time peak oil occurred in the United States, the Organization of Petroleum Exporting Countries (OPEC) had formed and Americans were unprepared for the 1973 energy crisis, which quadrupled the price of a barrel of oil (Maugeri, 2006). It was during the 1970's that research into alternative energy began in earnest.

For the first time in history, an energy infrastructure transition will need to be made based on the availability of a resource, not its' convenience. The renewable energy to coal transition fueled the industrial revolution, oil had allowed for the transportation and automobile boom in the 1950's, and nuclear energy had once purported to soon make electricity free only to be severely limited by the disasters at Chernobyl and more recently Fukushima (Blair, Kay, and Howe, 2011). In every one of these transitions, the amount of energy which could be extracted from a given volume of fuel increased. Modern Americans have relied on these increases in "energy density" to both fuel their economy and establish their current consumption patterns (Smil 2010). However, the transition back to renewable technologies will not have this luxury.

When considering the switch from fossil fuel technologies to renewable technologies, two issues must be addressed. First, the energy density of fossil fuels surpasses that of existing renewable technologies, meaning that any existing renewable device must be larger than a fossil fuel device meant for the same purpose and output (Smil 2010). Secondly, modern renewable technologies cannot match the industrial output of fossil fuel boilers and work best on a regional scale that takes into account the climate and efficiencies of the technology. In order to combat this, renewable technologies must be considered by region and implemented on a scale beneficial to a specific technology, not the energy demands of a population. Early adoption and less reliance on fossil fuels can make the transition out of a fossil fuel based economy much less painful for the individual adopter.

Renewable energy technologies often rely on the local climate, making maintenance, running costs, and expected output values inaccurate and hard to understand (Hand, Baldwin, et al, 2012). This means that evaluations for renewable energy devices must be done on an individual and regional basis. Renewable technologies performance is often given in a “best case” or “best location” scenario which is not at all helpful to early adopters. These figures can misrepresent the performance and thus payback period and monthly savings that the adopters are hoping to achieve.

The purpose of this project is to develop regional metrics and expected returns for residential renewable energy devices if they were retrofitted into an existing Montachusetts home. Describe how the technologies work, what they cost, and how they can be adopted by a residential homeowner in this area. This will be done using a payback period analysis to show the amount of time needed to recoup initial losses and generate monthly savings. This payback period analysis will include a regional evaluation of the renewable technologies, an energy use profile for Montachusetts residents, and the current grants, subsidies, and tax credits that may apply to such a renewable device located in the area. This information will then be given to the Montachusett Regional Planning Committee to assist them in developing a renewable energy plan of action. With this data, the group hopes to be able to make a set of recommendations for the MRPC to pursue in the region.

Background

Federal and state promotions of renewable energy technologies have encountered resistance in the past and been met with mixed results. The implementation of subsidies purports to lower the cost of these technologies in the short term in order to allow them to compete with established fossil fuel technologies. However, these subsidies cannot be indefinite, the need to promote or increase these subsidies long term would imply that such technologies are not viable and can never truly compete with the establishment. Imposing stricter regulations on emissions has also been attempted. These programs usually claim to be taking into consideration the externalities of producing unclean methods of energy generation and create an economic incentive to reduce such emissions. Some cases of direct government financing of renewable technologies have been attempted. Normally, the goal of direct financing is to promote research and implementation of these technologies in the country and provide "green jobs". However, allegations of cronyism and the failure of unsound investments imply that such financing is often done for political rather than economic gain. This review looks at some of the more recent attempts of Federal and state governments to promote renewable energy technology.

The Federal Residential Renewable Energy Tax Credit program was started in 2006 and has been scheduled to continue until at least 2016. This program promotes renewable technologies for homeowners by providing up to 30% of the cost of installation of a renewable energy device to be claimed as a tax credit for the fiscal year in which it was installed. The program has been met with much success. Initially only covering solar-related technologies, it was extended to wind, geothermal, and biomass options for residences in 2008. The 30% tax credit is currently the largest and most important discount available to homeowners, drastically lowering the initial investment required of homeowners and potentially making renewable energy devices competitive with nonrenewable technologies. The results of this program are uncertain as it is ongoing. Most of the technologies we reviewed qualify for such a tax credit and that reduction in cost is factored into our payback period analysis.

In some parts of the country, state subsidies match or supersede government incentives. California has long been a leader in the wind industry due to its early promotion of the technology and large scale state subsidies that supplement existing federal ones. From 2004 to 2008, the United States became the largest producer of wind energy worldwide thanks to huge state subsidies in California, New Jersey, and other states that attracted large amounts of investment capital in those areas (Hinman, 2011). The subsequent financial collapse of 2009, however, lowered the price of fossil fuels and dried up available investor capital. The wind industry in the United States has largely been at a standstill since this time. The financial collapse exposed the relative instability of wind power as an emerging industry. While technological increases in the efficiency of energy generation and storage of wind power will continue to make the technology more competitive, current evaluations of the viability of wind power must be based on locally available subsidies and the fluctuating prices of fossil fuels (Hinman, 2011).

Environmentalists have promoted emissions control as method of reducing greenhouse gases and curbing reliance on foreign fossil fuels. The Clean Air Act of 1969 included a provision for a cap-and-trade system to be implemented for SO2 emissions. While such a program was successful at reducing total emissions, its ability to promote renewable technology over the fossil fuel alternatives is questionable (Wooley, 2001). While the Clean Air Act set limits on the allowable emissions a given factory or plant was allowed to produce, businesses could circumvent this limit two different ways. The first was the cap-and-trade approach where businesses exceeding their emissions output could buy emissions credits from other businesses who were producing under their allotted emissions numbers. This first approach made the benefits for reducing emissions twofold. Businesses were given increased incentive for efficiency by installing scrubbers or switching to a more environmentally fuel source or method of production. Additionally, they would then be able to sell their excess credits to other businesses. The other method by which they were allowed to overproduce emissions was by participating in the Conservation and Renewable Energy Reserve (CRER) program. The CRER program granted additional emissions credits to a business that could demonstrate they were investing in renewable sources of energy or by demonstrating a significant increase in efficiency. While the cap-and-trade system is considered successful, there was little use of the CRER program. It was both easier and made more economic sense to reduce emissions or buy credits from another business than it was to implement renewable energy programs (Wooley, 2001). While the Clean Air Act succeeded in reducing emissions, it failed to promote renewable technologies.

Through various programs, the Federal government has at times tried to promote and fund renewable energy companies directly. A number of "green" investments made in the 2008/2009 stimulus package have come under fire for making hasty or politically beneficial decisions. One such case would the failure of Solyndra and Evergreen Solar renewable energy companies. Funded by the stimulus package and a Massachusetts incentive, Evergreen Solar opened a MA facility in 2008 near Fort Devens. The company filed for bankruptcy in 2011 and shifted all production to China. Solyndra received $535 million from the same stimulus package as well as a $25 million incentive from the state of California (Jabusch, 2011). This funding allowed the company to open a major state-of-the-art production facility in California, however, shortly after receiving these loans and beginning these projects the company rapidly started decreasing its orders and downsizing. Citing an inability to compete with Chinese manufacturers, Solyndra filed for bankruptcy in 2011. The exact cause of these failures is still the subject of investigation. Both companies sold high-grade, innovative, and much more expensive solar panel arrays than their competitors. The primary issue implicated in the failure of both companies is that they had priced themselves out of any reasonably-sized market (Jabusch, 2011). Despite the failures of these two federally-backed businesses, the rest of the solar industry is rapidly growing.

Not all government funded companies fall into the category of crony capitalism. Tesla motors, funded in 2003, had a focus on making electric cars aimed at wealthy early adopters with the end goal of transitioning into mass-market, affordable vehicles as the technology became more competitive. Tesla motors received a $465 million loan from the U.S. Department of Energy in 2009 through a program unrelated to the stimulus package (Unger, 2013). With strong private funding and success of their early Model S vehicle Tesla has been expanding production. Tesla Motors itself focuses on the design and improvements to the "electric powertrain" the device that replaces the engine in traditional cars. By purchasing motorless vehicles from other auto manufacturers and retrofitting them with an electric powertrain, Tesla's early business model seems successful. The company posted their first ever profitable quarter in 2013 (Unger, 2013).

With these past successes and failures in mind we set out to determine a best course of action for the promotion of renewable energy technologies. We have seen that governmental support of a project has little bearing on its success or failure. We have also seen that subsidies are still necessary for many of these technologies to be considered competitive. The MRPC operates on a local level and its promotion of renewable technologies is limited to incentives to local businesses and residences in the area. Payback period analysis is the most common technique used to evaluate projects on a small scale.

Several small scale state and federal evaluations have utilized payback period to demonstrate the efficacy and savings of a particular renewable energy device. The Federal government has long used payback period to evaluate the potential of renewable energy technologies in remote or off-the-grid areas. Both the Federal Tribal Energy program and Rural Energy for America Program (REAP) have conducted this type of evaluation in the past (Peirce, 2013). In the state of Massachusetts, the towns of Amherst, Ashfield, and Lancaster have qualified for the state designation of "Green Community" by utilizing payback metrics to demonstrate the feasibility of a renewable technology in their townships (Fister, 2012). The 2012 Comprehensive Energy Strategy for Connecticut utilized payback period to demonstrate the relative strength of renewable energy and natural gas energy compared to that of oil and electric (State of Connecticut, 2012). Payback period is not only a commonly used evaluation technique but one of the most useful evaluations to conduct on a local scale.

Methodology

Each individual technology must be considered and evaluated for its’ potential home use in Montachusetts in order to determine its viability and make recommendations to the MRPC. Popular opinions on the use and viability of renewable technologies vary greatly from person to person, may not be up to date, or reflect the actual performance that a renewable energy device could provide in the region. First, we determined regional feasibility by conducting a review of the technology, understanding what the technology needs to operate, and if climate conditions in Montachusetts were sufficient to support a specific device. Second, we had to develop payback metrics for a technology or device that was deemed functional in the Montachusett region. We gathered energy output, installation/running costs data, and applicable grants and subsidies that would apply to that device if it were installed in an existing Montachusett home. Then, for comparison purposes, we gathered information on the cost of running standard fossil fuel based utilities using recent prices of #2 fuel oil, natural gas, and grid electricity in the region. Finally, by comparing the cost of installing and operating a renewable energy device on an existing home against that of “doing nothing” and having to pay for an equivalent amount of energy from a standard utility we could see the monthly savings a renewable energy device would generate and determine how long a renewable device would need to operate in order to “payback” the cost of installation. Our results include the expected length of time each technology needs to recoup initial losses, as well as expected monthly savings from switching to such a renewable device. With this information we can present our findings to the MRPC in order to assist them with developing a plan of action to promote the best renewable devices for the Montachusetts area.

First, a review of the viability, use, and availability of popular home devices for each of the five renewable technologies was needed. The review included a description of how each device works and how it is used in or near Montachusett. Usage of renewable energy devices do not necessarily reflect common perceptions, one instance would be the viability of wind technology. Massachusetts is not traditionally known as a windy state, even though 10 of the top 20 windy cities in the United States lie within Massachusetts’ boarders (city-data.com, 2012). Each technology has potential in the region, but climate and lay-of-the-land can affect that performance.

Second, we collected data on the installation and running costs of a renewable energy device to serve as a basis for a payback period analysis. A payback period analysis is a capital budgeting technique designed to find the measure of time it will take to recoup, in the form of cash inflow from operations, the initial dollar amount invested (Horngren, 1974). This requires the installation cost for each renewable device, accounting for all steps required for installation and factoring in applicable subsidies and tax credits. It must also include the costs of running such a device, including fuel costs and maintenance.

Then, we collected data on non-renewable utility consumption patterns and costs to develop an energy profile and find a basis for comparison to determine the cash inflow from the investment. The primary benefit of renewable energy devices is that their running costs are substantially lower than a comparable standard energy utility costs which they replace. Therefore, this comparison requires that we develop an energy usage profile for Montachusetts homes. Energy utilities are not uniform, so in some cases it was necessary to develop metrics for multiple standard utilities for the comparison. Certain technologies, like solar Photovoltaics, have a direct basis for comparison as their output is measured by one metric (electrical output in kWh) and replaces/supplements a utility directly (grid electricity which is measured the same way). Other technologies, like geothermal heat pumps, provide energy in multiple forms and an approximation of their energy savings is needed for comparison.

Finally, once all of these metrics have been determined, they can then be graphed and compared directly to find a payback period. The standard capital budgeting formula for a payback period is the initial amount invested over cash inflow (Horngren, 1974):

$$P = \frac{I}{O}$$

P is the payback period measured in the same unit of time as the cash inflow (O). However, because renewable energy devices cash inflow is measured in the form of savings, we must determine the savings of each device when compared to a standard energy utility:

$$P = \frac{Initial\ investment\ (after\ subsidies)}{running\ cost\ of\ standard\ utility - running\ cost\ of\ renewable\ device}$$

This equation may be rearranged to more accurately reflect that the costs of a standard utility are being compared against the total cost of installing and operating a renewable energy device:

$$P(\mathit{running\ cost\ of\ standard\ utility}) \\ = \mathit{Initial\ investment} + P(\mathit{running\ cost\ of\ renewable\ device})$$

The equation may then be split in two, setting each half equal to a "cumulative total cost" of operation. When the cumulative total cost of each equation is equal for a given value of P, the two equations will intercept on a Cartesian graph.

$$\mathit{Cumulative\ Total\ Cost} = P(\mathit{running\ cost\ of\ standard\ utility})$$

$$\mathit{Cumulative\ Total\ Cost} = \mathit{Initial\ Investment} + P\ (\mathit{running\ cost\ of\ renewable\ device})$$

This calculation should provide an accurate approximation of the length of time needed to recoup initial losses. Payback periods do not account for depreciation, as there is no salvage value for most of the devices surveyed. Once the payback period has been found, it can be compared to the useful life of the device. Payback periods that take longer than half the useful life of a device are considered risky investments (Horngren, 1974). With this information gathered and the payback periods of the selected technologies found, we can then base our recommendations for renewable technologies in the Montachusett region based on the payback period, monthly savings, and energy provided by each renewable device.

Results

By understanding a Massachusetts residents expected consumption patterns and the average installation and running costs needed to get a desirable level of output for a specific device, we can then compare these two against one another to see where an investment in renewable technology finally pays off. All of the technologies that we reviewed for home use have a lower fuel and maintenance costs than that of traditional oil, gas, and electric energy utilities. However, the varying installation costs mean the time required to recoup initial losses changes significantly between technologies.

Renewable Energy Sources Viability in the Region

In order to determine the viability of each of the five technologies in the region, we first had to understand each technology, how it operates, and what conditions are necessary to get an acceptable level of performance. In order to do this we reviewed industry primers, government publications, and local implementations of these five technologies to better understand their functions. In the case of solar, wind, and geothermal technologies it was also necessary to confirm that the climate and weather conditions were appropriate to operate these devices in the region. Our findings demonstrate that all five of the technologies we reviewed were viable in the Montachusetts region, but dependence on large bodies of water and economies of scale eliminated hydropower technologies from being considered on a residential level.

Solar Photovoltaics

According to the Massachusetts Clean Energy Center, solar energy is the highest contributor to clean energy in Massachusetts (CEC, 2013). Massachusetts has a rapidly growing solar market (CEC, 2013). Photovoltaics collect energy even when not exposed fully to the sun. They work much like the small cell found in many lower end calculators. The Massachusetts commonwealth has many financing and ownership options for the installation and operation of solar technology. The options include full out ownership, leasing and power purchase agreement contracts (CEC, 2013). Power purchase contracts are contracts where a homeowner can purchase energy from a system located on their own property for a fair price (CEC, 2013). The owner of the equipment would be the company and the lease gets the benefit of purchasing power at a reduced rate, where the company benefits by giving excess power to the grid and also long term any investment they made is being returned as the leaser buys power. This may also be beneficial because the company leasing the land would repair any damage to the equipment. It is important for any homeowner to be cautious as they enter these contracts as with any other contract. That being said, solar technology is an efficient technology that is very beneficial to have on one's property. We will discuss some of those benefits in a later section.

Although solar technology is a fairly simple one, recent advancements have made it easier for the consumer to benefit much more from these technologies. There are two types of solar technologies. The two types of technologies are solar PV (photovoltaic) and solar heating. Solar PV is one of the most popular renewable technologies in Massachusetts for several reasons (CEC, 2013). They are very easy to install and generally make more sense in the area, as solar water heaters are not effective year round in Massachusetts. As a result, solar hot water heaters are not included in this analysis.

Solar PV, depending on the homeowners needs, requires few components and has two ways of working with the home to produce or produce and store power. The two ways are grid tie systems and off the grid or standalone systems. The two systems are different in both prices and the components they require. The only difference is the off grid capability requires the homeowner to have an array of batteries to store power for later use. The components are as follows for grid tie systems

- **Solar Array**
    - These panels are connected together to collect the sun's rays and turn them into electricity. Intensity of the sunlight is directly correlated to the amount of electricity produced both in duration and intensity. Solar panels generally produce DC current, which can be used directly by some electronics.
- I**nverter**
    - This component converts the current from DC to AC which is what most electronics use in the home. Inverters are usually connected to both the panels and the main power input to the home. They are typically found next to the electric meter. Normally, they are made so that if the main power turns off so will the power from the panels as a safety feature so that your electronics are not damaged from over or under current. Although there is a voltage regulator included on all inverters it is always safer to shut off.
- **External Shut-off**

    - Electric companies may sometimes require a shut-off to be externally installed to ensure the safety of their workers while they are working on main lines. The shutoff feature is not necessary if you are using batteries in your system.

Generally speaking, any person capable of following directions and has a basic understanding of how electricity works can install one of these systems themselves. However, it is highly recommended that a professional installer is used as these systems produce a high current that can be dangerous and deadly. Maximum safety precautions must be taken to be sure that no injuries occur. Solar panels produce electricity whenever they are exposed to sufficient sunlight meaning that the installation process takes place with live wires. Carefully choosing a professional installer is important to ensure both safety of the device and maximum energy output. Due to the inconsistency of Massachusetts weather it is highly recommended that a grid tie system is used so a household can continue using electrical appliances during periods of overcast weather. While it is convenient to have off grid capabilities there is a price to be paid for that convenience. The batteries are an added expense that also adds to the maintenance cost. Solar photovoltaic systems can be difficult to install but the potential benefits are many:

- **Reduce your carbon footprint:** solar energy gathering is one of the cleanest ways to produce energy, there are no carbon emissions.
- **Economic Development:** as these systems grow more popular so does the demand for their manufacturing and installation jobs.
- **Reduce or eliminate utility costs:** Solar energy is nearly free. The more you gather the more money you will get back.
- **Value added to your house:** Most solar panel setups are installed on a rooftop and have little impact on the aesthetics of a house. There are few drawbacks to owning a solar PV system and potential buyers will benefit from the reduction in electrical costs.
- **Low maintenance costs:** Of all the renewable technologies surveyed, the maintenance costs for solar PV technology is the lowest. This is due to the lack of moving parts in a solar PV system.
- **Federal Tax Credit:** up to a 30% Federal Investment Tax Credit for qualified residential and commercial projects.

Geothermal Heat Pumps

Geothermal heat systems are energy saving technology that can be both retrofitted into an old house or built into a new one. Geothermals have a long history and are an established and reliable technology that has been in use on farms in the United States since the beginning of the 20th century (Patange, 2007). This system greatly assists with the heating, ventilation, and air-conditioning (HVAC) functions of a house. Geothermal systems cannot feed energy back into the grid, nor can they make a household entirely free of electricity bills. However, geothermals are one of the most efficient renewable energy devices we surveyed.

Geothermal heat pumps work by using the ground as a heat source/heat sink. The actual functionality of a geothermal system varies with the season. Earth is used as a cooling source in the summer and a warming source in the winter months. This is because the ambient temperature 20+ feet underground has little to no variability in change in temperature throughout the year (Patange, 2007). There are two main types of commercially available geothermal heat pumps, open loop and closed loop. They operate off the same thermal principals but differ in installation and space required. Open loop systems rely on groundwater for the transfer of heat, meaning they can only be installed in locations suitable for the drilling of an additional well. Closed loop systems work anywhere with sufficient space, they require digging up a large surface area (dependent on size of house) to lay coils which will be filled with some heat transfer fluid (usually glycol). A vapor-compression refrigeration cycle is used to extract/remove heat from the ground liquid as desired. This energy is used to preheat hot water tanks, warm, and cool air directly. The exact usage of a geothermal system varies with setup, as the device must be able to connect to the various HVAC functions of a house. Due to the reliance on ambient ground temperature, geothermal heat pumps may be installed anywhere in Montachusetts with sufficient space to lay ground coils or dig a well.

Biomass

Biomass is a term used to encompass a wide range of technologies. The term “biomass” refers to biological material from living or recently-living organisms, most often plant matter (Truini, 2012). Extracting energy from these sources is done either by a chemical process, such as pyrolysis, or simply by burning. Agricultural waste can frequently be converted or used as biomass in the form of corn husks, wood chippings, and byproducts plywood and other wood composite manufacturing (Bowles, 2008). In recent years, biomass has also come to encompass environmentally sound methods of burning municipal waste, such as landfill gas.

Space heating takes up a larger portion of New England home energy use than any other activity, as New England is one of the coldest regions in the US. Home space heating is so important in New England that its energy infrastructure is radically different than the rest of the country (EIA.gov, 2012). Instead of relying on electrical or natural gas heating, most New England homes opt for more efficient home heating by burning fuel oil. New Englanders burn about 14% more fuel oil than the national average (EIA.gov, 2012). This makes the region one of the most sensitive to fluctuations in the price of oil and creates an opportunity for renewable space heaters to flourish. This review will focus on pellet stoves and pellet boilers as they are more efficient than traditional wood burning stoves, receive tax credits, and can replace the space heating needs of a household.

Biomass energy is obtained by burning biological material or running a biomass through a specific chemical process like torrefaction, pyrolysis, or gasification. The modern wood burning stove has been in use for hundreds of years, recent innovations have created a higher efficiency wood burning stove known as a pellet stove (Truini, 2012). While the stove itself remains largely unchanged the major increase in efficiency is due to the compression of the plant material. Rather than using raw wood, the much denser pellets produce a hotter flame than an equivalent volume of wood. This has several distinct advantages over traditional stoves and fireplaces. First, the thermal efficiency is greatly increased, lowering storage requirements for the owner and the total space occupied by the stove itself. Secondly, the pellets can be produced from industrial waste. Waste particulates like sawdust burn violently and quickly in their normal state, being compressed into pellets allows them to smolder like embers, releasing a large amount of heat over a relatively long period of time. Finally, the pellet-making process standardizes the dimensions of the fuel source. This means that pellets do not have to be prepared and added by hand, like natural wood, they can instead be loaded into an auger and dropped into the stove at a controlled rate (nevelsstoves.com, 2013). The combination of these factors makes pellet-burning stoves far more convenient and efficient than their wood-burning predecessors. Assuming proper maintenance, pellet-burning stoves do not create creosote, the tar-like material that adheres to the inside of stove walls and causes chimney fires.

Scaled up pellet stoves have begun to be used as boilers to replace traditional oil furnaces. These pellet boilers have only recently entered the market but found much success in the state of Maine, where Kedal, the first pellet boiler manufacturer in the United States is located. Pellet boilers are intended to fully replace the furnace. Pellet boilers work much like existing pellet stoves only the heat generated is connected to the house's distribution system (radiators or fin tubing). As pellet boilers are much larger than their traditional oil and gas counterparts, installation of a pellet boiler requires the addition of a large hopper to maintain fuel intake. Combined, the boiler and the hopper take up approximately twice the space of a traditional oil burning furnace. Any household in Montachusetts with sufficient space can install one of these pellet devices. There are multiple pellet distributors that service the Montachusett region (nevelsstoves.com, 2013).

Wind Power

Wind is a powerful source of power. Wind turbines operate by converting the kinetic energy of wind into some usable form, like electricity. Wind is a powerful force that increases with height. Residential wind energy has a lot more to consider than other technologies, such as the height of the turbine and the average wind speeds around the turbine and wind directions. For the Montachusett region there are wind maps available that catalogue the wind speeds for each area and at each altitude in that area. These maps are easily accessible from the MRPC website. These wind maps indicate that the central region of Montachusett is quite windy and all four current windmills/wind farms can be found along this region (MRPC, 2013). This is due to the heights needed to find acceptable wind speeds in the region. Outside the shores of Massachusetts and certain select areas wind is not always worthwhile unless you reach certain heights.

Wind turbine towers are made of a few components: the tower, the nacelle and the rotor. The nacelle and the rotor are at the top of the tower. The nacelle houses all the electronics and the gearbox while the rotor is the blades which are connected to the nacelle (CEC, 2013).

In order to use a wind turbine for residential establishments the installer must contend with the limitations that residential use brings. Safety laws require that any device installed on residential property must be small enough that if it fell, it would remain entirely on that property. Small scale wind turbines are simple especially for home use because the blades are usually not adjustable to compensate for wind speeds. The blades are placed on and oscillating base where they are designed to automatically face the direction of the wind. When the turbine starts to move it moves the generator. However, wind turbines must spin within a specific speed range to operate effectively. Outside this range wind turbines generate little power. This is because of the generator, which is only efficient between certain speeds (CEC, 2013). The installer must be certain that the local wind speeds match that in which the generator is rated for. It is important to make sure when installing wind turbines that there is clearance all around the turbine or that the turbine clears the tree lines by a few feet. This is sometimes an issue as the turbine can cast shadow flicker and cause motion sickness in some people. Common complaints for wind turbines often include noise infractions, although allegations of “wind turbine sickness” have proven largely unfounded (Guardian, 2013)

Hydropower

Hydropower is the oldest renewable technology, having been utilized in various ways by many ancient civilizations. Hydropower is the process of deriving power from falling or running water and converting that energy into a useful form (Atkins, 2010). Although this can mean anything from running saw mills, to hydraulic lifts, and textile mills, modern use and research of hydropower has focused exclusively on the generation of electricity. Hydroelectricity requires a large source of water that is constantly in motion; this heavily limits the number of potential sites used for energy generation.

Hydroelectricity accounts for 16% of all electricity generation worldwide (Atkins, 2010) accounting for 12% of the US’ electricity use and 49% of its total renewable energy generation, making it the most widely used renewable energy technology in both the US and internationally (Aguirre, 2011). Large scale hydroelectric operations require a reservoir usually in the form of a dam. Selecting a site for dam building is a delicate and risky prospect as the environmental impact of damming a major body of water is often difficult to understand and affects the entire range of the river in question. Without proper planning, a dam can affect fish migration patterns, water levels, oxygen levels in the water, and sedimentation or erosion of the lower plains

(Atkins, 2010). New dam constructions on bodies of water that cross country boundaries can also often be the source of dispute, such as water-sharing agreements in southwest United States and neighboring Mexico (CIA.gov, 2009). Most dams in the United States were constructed before their environmental and foreign impact was fully understood. Modern dam construction must carefully consider the area in question before construction can begin.

Conventional hydroelectric dams run water through a turbine to generate electrical energy. This electricity is then distributed normally throughout the grid. Conventional dams require large volumes of water to generate an appreciable amount of electricity requiring a large water source and/or extreme gradient. The closest conventional hydroelectric dams are the Robert Moses Niagara Hydroelectric Power Station and the Moses-Saunders Power Dam. Both are located on the New York-Canadian border and provide the household electrical needs of much of upstate New York, Vermont, and Canada. Combined these two dams produce 4,500 MW of energy for use in the surrounding areas (Maloni, 2010).

Pumped-storage hydroelectric facilities work differently than conventional dams in that they supplement additional electrical generation processes and have a much more variable output. Pumped-storage facilities serve as a load balancer to electrical demands on the grid. The stored water is a source of potential energy that when released through a turbine system will generate electricity in the same manner as a conventional dam. However, during periods of low energy consumption, the water is reversed, pumped into the reservoir to be held until energy demand rises again. This relieves the burden on traditional oil and coal boilers, which lose efficiency when run over the standard demand. Although the reservoir pumping process is energy intensive, the costs associated with running fossil fuel burners over capacity and the profit made from selling electricity only during peak hours make pumped-storage facilities possible. One major pumped-storage facility actually serves the western Montachusett region, the Northfield Mountain Pumped-Storage Reservoir. The plant is located in Erving and Northfield Massachusetts and is capable of producing 1,080 MW of electricity (Maloni, 2010). The actual facility is located entirely underground and is part of the Turner Falls canal system. This is the only hydroelectric technology that services the Montachusett region. While small scale hydroelectric turbines exist, their use is largely confined to poor and remote areas of the world that would otherwise lack electricity. Installation of a small scale hydroelectric turbine is not feasible in the Montachusetts region as there are several laws protecting the moving bodies of water located there.

Cost of Installing and Operating a Renewable Energy Device

Solar Photovoltaics

Initial installation costs of solar photovoltaic systems can be high, but this is offset by their low maintenance costs. Maintenance and running costs are not normally required unless one of the components break, otherwise it is no required. Our running costs for solar Photovoltaics include yearly maintenance and the expectation that the inverter will need to be fully replaced once over the lifetime of the device. However, solar panels have a life expectancy of about 30 years, due to solar cell degradation that occurs over time (CEC, 2013). The systems eventually end up paying for themselves and the full cost of installation is eligible for a 30% Federal Tax Credit. Solar photovoltaic systems qualify for the major Federal Tax Credit only if they reach a predetermined efficiency. It is important to understand what kind of initial cost you are looking at. The charts below give estimates for what you can expect to pay depending on the size of the system.

Figure 1: Cost of Installing a Solar Photovoltaic System by Size

Grid Tie Systems			
Array Size Watts STC/PTC	Monthly Output Based on 5 hours of sun a day	Number of Solar Panels	Price
3,000 / 2,700	405 kWh	12	$4900-$5800
5,000 / 4,500	675 kWh	20	$7800-$9300
6,000 / 5,400	810 kWh	24	$9500-$11500
7,500 / 6,750	1,012 kWh	30	$13,000
9,000 / 8,100	1215 kWh	36	$16,000
10,000 / 9,000	1350 kWh	40	$17,000
12,500 / 11,250	1687 kWh	50	$21,000
15,000 / 13,500	2025 kWh	60	$26,000
20,000 / 18,000	2,700 kWh	80	$35,000

Grid-tie Solar Systems with True Off-grid Capability				
Array Size (watts)	output in V	Monthly Output at 5 hours a day of sun	Number of Panels	Price
1500	120	203 kWh	6	$6,000
2250	120	304 kWh	9	$7,000
3000	120	406 kWh	12	$8,000

3750	120	508 kWh	15	$9,000

Prices will vary from one installer to another so it is important to get multiple quotes to get the price. The operational lifecycle of the system is 30 years making solar PV an ideal candidate for a payback period analysis.

Geothermal Heat Pumps

Geothermal systems have high upfront initial costs, but very little in the way of maintenance. Single-home installations vary with the size of the house. Cost estimates range between $14,000 and $20,000 for the average home in the Northeast. Massachusetts offers no subsidy programs but up to 30% of the total cost of installation may be claimed as a tax credit through the Residential Renewable Energy Tax Credit Federal program (MassCEC, 2012). This tax credit has only recently been applied to geothermal systems, as they were traditionally only considered a commercial device and do not “generate” energy, they merely extract/diffuse heat from the ground. As of 2008, they have been added to the list of devices eligible for the Federal Tax Credit program.

A typical system can last anywhere from 25 to 50 years. The running and maintenance costs of a geothermal system scale with the size of the heat field, they can range between $200 a year for small systems to $500 a year for large systems (energystar.com, 2013). Geothermal systems use a small amount of electricity to operate the heat pump; these costs have been factored into the running costs of the device.

Biomass

Pellet stoves come in a wide variety and sizes and capacities. Adding a pellet stove to your home will require the addition of a new vent that is capable of handling the high-temperature exhaust and most chimneys are unsuited for this task. Depending on the model, it may also be necessary to buy a hearth to rest the stove on although many models are freestanding or come with a hearth. The typical cost of the stove itself ranges from $1,500 to $2,500, professional installation adds about $500 to that cost, and an average Massachusetts user burns about three tons of pellets a year creating a running cost of approximately $880 to $1300 (Truini, 2012). The installation procedure varies by house, can be done by the homeowner, and only requires that one exhaust vent be added in most cases.

Pellet boilers must be professionally installed and require sufficient space where the previous furnace was located in order to be properly connected to the house's heat distribution system. Full pellet boiler/hopper installations range between $25,000 to $28,000 in price but a current MassCEC grant can provide up to $7,000 for eligible applicants (MassCEC.com, 2012). Pellet boilers are intended for large homes and homes which do not allow a pellet stove to adequately distribute heat via convection. Their fuel consumption is likewise much higher, needing 8 to 10 tons of pellets a year at a cost of $1,730 to $2,600 a year to handle a typical New England year (maineenergysystems.com, 2013). Pellet distribution is a growing industry and many Maine distributors now service all of New England. Both pellet stoves and pellet boilers have a useful life of 25 years (Truini, 2012).

Wind Power

Due to the high risk involved in installing a wind turbine it is recommended to have a professional installation done which drives the upfront cost upward. Unlike other renewable energy systems, wind turbines must always be free standing, which makes installation and maintenance difficult. There are also a lot more bylaws and safety problems to deal with compared to most technologies. However, even with these drawbacks, it is undeniable that wind technology is a valid technology with a lot to offer. Wind turbines can operate at all hours of the day and throughout all seasons. In the Montachusett region, it is important to be located in the windy central corridor of the region as turbine installations elsewhere will not receive sufficient wind (MRPC, 2013). Once the area is deemed appropriate for a wind turbine the installer must also cite these turbines carefully and make sure there is safe clearance on all sides.

While wind turbine installation costs are comparable to that of other large scale renewable technologies we observed, maintenance and expected repair costs are higher than other technologies. A basic windmill for a residential installation can run between $5,000 to about $35,000 just for the equipment. The installation is also very costly for the reasons mentioned above. Wind turbines have a life expectancy of about 20 years (CEC, 2013). The parts in the turbines can be manufactured of better materials and thus increasing the life expectancy of the turbines, but because of the continuing advancements in efficiencies and power production.

Larger and more effective wind turbines cannot be placed closer than 300 meters to any residential area due to the noise they make. Maintenance is minimal once installed but still costly as some sort of lift is required for most repairs. As with all renewable energy devices, wind turbines qualify for the 30% Federal tax credit on installation costs.

Non-Renewable Utility Consumption Patterns and Costs

Massachusetts residents must deal with some of the highest utility costs nationwide. Infrastructure, average age of a residential home, and long winters are the primary contributing factors to the region's high utility costs (EIA.gov, 2011). For example, Massachusetts residents pay significantly more for electricity than the national average:

Figure 2: Grid Electrical Use in the United States

Region	Monthly Electricity Use (in kWh)	Average 2011 Price of 1 kWh Grid Electricity (U.S. Dollars)
MA	633	0.1467
New England	639	0.1589
US Average	940	0.1172

Data taken from the EIA.gov factsheet and US census

The only portions of the United States that experience higher average electrical costs are the Northern regions of New England, Hawaii, and Alaska. The national monthly use is substantially higher than the region for multiple reasons. Space heating and water heating, the two most energy intensive processes used at an average American home, are not financially feasible to do in Massachusetts via electricity. Electrical heating comprises a small minority of Massachusetts homes. This is a stark contrast to the national average, where electricity is much cheaper and shorter, milder winters allow the extreme cost of electrical heating to be marginalized. Additionally, central air conditioning systems are found in 40% of US homes compared to just 8% of New England homes (EIA.gov, 2012). Air conditioning makes up a significant portion of electrical use outside of Massachusetts. In a typical Massachusetts household, grid electricity supplies the energy needed to run appliances and seasonal, window-mounted air conditioning, not the year-round HVAC systems found in much of the rest of the country.

The New England heating market is dominated by oil. Oil burning furnaces and water heaters are better suited to New England weather than the other standard options. New England encompasses a full 82% of all oil-burning space and water heaters used in the United States, this figure is so large that it actually dramatically shifts the national averages for residential oil use and cost upward (heatingoil.com, 2013) (EIA.gov, 2012)

Figure 3: Heating Oil Use in the United States

Region	Monthly Fuel Oil Use for Space Heating (in gallons)	Monthly Fuel Oil Use for Water Heating (in gallons)	Average 2012 Price of 1 gallon #2 Fuel Oil (U.S. Dollars)
MA	66.66	18.33	4.0342
New England	70.83	18.33	4.0156
US Average	55.25	19	4.0028

Data taken from the EIA.gov factsheet and US census

The remainders of oil-burning furnaces in the US are located primarily in the South. The East coast of the United States is the only region that has grown to support oil-furnace infrastructure.

The third major energy utility, natural gas, is little used in Massachusetts, found in only 4% of homes (EIA.gov, 2012). Like oil and electric costs, Massachusetts residents pay above the national average.

Figure 4: Natural Gas Use in the United States

Region	Monthly Natural Gas Use for Space Heating (in hcf)	Monthly Natural Gas Use for Water Heating (in hcf)	Average 2012 Price of 1 hcf Natural Gas (U.S. Dollars)
MA	71.33	18.88	3.2787
New England	74.91	18.88	3.2327
US Average	73.08	23.02	2.6132

Data taken from the EIA.gov factsheet and US census

Rather than growing to depend on oil, the north central regions of the US rely primarily on natural gas, especially in the colder states bordering Canada (EIA.gov, 2012). With this information we can establish a reasonable energy profile for an average Massachusetts resident who is not invested in renewable energy technologies.

Figure 5: Average Monthly Utility Bills for Massachusetts Residents

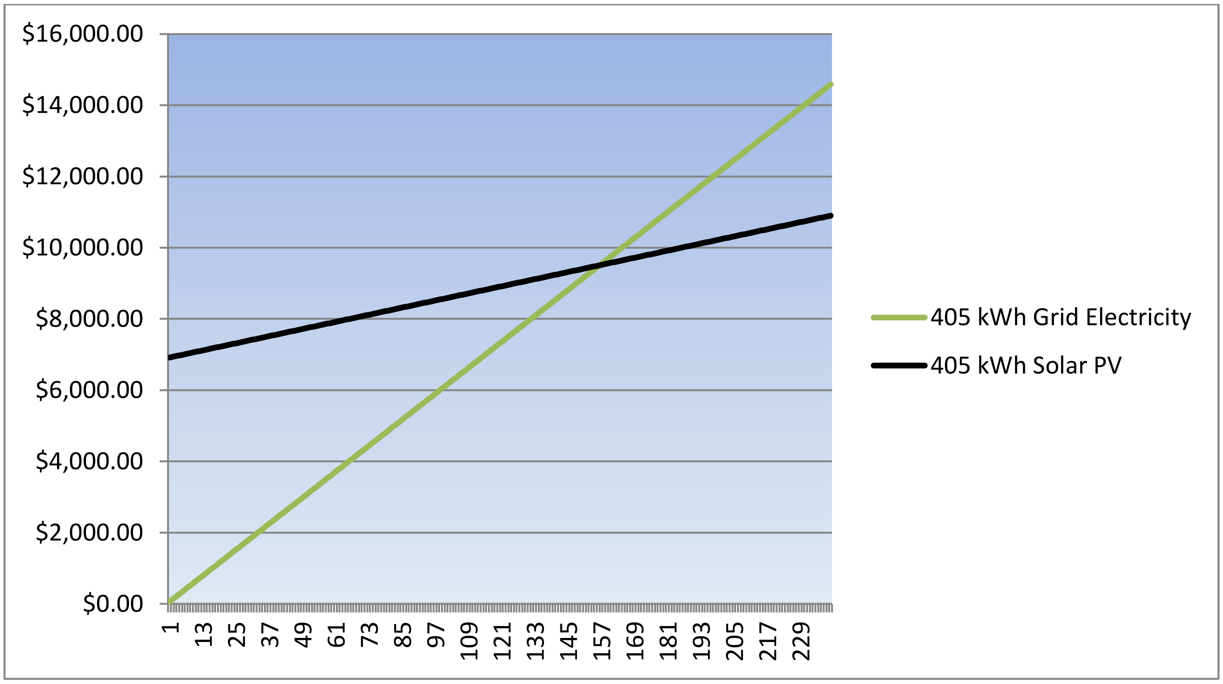
User	Monthly Electric Bill	Monthly Heating Oil Bill	Monthly Natural Gas Bill	Total
MA Oil Household	92.86	342.86	-	435.72
MA Natural Gas Household	92.86	-	295.77	388.63
MA Electrical Only Household	675.77	-	-	675.77

These figures represent the average monthly utility bills a Massachusetts resident could be expected to pay depending on the heating source used in the home. These are averages of a full year in Massachusetts to control for seasonal highs and lows. Unsurprisingly, those reliant on electrical heat face the highest monthly bills. Natural gas prices currently make natural gas heaters slightly less expensive to operate than oil-burning ones but the two are close and the price of these two utilities varies much more throughout the years. These findings are consistent with the various reports that renewable energy technologies are most immediately beneficial in electric heating homes (EIA.gov, 2011). By using these monthly figures as a basis, we can compare them to renewable energy devices and see how long a specific product requires to recoup its' own installation costs.

Solar Photovoltaics

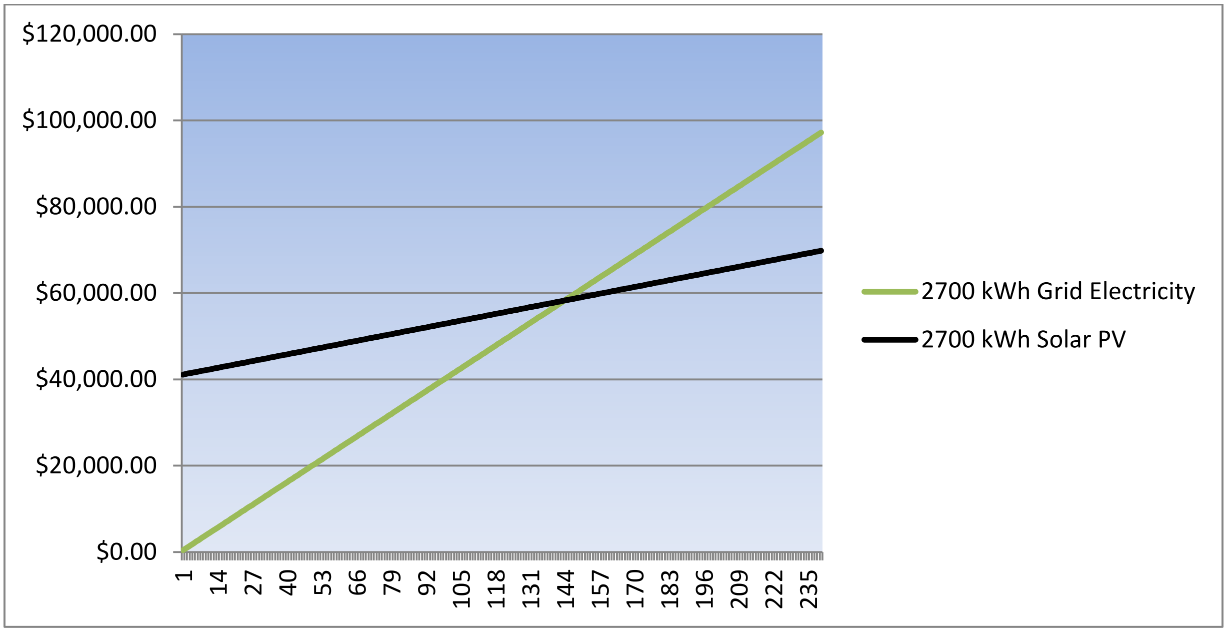
The cost of solar PV systems is not linear. Every solar PV installation must have several core components (inverter, grid tie, external shutoff, etc.) and a varying number of panels that effect the size (and cost) of the core components. The installation cost and savings generated by both small and large scale systems actually makes the payback of these systems longer than that of the medium-sized systems we reviewed.

Graph 1: Small-Scale Solar System Payback Period in Months



Small scale systems like the 405 kWh example above have a fairly long payback period. Solar photovoltaic systems scale in capacity with the number of solar panels used but all systems require an inverter, external shutoff, or storage battery, making the cost of installation comparable to larger scale systems. Additionally, the payback period analysis uses savings as its cash inflow and a small system would only generate $45 in savings monthly when compared to an equal amount of electrical usage from the grid. If a household is not using very much electricity to start with then they may actually sell some of that power back to the grid. As it stands, smaller systems have longer payback periods.

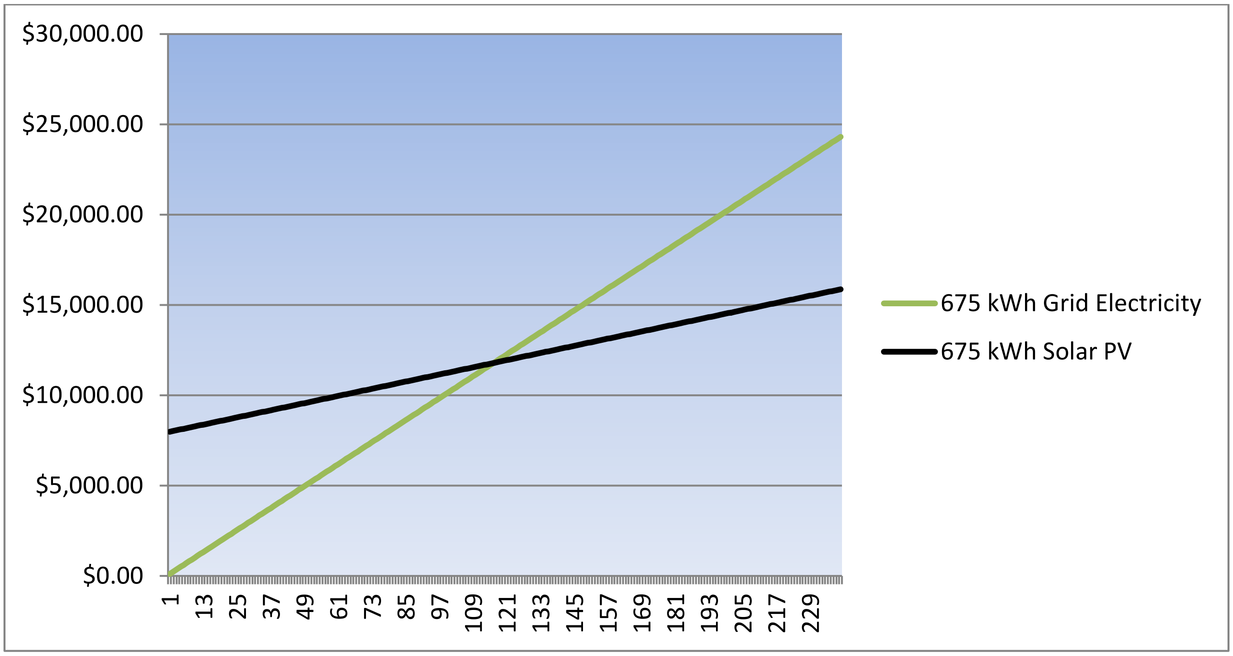
Graph 2: Large-Scale Solar System Payback Period in Months



Large scale systems also seem to have long payback periods this is because of the larger installation cost due to there being so many panels. Based on the estimates found on in the attached documents there is a large gap between the power output from the smaller systems output and this system's output. Again, this graph describes how long it would take if you were using as much power as the system is providing. If you are not using that much power any excess would go to the grid and you would stand to gain from that excess. Refer to attached charts to further understand the numbers.

The average cost per kWh in Massachusetts was $0.1467 in 2011. A Massachusetts resident uses approximately 633 kWh of electricity per month at a monthly cost of $92.86 provided they don't use electricity for heating purposes. A 20 panel solar array produces 675 kWh of electricity monthly, just enough to eclipse the electrical needs of an average MA household.

Graph 3: Average MA Resident Replacement System

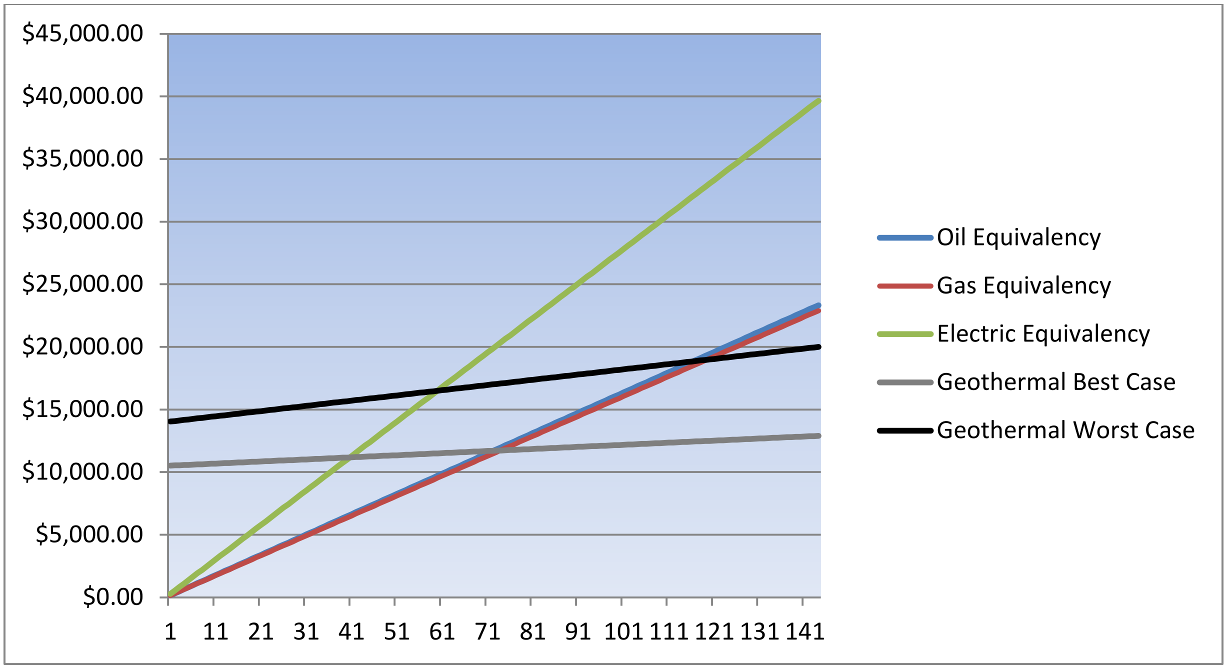


This is the payback period for a solar PV array that replaces the electrical use of an average MA household. This average usage solar array actually hits an optimal payback period niche as it only takes 10 years to recoup instillation costs compared to 12 to 13 years for the larger and smaller systems respectively. Average electrical consumption households that are located in an appropriate location for solar photovoltaic use should be considered prime candidates for this technology. However, it is still prudent to study the unique situation of each home to be sure of how much this system will benefit the homeowner and when they can expect to see payback.

Geothermal Heat Pumps

Geothermal heat pumps do not replace any individual technology wholly; rather they supplement a household's water heating, air heating, and air cooling systems. Geothermal systems vary greatly in capacity, ranging from 28,000 to 78,000 BTU per hour output (energystar.gov). The capacity of a geothermal system scales with the size of the heat field. Larger heat fields have a higher upfront installation cost. When properly connected to all relevant systems, a geothermal heat pump can offset roughly 40 gallons of fuel oil worth of energy per month.

Graph 4: Geothermal Payback Period in Months

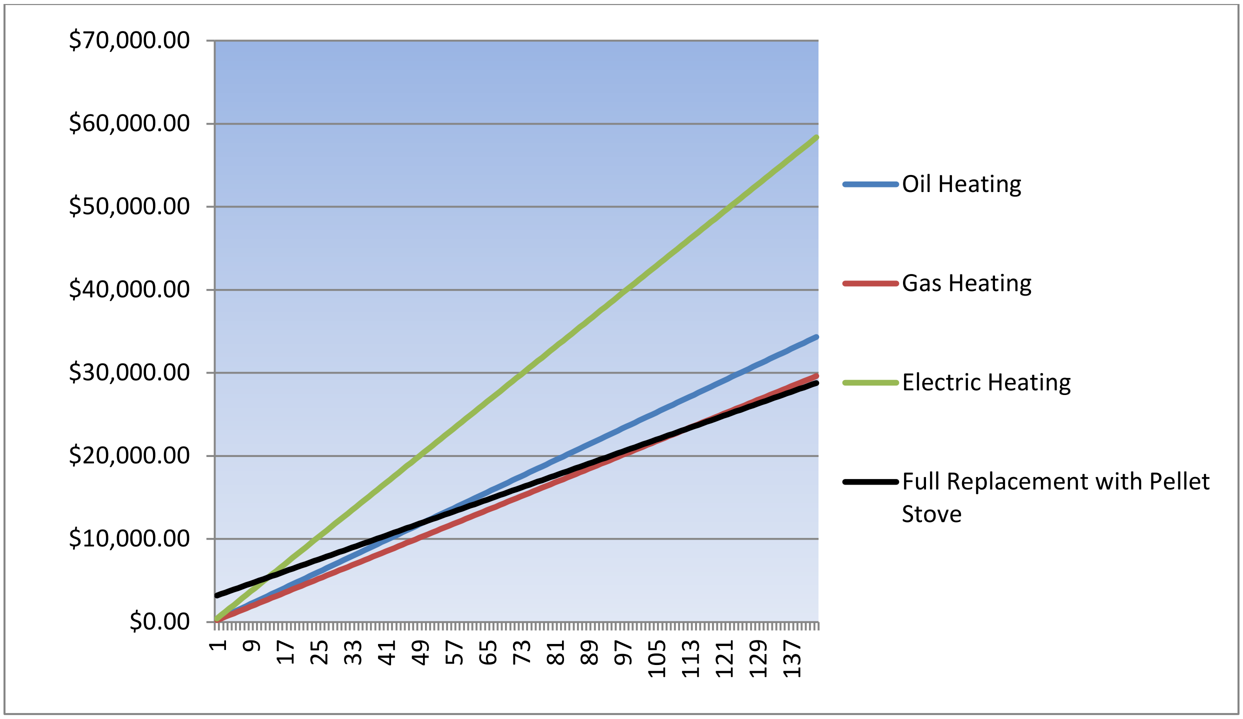


The best and worst case scenarios are based on the size of the system installed. Geothermal installation cost increases significantly with the size of the system as the larger the heat field, the more space and backhoe work is required to lay coils. Offsetting the costs of electrical space and water heating has the fastest payback period as usual, ranging from 3 to 5 years. Gas and electric systems take longer, 6 to 10 years, and are highly dependent on the size of the system installed. Running costs for geothermal systems are minimal so the payback period for the system in question is mostly dependent on the desired capacity and thus size of the geothermal heat pump. Once again, the payback period is shortest when supplementing electrical heating appliances.

Biomass

There are two heating systems to consider, pellet stoves and the much larger pellet furnaces. Both of these devices aim to replace the space heating needs of a household. Whether or not a pellet stove is sufficient space heating for a household depends on several things, primarily the floor space and age of the house. Older homes tend to have significantly lower thermal efficiency and are more suited to pellet furnaces. Newer or smaller homes can adequately heat themselves via just a stove.

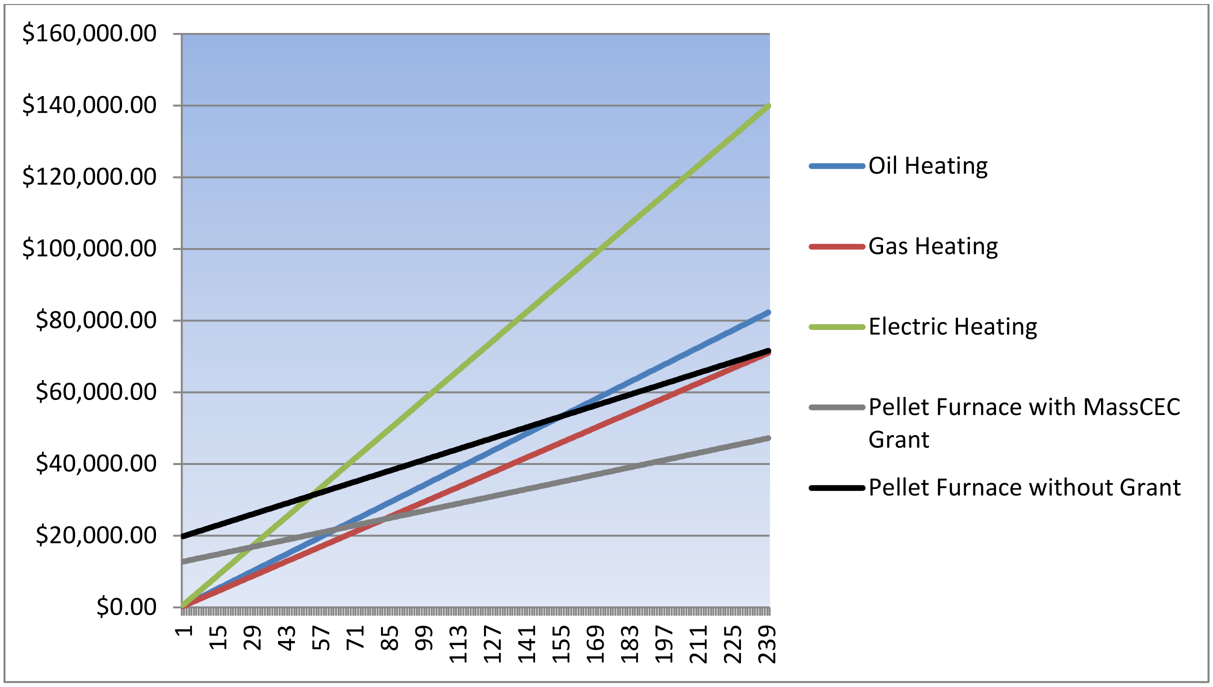
Graph 5: Pellet Stove Payback Period in Months



Pellet stoves payback period is the most dependent on the kind of utility it replaces. With a 30% Federal tax credit; the installation price of a pellet stove can be paid in about a year for electrical heaters, 4 years for oil heaters, and as long as 9 years for natural gas heaters. This is due to the running cost of a pellet furnace being comparable to that of current fossil fuel prices. When replacing a natural gas system, a pellet burning stove only saves the user about $27 monthly.

Larger and less energy efficient homes will have to opt for a large scale pellet furnace. This has the benefit of more even space heating but pellet furnaces come at a significantly higher upfront cost. This cost can be offset by a large MassCEC pellet furnace grant program and the 30% Federal tax credit, but the size of the grant program is limited to 40 households.

Graph 6: Pellet Furnace Payback Period in Months

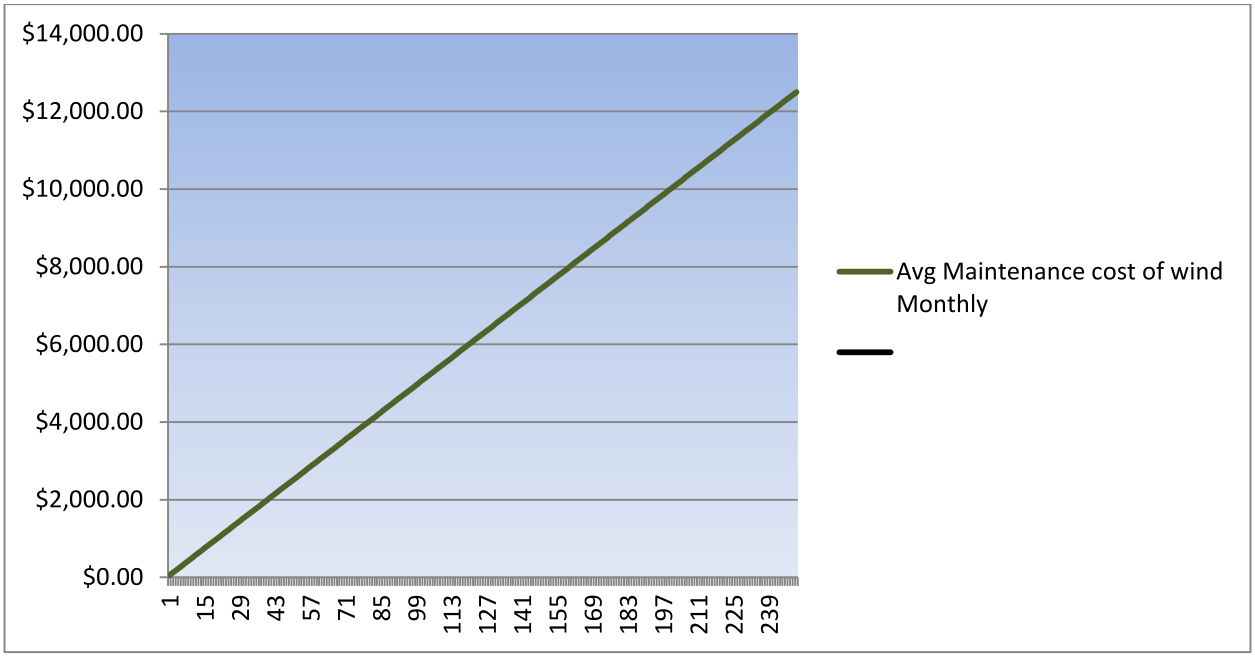


With a MassCEC grant, payback period for a pellet furnace is as low as 2 to 8 years. However, because the grant is limited in scope and duration, most households will only be able to qualify for the 30% Federal tax credit. The payback period for a pellet furnace without the grant can be as long as 12 to 20 years when compared against oil and gas heating methods. This is over half the useful life of the device, making it a risky investment by payback period standards (Horngren, 1974). While operation costs are lower than any utility, the running costs of pellet burners are much higher than the running costs of most other technologies we reviewed, leading to a higher payback period. Unless a household is seeking to replace an electrical heating system, the pellet boilers are not worth considering without the large MassCEC grant.

Wind Power

Wind has the longest payback period of the technologies we reviewed due to its' high installation and maintenance costs. The high maintenance cost is due to the equipment necessary to work on a wind turbine and the safety precautions that must be taken. Located outdoors and possessing several critical moving parts, wear and tear has a much larger impact on wind turbines than the other technologies. It will produce a lot of power depending on wind in your area and the size of the turbine installed. The graph below is based on an 8 kWh turbine that is installed at an area with average 12 MPH wind. The payback period is approximately 230 months, which is about 19 years.

Graph 7: Wind Turbine Payback Period in Months



According to MassCEC, wind is not always the best option for residential use, as it requires great heights to be effective. This is not easy to do in a residential area because higher and bigger turbines require a lot more money, usually breaking the $1 million dollar barrier. The high upfront and running costs makes wind turbines a difficult prospect for a residential home. The difficulty of adhering to the strict bylaws that govern wind turbine installations only further dissuade homeowners from pursuing a residential scale wind turbine.

Comparisons to Previous Studies

Payback period is a common metric used in the renewable energy market to give homeowners a good measure of how long they would need to suffer a financial loss in order to see savings generated by such devices. Throughout our research, payback period was consistently a given point of data but rarely was the information used to determine this number divulged as well. By comparing our payback analysis to that of the given payback numbers from another study, we can see if our findings are accurate. These comparisons must take into account the age of the study as well as the region it was conducted in as they both have an influence on the potential cost and output of a given system which affects the payback period.

Taos Pueblo Reservation, New Mexico

One of the most major recent Federal studies in renewable technologies was the Taos Pueblo Renewable Energy Feasibility Study conducted on the Taos Pueblo reservation in New Mexico. The scope of the project included all five of the technologies we reviewed, used payback period as one of the primary determining factors, and also accounted for the cultural and political inclinations of the Taos Pueblo people. Additionally, it accounted for financial factors that were not applicable to our project, such as the New Mexico Clean Energy Grant. As our project used Massachusetts resident's utility data as a basis for comparison, the energy profile for the Federal study was determined by finding the average user metrics from the Taos Pueblo Utility company.

Despite the differences of the two regions, many of our findings were remarkably similar. Geothermal heat pumps were given the same upper limit in payback time at 10 years (Mason, Gomez, et al, 2006). We reached a shorter lower limit because our geothermal survey included a electrical heating comparison, the Taos Pueblo study only considered the more economical natural gas heating utility in it's payback analysis (oil heating and infrastructure is not present in this region of the US).

The Federal study also found huge potential for solar technologies (solar PV, solar pumped-hydro, and greenhouses) in the region but did not include payback as a metric in the solar analysis. Given that electricity is roughly half as expensive in New Mexico as it is in New England and that New Mexico receives nearly twice the sunlight exposure than New England does, entering this data into the calculations we used gives a solar PV payback of about 10 years for the Taos Pueblo reservation (Mason, Gomez, et al, 2006).

Some findings in Taos Pueblo study differed from our own. One of the largest discrepancies was the Federal studies high opinion on large scale wood boilers. The Taos Pueblo region had several conveniently located sawmills and other wood waste producers that lowered the fuel costs to less than half of the national average (Mason, Gomez, et al, 2006). Additionally, the need for space heating is much lower in New Mexico than Massachusetts, meaning these large wood boilers would only be used a portion of the year. The projected payback for a Taos Pueblo wood boiler was expected to be 15 years compared to the 20 year payback a Massachusetts resident might encounter.

Interestingly, the Federal study reached a far different conclusion on the viability of wind. Our study found wind turbines most appropriate for large scale commercial uses and residential applications were both difficult to carry out and financially unsound. The Taos Pueblo study eliminated commercial wind farms from consideration citing a lack of sufficient wind speeds in the area. This is a regional difference that does not impact our findings for Massachusetts. However, the Federal study also suggested that wind power may be adopted in Taos Pueblo on a residential scale, not due to economic benefit, but because wind power was deemed more culturally acceptable to the Taos Pueblo people (Mason, Gomez, et al, 2006). A detailed evaluation of hydropower feasibility was also conducted and found potential for a pumped-storage facility in the region similar to the North Brownfield facility that services western Montachusetts. However, a pumped-storage facility was not possible in Taos Pueblo due to an insufficient amount of capital.

Other Studies

The UK Carbon Trust organization conducted a feasibility study for several of the technologies we reviewed for both home and small business use. The Carbon Trust study found that small scale residential wind turbine had payback period of 20 years, identical to our evaluation for wind turbines installed in area with sufficient wind in Montachusetts. The Carbon Trust also found a similar range for biomass pellet stoves, with an upper limit of 10 years depending on the type of fossil fuel replaced and the type of biomass used. Solar PV systems purportedly have a lower payback period in the UK of 5 to 8 years. This is likely due to the heavily subsidized cost of installation through the UK's FIT program, as the UK actually receives less light annually than Massachusetts. Geothermal heat pumps have a higher expected payback period of 15 years, but the RHI incentive program lowers this figure to 5 to 8 years. This is the only major deviation from our results which is interesting because geothermal systems allegedly have the most consistent performance regardless of the location they are installed. One cause for the discrepancy could be the tariff that such geothermal systems are subjected to in the UK. Despite the location for this feasibility study being located on the opposite side of the Atlantic Ocean, the performance for many of the devices, in conjunction with available UK subsidies makes many of the payback periods comparable (UK Department of Energy and Climate Change, 2012).

The Alliance for Green Heat lists the expected payback periods of various renewable technologies. Most notably, it does not take into account any Federal or state subsidies so its results are consistently slightly above the time periods we reached for our Montachusetts evaluation. The Alliance for Green Heat survey found an expected payback period of 30 years for wind turbines, 7-12 years for geothermal heat pumps, 10+ years for solar PV arrays, and 4-6 years for pellet stoves (Wise, 2009). Without accounting for the 30% Federal tax credit, the payback periods for the above listed technologies are predictably about 40% higher (1/0.7 = 1.42) than the results we reached.

The Synapse Energy Economic Company conducted a feasibility study into the possibility of renewable technologies in low income Massachusetts homes in 2005. While the scope of the project only overlapped with two of the technologies we surveyed, its results for solar were quite different. Its analysis of small scale wind turbines found an expected 20 year payback period matching the results of our study. However, it also found a 20 year payback period for solar PV arrays regardless of setup (Woolf, 2005). This figure was twice as large as the expected payback period we reached. However the age of study predates the 30% Federal tax credit and increases in solar PV efficiency (discussed below) could have resulted in this payback period falling within an expected range.

While most of our comparisons have a similar expected payback period or a payback period which falls within an explainable range, a complete analysis should include an example that does not agree with our findings. The WisconSUN payback analysis for solar PV systems came up with a substantially longer payback period for any of its solar PV calculations. The program indicted that a solar PV system installed in Wisconsin could take anywhere from 34-76 years to payback fully (Gretz, 2004). This figure was odd considering Massachusetts and Wisconsin receive roughly the same amount of light annually. The two major contributing factors to this longer payback period are likely both related to the age of this study. Conducted in 2004, the 30% Federal tax credit which now applies to any home installation of solar PV did not exist, meaning the WisconSUN analysis included the full price of installation. The other impact the age of the study has is the efficiency of the solar cell itself. The National Renewable Energy Laboratory claims that solar cells have increased from 30% to 40% efficiency in the last 9 years alone. Despite these differences, we are unable to account for the extreme length of time the

WisconSUN study found. The WisconSUN organization has no overt political affiliation and its stated goals are to promote solar technology in the state of Wisconsin. With the stated goal of promoting such technologies, it is surprising that their evaluation of solar PV was so negative.

Concerns

Throughout the project, we constantly refined our methods of data collection and analysis before we settled on payback period as our primary evaluation metric. Payback period analysis is commonly used by both private and public organizations and readily understood by most people; however it is not without drawbacks. Payback period analysis does not account for the time value of money, risk, or opportunity costs. It assumes that the homeowner has sufficient capital to pursue the installation of a renewable energy device and does not consider the other potentially beneficial investments that could be made with said capital. We only account for the expected maintenance costs that would occur over the life of the device. An unlikely, but entirely possible, failure of a device (such as a cracked solar panel or leaking heat field in a geothermal system) could radically increase the payback period due to costly repairs. Finally, our payback period analysis was a “do nothing” analysis, comparing the costs of installing and operating a renewable energy device against a status quo of fossil-fuel based utilities. It does not account for the potential of investing that capital elsewhere. As the scope of this project was renewable energy devices in the home there are several other investments a homeowner could make if their desired goal is to save money or energy. Investing in energy saving retrofits could have a larger or more immediate impact for the homeowner. Further research into the payback period of commonly used retrofits like window or roofing replacements is suggested.

Our data collection was limited to historic values. At no point did we attempt to calculate the projected values of any of the metrics used. Although this certainly resulted in a less accurate prediction, we feel that a payback period analysis that accounts for future changes in price would likely reduce the payback period. This is due to two factors. The first is that projections involving the future price of oil, natural gas, and coal are certain to increase, which would result in a larger monthly savings figure generated over time. The other is increasing amount of research being dedicated to renewable technologies. This is even more difficult to predict than fossil fuel futures. Subsequent improvements to renewable energy devices could result in lower installation and maintenance costs which would also lead to a more favorable payback period.

Other market forces are harder to predict. A sudden widespread adoption of pellet stoves could drive the price of wood pellets to an unfeasible level. The current expected cost of operating a pellet device year-round is only 15% lower than that of a comparable fossil fuel based heater.

While payback period is a commonly used technique, there are two similar methods of analysis that are regarded as more accurate, as they account for more aspects of the investment. A Net Present Value analysis (NPV) accounts for the discount rate. This would demonstrate the benefit of adopting a specific renewable energy device compared against making another investment with the same amount of capital and similar amount of risk (Buser, 1986). An Internal Rate of Return analysis (IRR) factors in the savings or profits generated by carrying out a specific project and assumes this cash inflow is invested elsewhere, leading to a more accurate evaluation. However, an IRR analysis could not be used to compare multiple potential renewable energy projects against one another as this method is used to evaluate the potential of individual projects (Horngren, 1974).

Recommendations

Emerging technologies are making a future without fossil fuels possible. The goal is closer today than it ever was and the new goals being set are making the realization of a future with no fossil fuels a reality. A precise plan must be created and followed to maximize the chance of success while transitioning to renewable energy. Our recommendation is that the following technologies are promoted and specific residences targeted. First, we recommend that the Montachusett region focus on supplementing and replacing electrical heating devices with geothermal systems and pellet stoves. Second, promote Photovoltaic technology throughout the region and provide incentives for using said systems. Third, promote the Massachusetts CEC pellet boiler grant program as it brings the payback period of this technology to an acceptable level. Do not promote pellet boilers otherwise. Finally, do not promote residential-scale wind turbines. They are too small to truly take advantage of current wind technology. These recommendations are for residential purposes only and do not necessarily affect the commercial viability of any technology in the region. We will discuss further the benefits of making these choices and why they are so important.

As discussed earlier in this document one of the costliest utilities to a home in Massachusetts, more specifically the Montachusett region, is heating. This cost is further increased by those that rely on electricity for heating. Radiant heating requires a lot more energy to heat a space. This is largely the reason why forced hot air has been the prime choice of many designs for heating in a home. Since the most energy consuming electrical usage is heating we recommend that systems utilizing electricity to heating be supplemented with geothermal and pellet stoves to heat the home. Homes that utilize these systems see a dramatic decrease in heating utility bills. Both these systems have and upper limit on payback period of about 10 years, a figure which is markedly shorter when considering electrical heating appliances. We have also seen that the consumer can live in more comfortable temperatures when using these systems. The geothermal systems take advantage of the radiant energy of the earth which is the same year round so the consumer never stops benefitting for the system. It can supplement both heating and cooling needs. Pellet stove are inexpensive and easily installed. They have the most direct effect and can fully replace a home heating system. Although, the consumer should be aware of the minor inconveniences involved with owning this system, such as cleaning pipes yearly, filling a hopper daily and about every ton of wood the consumer goes through they will need to empty the ash container which means intermittent use for about a few hours. Also, consumers should be aware that modern pellet stoves take significantly less work to operate than their standard wood burning predecessors. Both systems add huge savings and advantages to medium and smaller sized homes and are strongly recommended.

Solar photovoltaic systems seemed to have the one of the shorter payback periods and it is one of the most practical for many reasons. Some the reasons include that it is directly related to the amount of power the consumer is using and in some cases it can even pay back monthly other than the savings if the system is large enough. These systems have very little visual impact and they work year round as long there is sufficient sunlight. Solar panels melt snow at a much faster pace than that of a normal roof. They require little to no maintenance and have many financing options. They are easier to install and do not require as high installation cost as other systems. Although they cannot be used on all homes they are a preferred option among the technologies discussed for the long service life, lack of maintenance, and clean energy they produce. For these reasons, solar Photovoltaic systems should be one of the chief technologies promoted in the region. It is important to mention that solar photovoltaic cells produce power in all temperatures. New advances have made it so that they can be more efficient in colder climates. This is especially useful in Montachusetts because of the temperature range that exists in this region. Solar Photovoltaic cells do not make noise and they often sit on roofs and do no cause a large visual impact. Also, because there are no moving parts that technology is long lasting. Solar panel systems can last over 30 years depending on the usage and how much sun they are exposed to.

Mass CEC pellet boiler program has many benefits but is too small for everyone to benefit from. Pellet stoves are the more convenient option but those that can qualify for the 40 person boiler pilot grant program will receive a much larger capacity system with a comparable payback period. The boiler/hopper installations are large, but require less maintenance then the smaller scale stoves. They can also be connected to existing duct tunnels in the home. However, because of the high cost of the systems and the installation costs it is not easy for all to afford. If there are no grants to supplement the installation then they should not be promoted as the 30% Federal tax credit is not sufficient to make pellet boilers a competitive technology. We suggest that the MRPC promote the MassCEC boiler grant program but do not otherwise promote pellet boilers.

Wind turbines are good for power output but do not always make sense for residential use. The usability factor in the Montachusett region for residential district is much too low to consider installation. Even in areas where they can be installed it is not feasible because the wind readings are too low at the heights required for residential use. There are too many bylaws including the noise levels and safe height requirements for residential use. There are also laws protecting others from shadow flicker and the distance between the wind mill and the objects next to it if it were to fall. As we already know that wind is not constant, the 8 kWh turbine used in our calculations is rated to output that 8 kW per hour at ideal conditions, realistically it only produces about 9% of that energy over a long period of time. Also wind turbines for residential use don’t always come prepared for all wind speeds. The turbine will perform best only between certain wind speeds. There is also much opposition to the installation of wind turbines and it is for many reasons. Many believe these large structures can ruin a view. There are also those who oppose installations due to the noise. So when installing one of these structures it is important to consider the noise level. Normally, for a larger turbine, most would agree that it would have to be at least ¼ of a mile away from the nearest home. For Montachusett region to benefit from wind power large wind farms would be required and Montachusett region does not seem to have many places where this would possible. So it is important to note also the longer payback period due to the higher maintenance costs and initial installation. All these facts add up to one fact. The average Montachusett homeowner should consider other alternatives to wind energy and leave the bigger turbines for wind farms.

To conclude the recommendations, our largest energy concern in Massachusetts can be covered using renewable energy sources. Since the largest energy consumption in any home in Massachusetts is heating, renewable energy systems should be considered for supplementing or eliminating these energy needs first. Second, Solar photovoltaic systems may be used to eliminate and even produce excess power in some cases with grid tie systems and since they are becoming more widely available it is a good idea to keep investing in these systems to supplement the technology. Wind energy is competitive only with economies of scale. The MRPC is aware of this and they are largely promoting wind turbines for mostly commercial use.

Bylaws exist to protect residences from the hazards of using wind turbines locally but that strict regulations make installation of such a device nearly impossible for a homeowner. The MRPC should promote pellet stoves further as heating is one of the region's primary concern. The fledgling pellet burner industry in the U.S. is located in Maine and promoting or incentivizing expansion to Massachusetts is recommended. Renewable energy is the future and it will create jobs and improve the economy. Eventually this will lead to dependence from foreign oil and better economic stability for the residents of Massachusetts

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