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An Investigation of Renewable Energy Projects and their Potential Applications at Assumption College: Wind Turbines and Geothermal Heat Pumps

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INTRODUCTION:

Created in 1970 by President Reagan, The National Oceanic and Atmospheric Administration records global precipitation amounts, temperatures, and weather trends. NOAA has compiled temperature records – as many as 1,000 of these records are from the 19th century – from over 7,000 stations around the world to create the Global Historical Climatology Network. Two widely recognized research programs have used the available instrumental data to reconstruct global surface air temperature trends from the late 1800's through today (Instrumental). Using these trends, NOAA released a report stating that globally, Earth had its warmest year across both global land and ocean surfaces on record. "Including 2014, 9 of the 10 warmest years in the 135-year period of record have occurred in the 21st century" (Global Analysis). It is evident that ecosystems are already experiencing the effects of climate change, but a new study revealed probable dates in which the temperatures will regularly increase. A map shows cities across the world and where the temperature is expected to always be hotter than the previous year. The temperature increases are correlated with the increased burning of non-renewable fossil fuels (oil, gas, and coal) over the past few centuries. When burned, fossil fuels emit greenhouse gases such as carbon dioxide, methane, nitrous oxide, and fluorinated gases which trap heat in the atmosphere (Global). Unless emissions are stabilized immediately, the entire world is expected to experience these effects by 2047; even with immediate unanticipated reductions in the burning of fossil fuels, these temperature increases are expected to occur by 2069 (Borenstein). Chris Field, a climate scientist from Carnegie Institution states, "One can think of this year (2069) as a kind of threshold into a hot new world from which one never goes back."

The issue of the global warming is a problem that affects every life because even small alterations in the Earth's climate can have devastating effects. Here we may have begun to see many of these effects such as a rise in sea levels, coral bleaching, droughts, glacial melting, and other phenomena. The Earth is heating up largely due to the carbon emissions that we have introduced into the atmosphere through the burning and usage of coal, oil, and gas. Fossil fuels are non-renewable energy resources that formed when prehistoric plants and animals died and were gradually buried by layers of sediment. As mentioned earlier, when fossil fuels are burned, they emit greenhouse gases which contribute to climate change (Fossil). These issues are not going to disappear, and the sooner people become more environmentally aware, the better our future can be. However, without a serious change in society and our willingness to explore alternate energy sources, climate change will only intensify.

There is another problem looming in our future besides the harmful impacts of carbon based sources of energy on the environment: what do we do when non-renewable natural resources run out? These resources cannot be replenished and once depleted, we will have no other recourse than to invest in renewable energy forms. If we can lessen our dependence on fossil fuels now, we can avoid an energy crisis in the future. This is an opportunity for Assumption College to be a leader in the community and encourage "green energy" over typical carbon based energy.

Assumption College's mission states their goal to teach their students "thoughtful citizenship," and can do so through the use of renewable energy. The school has already begun to explore renewable energies through the use of solar panels atop the Emmanuel d'Alzon Library and the Assumption College solar energy system. ConEdison Solutions (CES) agreed to own the solar assets and equipment, and covered the cost of designing, and installing the 18 acre solar photovoltaic farm in Spencer, MA. In return for this, Assumption College has a contract to purchase the energy credits produced by the system for the next 20 years. “The energy produced by the solar array, enters the National Grid utility grid and is counted towards National Grid's renewable portfolio. The energy is then applied, in the form of a credit, to the Assumption college utility meter, reducing operating costs. This ability to produce power in one location and apply credits to a meter in another location, but still within the same utility load zone, is called virtual net metering” (Borrego). As Assumption College has already invested in solar energy applications both on and off campus, there is little need to evaluate their further potential at Assumption. However, this paper will discuss two other alternatives not yet used by the college.

This paper discusses large-scale renewable energy projects for the campus, rather than additional conservation efforts that the campus could invoke. The term large-scale in this paper refers to projects that consist of some form of construction on the campus, either by building a plant or installing the technologies. Small scale conservation projects are not going to be evaluated because they depend strictly upon the behaviors and habits of the residents of the college. The next logical question is, which renewable energy project would benefit the campus the most?

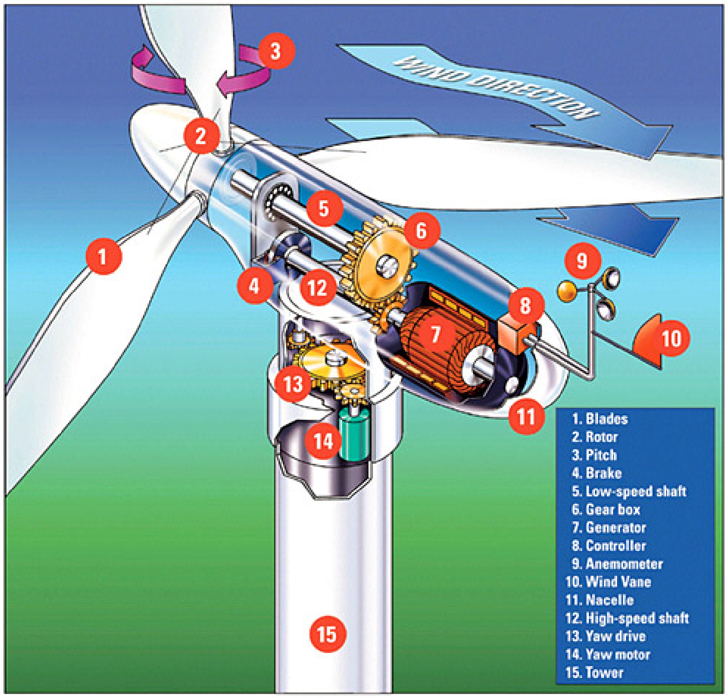
This paper will analyze the possibility of wind and geothermal energies on campus by taking into account the costs of installation and maintenance, the expected payback, funding that may be available, and any other potential community harm or benefit that coincide with these projects. I conducted interviews with institutions in Massachusetts that have undertaken these projects to determine the process that they followed, the companies that they used for installation and maintenance, and any problems that they have encountered. I then interviewed the installation and maintenance companies of these technologies to discover the best models for

Assumption based on our energy use, expected energy production, and the costs associated with the project. Their advice provided me the information to conduct a cost-benefit analysis of a wind turbine and a cost comparison analysis between a geothermal heat pump system and a conventional gas heating system.

NEW ALTERNATIVES:

Wind energy is produced when wind flows over the blades of wind turbines and creates lift, which causes them to turn. Induction generators produce current by first creating an electric field by passing alternating current through a coil. The blades are connected to a drive shaft that turns a rotor. Surrounding the rotor is a stationary series of coils, a stator. When the electric fields on the rotor pass coils on the stator, the field induces a current in the stator coils which is conducted away as output. Induction generators require an external power supply to produce a magnetic flux or field. However, there are also permanent magnet generators, which do not require an external power supply because they create a magnetic field generated by magnets mounted on a rotor. Seen on the next page, Figure 1 is a diagram of the inside components of a typical horizontal wind turbine design. The implementation of wind energy depends on whether a site receives enough wind for consistent energy. A question to be considered is do municipal ordinances and zoning laws allow the construction of a wind turbine on campus? Others might include, how long would the payback period be and how does this technology compare with the costs of projected energy usage?

Figure 1: Components of a Horizontal Axis Wind Turbine



(Wind Turbines).

Another option would be geothermal power; most people would not expect this as an option in the Northeast because they misunderstand the basis of this energy. There are several different types of geothermal energy, but all are based upon the concept of using the heat within the Earth. Geothermal heat pumps depend only on the temperature underground. As the seasons change, temperatures across the globe vary dramatically, but the temperature below the earth's surface remains at a relatively constant temperature. Ground temperatures range from 45°F to 75°F, depending on latitude. These temperatures are helpful because one can use them to heat and cool air and water for buildings. A ground heat exchanger sends air or water down through pipes and either warms (in the winter) or cools (in the summer) the air or water to the constant temperature before returning it to the surface. A geothermal heat pump at Assumption would depend primarily on the costs and benefit period. Initial costs include the extensive construction, which may not be possible for Assumption to currently fund. Financial aid from the government and the overall costs and benefits will be the deciding factors to the feasibility of a geothermal heat pump system at Assumption College. As Assumption is currently in the planning phase to construct a new office building, it is a perfect opportunity to consider a geothermal heat pump. It is easier to incorporate this technology in the design plans of a new development than in an already existing building. Thus, the cost-benefit analysis will be a comparison between the new building's proposed heating and cooling system and the geothermal heat pump system.

Originally, biomass energy units were going to be considered in this paper, but after interviews with Anna Maria College and Mount Wachusett Community College, this project was deemed not practical because of lack of fuel available. Biomass energies involve the production of electricity, heat, or compost from organic waste materials. There is stored energy from photosynthesis in vegetation, and any scraps (such as branches and unused parts of crops) that would be thrown away can be converted into energy. Nearby towns collect waste wood, tree branches and other scraps from factories and farms and ship it to a biomass power plant. The waste materials are then burned in a furnace, creating heat which boils water.

Both colleges that were interviewed use a wood pellet boiler system, which requires small wood pellets as fuel. Anna Maria orders their fuel through a company called Sandri which offers energy related products and services throughout the Northeast. However, the actual wood pellets are created by a company called New England Wood Pellet, which supplies most of the pellets in all of New England. Mount Wachusett Community College received their pellets from a saw mill in Connecticut. This is counterproductive at reducing carbon emissions because of the emissions produced by the trucks that transport the wood pellets to the school. It reduces emissions of the school, but increases the car emissions. Additionally, this type of fuel is becoming increasingly popular and as the demand for this fuel increases, this will limit the supply and cause the prices of wood pellets to increase. The supply problem is not the only one, as many studies are now finding that biomass energy units may not recycle the same amount of CO_2. The forests that are cut down for fuel are sometimes not replanted. Even if they are replanted, the regrowth does not intake the same amount of CO_2 as the output by the burning of a full grown tree. The choice between carbon sequestration (preserving the forest) and harvesting the forest is dependent upon its energy conversion efficiency and yield (Johnson 166). Once these problems were established, it was decided that installation and a cost-benefit analysis would not be considered. Though an interesting concept, a biomass energy unit would not be practical economically due to the supply issue and would emit CO_2 into the atmosphere which defeats the theory of the thesis.

INTERVIEWS: WIND TURBINES

HOLY NAME JUNIOR SENIOR HIGH SCHOOL:

Holy Name Junior Senior High School is a private Catholic school with a student population of 570 and located at 144 Granite Street in Worcester, MA. Just five miles away from Assumption College, atop one of the many hills of Worcester, the school undertook a wind turbine project in 2001. I interviewed Mr. Edward Reynolds, the current Headmaster at Holy Name about the process of deciding on a turbine and its functionality over the past several years. Built in 1967, the school's heat is electric, but this creates high energy costs, particularly in the wintertime when the temperature can often dip into the negatives. Although they did not have gas or oil bills, the monthly electric bills in January and February ranged between $30,000 and $40,000 and the yearly electric bill could run as high as $180,000. They realized that their placement at the second highest point in the city would be ideal for a wind turbine due to the high wind speeds throughout the year. A nearby college, Worcester Polytechnic Institute requires their students to undertake a Major Qualifying Project in order to graduate. Four juniors took it upon themselves to conduct a wind study at Holy Name High School. They built an anemometer on the roof and gathered the wind measurements for a full year and compiled the data together, determining that the area's wind speeds were consistent and high enough for a wind turbine. Next, the school asked their founding sisters, the Sisters of Saint Anne, for a grant of $50,000 to pursue a wind turbine project. The $50,000 was used to conduct a more formal wind study by a company out of Ontario, New York called Sustainable Energy Developments. They too, determined that the wind speeds sufficient to produce a substantial amount of energy.

The school began fundraising for the project, receiving a $575,000 grant from Massachusetts Technology Collaborative, along with some Alumni donations, and funds and foundations throughout Central Massachusetts. The federal funding came through the Massachusetts Technology Collaborative, which is a public agency that works to develop partnerships and collaborations across industry, academia and government for economic opportunities within the state's technology sector. Massachusetts Congressman Jim McGovern helped to procure donations and funding for the project. Beyond that, the Diocesan loan, alumni donations, and also some funds and foundations around the city of Worcester helped fund the wind turbine. Once they raised approximately 1 million dollars, the Diocese agreed to loan the other million dollars necessary for the project. Construction and installation cost a total of two million dollars and the project, which began in 2001 with the wind studies, was finally completed in October of 2008.

This process took several years because of the studies, fundraising, and the zoning regulation approval process in the city of Worcester. In order to build anything on the property, the school had to have the project approved by the city of Worcester's Zoning Board, which had not previously considered a wind turbine proposal. One regulation stated that the airport must be over five miles away from the site, and Holy Name was lucky enough to be just beyond that distance. Another concern with the construction of the turbine that the zoning board took into account is the flicker created by the turbine. The flicker shadow is the shadow made by the spinning blades, and due to their ability to rotate 360 degrees on top of the tower, this can fall at different angles and distances depending on the height and angle of the sun. Luckily again, Holy Name was fortunate enough that shadows produced by the blades, in any situation and any time of day, fall on the school's property. In terms of noise, it is indecipherable outside of their property as well.

Another possible concern was the noise of the turbine, but once again, the school has not had a problem with complaints from neighbors and it has not interrupted their classrooms. The noise of the turbine depends on the direction the blades are pointed towards and the distance to it. It is audible only if the sound waves are coming in your direction and will be louder with decreasing distance. The neighbors to the north are residential, but are a far enough distance away that if the blades do point in their direction, it does not hinder their daily lives. The neighbors to the south are mostly business such as Linder's Auto and Standard Auto, which appear unaffected by the turbine's existence.

Not only did they not receive complaints or concerns from the neighbors, many were curious about the project and offered their support. Before construction, all nearby residents and businesses were notified and two public meetings were held in at Holy Name High School to address any concerns from neighbors. There were representatives from the school as well as one from Sustainable Energy Developments and one from the city of Worcester to answer questions.

No more than ten people attended and they came because they were interested in the project, not to raise concerns. Nearby, the largest urban wildlife sanctuary in New England, Audubon's Broad Meadow Brook Conservation Center and Wildlife Sanctuary, sent letters that actively supported the project. Many members of the neighborhood even travelled up to Holy Name's campus to watch the construction of the turbine. Mr. Reynolds stated, "I think that the neighbors are very proud of having this in their neighborhood. In fact, were very supportive of it from start to finish and continue to be." Luckily again for Holy Name, there were no obstacles to address with neighbors as far as noise or flicker complaints due to their campus's location.

The wind turbine that Holy Name purchased and SED installed is a 600kW Vestas RRB. It is a horizontal axis wind turbine, which means it spins around a horizontal axis rather than a vertical one. When asked if a vertical axis turbine was considered, Mr. Reynolds answered honestly that their knowledge of wind turbines at the beginning of the project was sparse and thus, they did not know this technology existed and did not investigate it. The wind turbine that was ordered had an interesting shipment method because the Vestas was actually built in India. It was shipped across the Pacific Ocean through the Panama Canal to the Port of Newark. Once in the United States, former Governor Deval Patrick allowed it to be delivered from New Jersey to Worcester, MA over the Memorial Day weekend. It was an extensive project just to receive the wind turbine. Once on the property, installation did not occur for another month. There was an unexpected cost of hiring security to monitor the turbine until construction began.

Once completed and operational, Sustainable Energy Development did maintenance on the turbine, but the distance between their company location and Holy Name High school was a problem. If the turbine shut down or experienced problems with its operation, it took SED many days to come to Worcester, diagnose the problem, and fix it. Thus, Holy Name hired a Spanish manufacturing company called Gamesa Technology Corporation to maintain the turbine. They have an office in Feasterville-Trevose, Pennsylvania which handles the Holy Name turbine and maintenance costs are $25,000 a year. When hired, the company came in and did an audit of the turbine's mechanics to ensure its health and status of its condition. Mr. Reynolds noted that Gamesa has been much faster in response time to problems associated with the turbine.

The turbine has provided the school with approximately 90% of its annual energy usage. With the electric heating system, the energy usages ranges anywhere between 800 and 900,000 kW hours per year. The turbine produces anywhere between 675 to 800,000 kW hours per year. As stated, their original energy bills cost as much as $180,000 without the turbine. Their loan from the Diocese totaled at $110,000, saving the school $70,000 in expenses. They are repaying that loan, and once repaid, will allow the school to reap the total benefits of the wind turbine. Of course, as discussed, there are the yearly maintenance costs, but these are offset by the sale of renewable energy credits, which again run anywhere between $15,000 and $25,000 a year. However, the school does not run entirely on the turbine and requires the purchase of some electricity. Therefore, the school does not save the full $70,000, but realizes anywhere between $30 and $60,000 in savings annually.

The renewable energy credits the school receives are through a process called net metering. The turbine does not provide enough energy to sell back to the grid, but in months where the energy production of the wind turbine exceeds the amount of energy the school requires, that energy for that month gets credited back to the school. Mr. Reynolds explained the process in the form of an example; "So if we send them let's say $30,000 worth of kW hours, they will come up with a number, a dollar figure, that we have as a credit on our bill that can applied in the winter months, where we have to purchase electricity. Usually in the winter, no matter how fast we are spinning, we still have to get energy from the grid." These renewable energy credits provide the school with additional funding to pay for the maintenance of the turbine.

Though Holy Name has not had any severe problems with the mechanical aspects of the turbine such as broken blades, the maintenance is difficult because many small electrical problems can cause the turbine to shut down. Holy Name's turbine has shut down due to several small things such as sensors and wiring issues. Mr. Reynolds explained the issues as part of the functions of the turbine, "…turbine's first function is not to produce energy, that's its second function. Its first function is to protect itself. So anytime there is an extremely high wind or a high wind gust, any type of small misread by the computer within the turbine, any little thing that goes wrong, its first response is to shut down." I have seen turbine shut down myself while driving on Route 146 N following the major winter storm, Juno in January of 2015 as the turbine's blades were not spinning. If the wind speeds exceed 30 to 40 miles per hour, the turbine shuts itself down, turns into the wind, rotates its blades in and stops spinning. However, these problems have never caused a large problem with energy production because of the maintenance company, Gamesa Technology Corporation, which quickly resolves any shut downs due to wiring, sensor problems, or storms.

An interesting point is the positive publicity that Holy Name has received as a result of their renewable energy project. As the first in the area, the wind turbine project was a pioneer and it helped the school to promote its values. The turbine does not provide only an economic benefit. There are educational values that accompany it. They realize that they are leaders in the community to encourage the protection of the Earth. As a Catholic institution, they believe that it is their call to be "stewards of God's gifts". The school teaches that mankind care for the earth as God gave it to His people. “The mission of Holy Name Central Catholic Junior Senior High School, as a part of the Roman Catholic Church in the Diocese of Worcester, Massachusetts, is to inspire our students to study and apply Gospel values and the moral principles of Jesus Christ to all of our academic, artistic, social and athletic programs. Students are provided a stimulating learning environment to encourage them to become life-long learners. Each student is empowered to master the high academic and ethical standards necessary to achieve success and to be a Catholic Christian witness in the world” (2011). Holy Name teaches their students the importance of following the Gospel’s message to be stewards of the Earth.

Mr. Reynolds recalled a visit to Los Angeles where he stood atop the Trans American building and could not see past a quarter mile down the road because of the thick smog that coats the city. He stated, “We have to take better care of what God has provided. Our number one reason for this project was to be stewards of God’s gift for us. I believe it was Pope Francis who came forward in terms of climate change and the importance of green energy and the Vatican has made this one of their strong talking points as to how they want to direct the world.” There is a benefit to this technology because it sets an example for other institutions and companies to use renewable energy to try to protect the earth. It also sends a message to the growing belief that Catholic schools are a way of the past. Many Catholic schools have issues with enrollment due to the belief that Catholic schools’ teachings are too traditional for today’s society, but this wind turbine is a symbol of the future. “We promote ourselves as a Catholic institution and sometimes the church is seen as ultra-conservative and certainly, we abide by all church doctrine, but this is a symbol of who we are in terms of being progressive. We are open to creative and new solutions to old problems and this has a great appeal.” The turbine is an indicator of the church’s open-minded thinking to address today’s issues. It shows that the church is forward-thinking and can adapt to these problems and any future problems, teaching children to be leaders in this society.

The turbine not only endorses Catholic teachings, but also is incorporated into the students' education at the school and influences the community. This influences the children at the school because it teaches them about renewable energies and their potential in real-world applications. Many classes such as AP Physics, eighth grade science, and environmental science use the turbine in their studies. For example, in the environmental science course, the curriculum includes a unit specifically on wind energy. The school also takes opportunity to teach others about the project to encourage renewable energy. Mr. Reynolds stated, "With the community, I have done dozens of presentations to middle schools, high schools, colleges, women's groups. We've gone and done presentations at places like the Grafton Job Corp, just using this as a real world model to educate others on this type of technology. We are still sort of well ahead of the curve on things and we are seen as a laboratory for this type of technology and we embrace that as an educational institution." Holy Name's turbine demonstrates their leadership for new ideas, promotes the school and the Roman Catholic Church, and influences the lives of both their students and the entire community of Worcester.

As far as additional renewable energy projects, Holy Name High School is considering solar panels on the roof of the school. Their roof needs to be replaced, but nothing has been decided yet. However, many companies want to install their solar panels on their roof for a low cost, but then sell the energy back to the school instead of going through national grid. It would not be beneficial for the school because of the small amount of energy they need. They would be paying either national grid or the company, and they would not receive a profit for the additional energy created. Gamesa suggested the installation of another turbine, but it would not help the school because they do not need that additional energy. Without a way to guarantee the sale of the credits at a stable price from National Grid, it is too risky for the school to undertake the project financially. They have not considered geothermal heat pumps either because the turbine provides nearly all the energy for electric heating systems. A geothermal heat pump would greatly reduce the electricity required to heat the school, and combined with the turbine's electricity, there would be no electricity required from national grid during the wintertime. However, the additional energy created by the turbine would no longer be net metered, and this additional energy could be sold off, but the rates would be uncertain. These could fluctuate and a hassle for the school to handle.

The information provided by Mr. Reynolds was enlightening because it proves the possibility of a wind turbine in Worcester, MA could be successful. The schools are similar not only in terms of distance, but in their Catholic roots. The turbine at Holy Name has given vitality to the school and demonstrated leadership that has helped with enrollment. A similar project at Assumption could show the progressive thinking available at a liberal arts college, mixed with the traditional roots of being stewards of God's Earth. However, Assumption College is different from Holy Name because its neighbors are much closer than Holy Name's and this would require the Zoning Board of Appeal to approve the project. The close proximity of the neighbors may also cause resistance to the project due to the fear of flicker shadow and noise. Holy Name was lucky enough to not encounter these issues, but Assumption College would possibly need to overcome these obstacles.

Following this interview, I contacted representatives at both Gamesa Technology Corporation and Sustainable Energy developments to try to determine a hypothetical wind turbine project for Assumption College. Based on our wind projections, Holy Name's wind turbine information, our energy usage, and our location in Worcester, they advised a certain size and model wind turbine. Once the engineers suggested the turbine type, I spoke with representatives to determine if they could provide me with an estimate of costs for installation and maintenance of the turbine, as well as the expected payback period based on expectations of energy production from the wind turbine. However, both were unable to provide even rough estimations because of the lack of information available. The initial studies are vital to determine the possible energy output. Thus, the cost-benefit section will be based primarily on Holy Name's prices and inflation rates. This information is available in the cost-benefit analysis section.

MOUNT WACHUSETT COMMUNITY COLLEGE:

Mount Wachusett Community College (MWCC) is located in Gardner, MA, 25 miles north of Worcester, MA. In March 2011, MWCC activated two new 1.65 MW Vestas V82 wind turbines, which now generate 100% of the college's annual electricity, as well as provide energy back to the grid. I met with the Director of Facilities Management, Mr. William Swift to discuss the two wind turbines that were constructed. The wind turbines are an invaluable asset to the both the school and the state because they demonstrate Massachusetts's dedication to renewable energy projects. "The wind energy project, a collaboration between the college and the Massachusetts Executive Office of Energy & Environmental Affairs, the Executive Office of Administration & Finance, the Division of Capital Asset Management, and the Department of Energy Resources, is an integral component in the Massachusetts Leading by Example – Clean Energy and Efficient Buildings executive order to achieve statewide goals." The former governor of Massachusetts, Deval Patrick's gave an Executive Order in April of 2007, demonstrating his support for the renewable energy developments. The $9 million wind project was made possible by the help of the State in the form of funding and promotion.

The project was first proposed in 2008, and a wind study was conducted to determine the speeds over the course of two years. According to an engineer at Gamesa Corp., most wind studies are conducted between 1 and 2 years to ensure wind speeds are monitored through all seasons. A 50 foot meteorological tower was built to collect this data and it was determined that there was enough wind to sustain two winds turbines at this location. Once this was finished, a feasibility study was conducted to explore the economic possibilities of such a project. Mr. Swift stated, “With support from the Massachusetts Division of Capital Asset Management, a consulting team was hired to perform a feasibility study: Several different turbines and ownership/financing options were studied. Detailed financial pro-formas were completed using several financing scenarios. The consulting team completed a feasibility study concluding that a one or two turbine project was feasible.” Again, the school only considered a horizontal axis wind turbine because they were unaware of vertical axis technologies. Other manufacturers were considered, and it was decided that the JK Scanlan Company, Inc. of Massachusetts would serve as general contractors.

Other studies undertaken included: “avian studies, bat studies, visual simulation study, sound impact study, shadow flicker impact study and EMI impact study. Since US Department of Energy funds are being used for the project, permitting requirements included assessments under the National Environmental Permitting Act.” These studies were conducted by specialists, including the company Curry& Kerlinger, LLC, a wind power and bird consulting company. Northeast Ecological Services conducted the Bat Risk Assessment. The University of Massachusetts Wind Energy Center conducted the shadow flicker analysis as well as the turbine sound analysis. The Division of Capital Asset Management (DCAM) hired an engineering company, Jacobs Edwards and Kelcey and a team of renewable energy consultants for feasibility and engineering studies for the project. The avian risk assessment studied the potential collision and displacement risk to birds due to the development of the wind turbines based upon a site visit, previous literature, and consultations with wildlife agencies. It was determined that few birds are killed by turbines, fewer than seven deaths occur annually in the United States and the site would not negatively impact any endangered wildlife. The assessment recommends certain actions to further protect birds and prevent collision with the equipment with suggestions such as underground wiring, or free-standing meteorological towers. A similar assessment was conducted for bats and it was determined that the turbines' location was acceptable because the bats indigenous to the area would not be harmed. Once the studies were finished, construction began and it lasted from October to March of 2011.

Founded in 1963, MWCC was originally run completely on electrical energy, similar to Holy Name High School. The average monthly energy bills were anywhere between $60,000 and $100,000 depending upon the season in the 2000's. Due to the high energy bills, the school began investing in renewable energy projects and conservation projects. First, as mentioned earlier, the school installed a biomass heating system, specifically a wood boiler unit. Following this project, they installed energy efficient chillers, solar panels, and conservation projects to bring down base load. The additional wind turbine provided enough energy not only for the school, but additional energy to provide to grid. MWCC also uses a net metering process as discussed earlier in the Holy Name wind turbine section. The winter months' energy costs are usually between $10,000 and $15,000 and the energy credits sold during other times of the year provide the money for the winter electric bills. The net metering depends on wind amounts produced, but traditionally more wind is produced during the spring and fall. The wind turbines have "have enabled the college to achieve the distinction of near carbon neutrality for campus operations" (Sustainability).

Generous grants and loans from multiple state and federal grants made the MCC wind project possible. MWCC received funding from multiple state and federal sources. The wind turbines were funded through $3.2 million in U.S. Department of Energy grants, $2.1 million from a low interest Clean Renewable Energy Bond, and $3.7 million from Massachusetts Clean Energy Investment Bonds. The two 1.65 MW Vestas V82 turbines were activated on March 25, 2011, and in the first year alone, they not only provided 100% of the school's energy, but also an additional 5 million kilowatts, which is net metered to the grid. The turbines exceeded the 4.97 million kWh annual production that they were expected to produce. It exceeded expectations even though the wind turbines experienced a break-in period during the first month and were intermittently operational.

Mount Wachusett Community College has a five year maintenance contract with the Denmark company, Vestas, the same company that provided the turbine. The annual cost of maintenance is $100,000. Similar to Holy Name wind turbine, there have not been any mechanical problems associated with the turbines, but there have been small maintenance troubles. These maintenance issues were usually due to sensor problems, such as sensors being out of calibration or failing. The wind turbines at MWCC shut down when wind gusts are over 50 miles per hour. Once the wind speeds reach this speed, the wind turbines turn into wind and the blades shut down. Though there have not been any technological issues with the turbines, there was one complaint even though the flicker and sound studies had determined that they would not affect local residents. A neighbor complained about flicker from the turbines and the state paid for motorized shades in upper windows to reduce the effects. Otherwise, there have not been any issues or complaints associated with the turbines. As a whole, the neighbors have been supportive of the renewable energy projects at MWCC.

The President of MCC, Daniel M. Asquino, stated, “The wind energy project is the crowning achievement in our portfolio of green energy projects. Combined, these renewable technologies provide an invaluable learning tool for the general public as well as students pursuing green careers in our Natural Resources and Energy Management programs. The turbines have become a source of pride and a symbol of progress for the college and for the local community.” The Director of Maintenance and Mechanical Systems, Bill Swift stated that the community benefitted from the wind turbines because they educate the public on the real-world application of renewable energy technologies. The public can take tours of the turbines and wind turbine and solar kiosks available to show production of the projects to educate people on these renewable energy projects. It also is available for the education of MWCC’s students; there is a renewable energy program which incorporates the turbines into their studies. Based on conversations with students in renewable energy programs, Mr. Swift agreed that these turbines are a big draw to students. He stated, “Students are interested and can see that these programs are an important part of the future.” Not only are renewable energy projects such as the wind turbines educational, but they also provide jobs in the region. “Community projects like this one not only create jobs and local sources of energy but stabilize energy costs, which traditionally have relied on volatile fossil fuel markets,” said Energy and Environmental Affairs Secretary Richard K. Sullivan Jr. “We’re a proud partner in this project because it sets an example of clean energy leadership for the students, residents and businesses of this community” (Sustainability).

MWCC have dedicated the turbines in honor of Congressman John Olver, for his aid and support for funding through the U.S. Department of Energy, and Edward R. Terceiro Jr., MWCC executive vice president emeritus and resident engineer, “for his leadership on the project and other campus energy initiatives, and to both for their renewable energy vision” (Sustainability). MWCC notes on their website that “A charter signatory of the American College and University Presidents’ Climate Commitment, MWCC was recognized with environmental awards in 2011 from the U.S. Environmental Protection Agency, Second Nature/ACUPCC and the Commonwealth of Massachusetts for its success in renewable energy and conservation” (Sustainability). The turbines are a vital part of the MWCC’s identity and have helped to promote the ideals and values of both the school and the state of Massachusetts. With the help of state and federal funding, Assumption College could undertake a similar project to continue to show the dedication of educational institutions to renewable energy. DCAM and other agencies would support the projects and offer assistance, at least with the design and preliminary studies.

The president of MWCC mentioned the expansion of environmental programs, giving students opportunities to explore “green careers.” This could be a valuable program at Assumption College because some people are apprehensive of liberal arts colleges not creating enough job experiences. As a liberal arts college, the purpose of education is to provide students with more than skills for a career. It is intended to create well-rounded individuals. However, more hands-on application could show students that a well-rounded education can be combined with career skills and equally prepare students for the future. It was also mentioned that MWCC has signed the American College and University Presidents’ Climate Commitment. Assumption College, unfortunately, has not (Signatory). However, a renewable energy project at the campus and a signature could demonstrate the college’s dedication to ensuring a better, greener future.

PRINCETON MUNICIPAL LIGHT DEPARTMENT:

Schools are not the only wind turbine projects investigated in this paper. While I did focus primarily on schools and the impacts of renewable energy projects on educational institutions, I researched other projects not associated with schools. One such example is the wind turbine project that was conducted by the town of Princeton, MA. In 2009, Princeton Municipal Light Department erected two 1.5 MW wind turbines, each with135 foot long blades and 260 feet high on Wachusett Mountain. However, this wind project has not produced the energy that was expected and has been an economic strain on the residents of Princeton. I spoke with Brian Allen, the current manager of the Princeton Municipal Light Department, and he gave a different account of the possibilities of wind energy than Holy Name High School and Mount Wachusett Community College reported. Unlike the previous wind energy projects discussed, the turbines have been unsuccessful at lowering energy costs in the town and have been difficult to maintain.

In 1982, there were eight small wind turbines at this site that produced only 1% of the town's energy and they were eventually shut down in 2002 due to their age and inefficiency. At the time, only three of units were still operational and the small amount of electricity produced by the remaining generators did not justify the high cost of maintenance and repairs. Thus, the turbines were dismantled in 2003-04. A survey was sent out to residents and 78 percent of respondents were in favor of acquiring larger, more efficient turbines. The positive response led the town to conduct wind resource tests, and informational meetings began. "Over the next several years, noise studies, photo simulations, shadow analysis, wind data analysis, National Heritage and Endangered Species studies, a bird-risk study, solar and shadow-flickering analysis, and site plan reviews were done. More than 24 public meetings were held, and bylaw changes were put into place. Eventually, a proposal was made to erect two 1.650-megawatt wind generators on 230-foot towers. A special town ballot was held on February 11, 2003 and a 74 percent majority of Princeton residents approved the wind farm project" (Booth). In 2009, the two new turbines replaced the previous eight wind turbines. The German wind company, Fuhrländer AG, that installed the turbines has since gone out of business. These new wind turbines were projected to produce approximately 6,000 MWhr, but they only produce about 4,000 MWhr. In 2008, the former Princeton Municipal Light Department Manager, Jonathan Fitch stated, "Once the generators are operational, if in any certain hour they produce more energy than the town needs, it will automatically go into the grid. If that happens we'll get credit for that excess energy. Once the windmills are producing electricity, it will help stabilize our rates, now and for the next 16 to 20 years." It is evident by his statement that he expected the turbines to substantially contribute to the energy uses of the town. The town was unprepared for the low energy production and this has caused economic problems, placing them in debt.

The lower production covered so little of the town's total energy that currently the energy made is sold back to the grid rather than be used by residents. Starting January 1, 2014, the town signed a ten year energy contract with a company that buys the energy at a full requirement service and provides a flat rate for the energy. Prior to this arrangement, the town sold it on the open market, but this fluctuated due the volatility in the electric market and the town of Princeton could not afford the uncertainty of energy prices. Instead of benefitting the community, the turbines have actually economically harmed the residents of the town of Princeton. The town is losing approximately $500,000 dollars per year as a result of the wind turbines. This is based upon the revenues versus their expenses. In Mr. Allen's opinion, the project was too large for a utility of their size.

The town borrowed 7.3 million dollars to construct the project and based their ability to pay off the loans on future projections of expected energy production from the wind turbines. The money borrowed is from a commercial loan through People's Bank. They did receive $50,000 as a loan from Massachusetts Clean Energy Center for engineering consultants prior to the project, but nothing further was provided by the state, the federal government, or donations. The loan was the primary source of funding, and it was expected to be paid off by the wind turbines. Mr. Allen explained, "The capacity rating was expected to be 28%, and they do more like 18%." During this time, electric rates were on the rise and the town anticipated that the trend was going to continue. They expected to receive $100-115 MWhr for the energy they produced, but instead, Mr. Allen stated, "due to natural gas fracking and energy market tanked, we only receive $30. That's 2/3 less income that they projected they were going to get. It's a big problem, there was no plan B. What if it doesn't work out according to the projections? It's a bad way to do business." The town had no other way to pay back their loans. In order to repay their debt, the town has added about 4-5 cents a kWhr to the retail rate of the resident's bill. This makes up the difference of what the town owes and what is actually produced by the turbines. Instead of paying about 14 or 15cents per kWhr, the residents of Princeton pay 19-20 cents per kWhr. In comparison, Assumption College paid $0.061 per KWH in 2014 and is estimated to be $0.070 for 2015. The additional costs to residents to repay loans are not the only issue that the turbines have produced, as they have been difficult to maintain as well.

The turbines have been difficult to maintain and maintenance costs were "severely underestimated in original plan". Mr. Allen stated that he has 50-60 air messages per week about the turbines shutting down. Sometimes, the issues are small, such as a problem with the brake system and he might be able to reset it through the system at the office. However, often times he has to send people to fix it. This was a frequent issue and maintenance costs were going up at a rate of 17% per year, prompting Mr. Allen and four of his linemen to become certified to do maintenance on the machines. The cost of maintaining the two turbines is approximately $100,000 per year between necessary repairs and salaries of maintenance workers and this, again, was not factored into the original business plan. The Princeton Municipal Light Department spends, Mr. Allen says, about1/3 of their time maintaining the turbines. Mr. Allen stated, “There are electronic, mechanical, and hydraulic components in the machines and there is always a small problem with something.” The complexity of the turbines and the time to maintain them was not considered originally because it was not expected that an outside engineering company would handle the maintenance of the turbines.

One particularly large mechanical issue with turbines occurred in August of 2011 when there was a catastrophic failure of one of the gear boxes, after only having been installed about a year and a half earlier. The manufacturer of gear box bought several parts from various companies and installed a wrong set of bearings in the gear box. This was not Fuhrlander, but it was another German company. Five of the six set of bearings were correct, but one was not. This defect caused a catastrophic failure of the gearbox. PMLD had a three year warranty with Fuhrlander to repair any machinery, but they refused because there was no contractual obligation to fix the gear box. The problem was that PMLD purchased the turbines through Fuhrlander’s American distributer that then sold them to the contractor who erected the turbine. Fuhrlander was the end beneficiary of the contract, but Fuhrlander has to receive 100% of the monies or the warrantees in the contract were void. As PMLD found out, the contractor, Lewis Construction, owed 2 million dollars to Fuhrlander. PMLD had paid the contractor, Lewis Construction and the American distributor, Lorax Energy Systems, but they had gone out of business and had never paid Fuhrlander. Due to the enormous loss of money for this project, Fuhrlander refused to repair the turbine's gear box. After 9 months of negotiating and 2 years of legal processes, PMLD finally received some help in replacing the gearbox. However, the issue occurred only a year and a half after installment. The average life span of a wind turbine is 20 years. Mr. Allen stated the gearbox is the "weak link" in turbines. The gearbox is a large and important part of the turbine, the ones in Princeton's turbines weigh 37 tons and is a $400,000 component. It costs another $100-150,000 to get a crane in to get the gearbox out, which totals the replacement cost to around $500,000 just to keep the turbine operational. Gearbox manufacturers state that they last about 6-7 years before they need to be replaced. The manufacturer told Mr. Allen that the gearboxes cannot handle the torque of the wind turbines and the technology has not advanced enough yet.

The unfortunate gear box failure, maintenance issues, and legal struggles, should be considered before a wind turbine is installed at Assumption College. It is a distinct possibility that there may be unseen mechanical issues with the turbines and the installation company might be apprehensive to help with the repairs. Wind turbines are an investment, and while they have been seen to have wonderful results such as at Holy Name and MWCC, unexpected costs should be anticipated. These unbudgeted maintenance issues cost both time and money for the Princeton Municipal Light Department. Mr. Allen stressed the importance of researching the costs of the turbine in the business plan because it is possible that the turbine could be an investment risk. "Realistically, we need look at the costs associated with it. Someone might say, well I'm more interested in reducing my carbon footprint and I'd like to do this because it seems like the right thing to do, and I don't have an issue with that. But, the costs need to be looked at realistically." Mr. Allen made an interesting metaphor as wind energy being similar to buying organic groceries. People may feel buying organic is natural and better, but they have to expect that, at the register, their bills might be much higher than if they had simply grabbed a box off the shelf. Princeton's original business plan did not consider the possibility that the turbine would not produce as much wind as projected. They also did not expect maintenance costs to be as high. These unfortunate additional costs have added up, costing the town rather than reducing their costs. It is important to consider all possibilities before undertaking a large renewable energy project such as a wind turbine because it is a financial risk. There is no guarantee that the technology will produce the expected amount of power or that there will not be a problem with its manufacturing or construction.

When Princeton was first presented with the plan, it was expected that the turbines would stabilize their energy rates and decrease the rate that they pay for electricity from the grid. The turbines did stabilize the rates, but at a higher rate than predicted. If the town and residents had known the impacts the turbines' installation would have on them economically and they had agreed to this, it would be a different story. The turbine issues were never considered and many of the residents are upset that the possibility of lower production was not explored. Mr. Allen has had numerous complaints about the costs and dissatisfaction with the turbines. However, Mr. Allen has never had any complaints about flicker shadows or noise. The turbines are 2,500 feet from nearest home. The current wind turbines are at the site of the previous ones, which prevented the area from residential development. There are several hiking trails nearby the wind turbines, and Princeton set up signs to alert hikers and to stop them from approaching the turbines. The only safety concern is a possible problem of ice building up on the blades during the winter months. This does occur and the turbines stop spinning due to the changes in weight. As spring approaches, the ice melts, so it is possible that the ice could come off the blades and hit a hiker. This “ice throw” is the only danger to hikers, but the town has never had an incident with the safety of hikers. The town purposely placed the turbines in their location for the safety of residents and hikers.

Mr. Allen has recently looked to the state for relief because the town feels the state is partially responsible for the wind turbine project’s development. Mr. Allen has documentation from 2004-2006 showing the state’s encouragement for the project. According to Mr. Allen, the state was pushing Princeton to do the project because it would encourage renewable energy projects in other communities and push the governor’s agenda forward. The town is seeking money from the state because they believe the state is partially responsible for the debt they have incurred. However, as of June 2014 when the interview was conducted, there has not been any aid from the state. Massachusetts Senator Harriette Chandler, during the last budget process, amended the budget to authorize Clean Energy Center (CEC) for up to 2 million dollars for aid in Princeton. The Massachusetts Clean Energy Center is a public organization that, “With economic growth in mind, Mass CEC invests in early-stage clean energy companies helping them to bring ideas to the marketplace. Mass CEC supports responsibly sited renewable energy projects and provides municipalities, homeowners and businesses with the tools needed to finance and locate renewable energy projects like wind and solar. Mass CEC also develops programs to build a strong clean energy workforce – including a successful statewide internship program – to give the clean energy generation the skills to compete for jobs in this emerging space”(About). Mr. Allen had gone to the CEC previously, but they could not statutorily help with the debt by giving the PMLD any funds unless they belonged to a clean energy trust. However, the state understood the need and considered pre-purchasing renewable energy credits from PMLD. This was never officially agreed to, but according to Mr. Allen, “the idea was they would prepay 3,000 renewable energy credits per year for the next ten year at something like fifty dollars per energy credit." This would help cash flow and the PMLD could take the $200,000 each year and incorporate it into the budget to offset the $500,000 they lose each year. Senator Chandler filed an amendment for the budget to allow for the pre-payment of renewable energy credits. It passed the state senate, but then was given to a committee and denied. It appears that the state is not going to take any responsibility or help the town in Princeton with their debt.

When asked if Princeton would have considered other renewable energy methods, Mr. Allen stated that solar might have been a better idea because of its low maintenance. Solar panels are less "hands on" and the technology's efficiency has come a long way in recent years. However, due to their debt and current situation, they are unable to afford to install the panels. If he could go back in time before the wind turbines were installed, Mr. Allen stated that his suggestion would have been to start with one turbine to see if it would produce what it was projected to, then add another if the project was going well. If it was not, then the town would still have some debt, but considerably less than they do currently. The two wind turbines was a project that "bit off more than we could chew," according to Mr. Allen. Also, if it were possible to go back, he would not have used Fuhrlander. Though they had an excellent reputation in Europe, the company was unaccustomed to this large of a wind turbine. The company was acquainted with smaller turbine chains than the model that is installed in Princeton. According to Mr. Allen, the 1.5 MW machine design rights were bought and all of those that had been constructed with this design had problems.

Princeton Municipal Light Department's wind turbines are an example of the negativities that are possible when investing in renewable energy projects. In order to conduct a large scale project such as a wind turbine, it is necessary to create a business plan that considers the worst case scenarios. Though Holy Name High School and Mount Wachusett Community College's wind turbines projects were both successful in lowering costs, PMLD's project was not. If a wind turbine is decided as the best renewable energy for the Assumption College, it is suggested that multiple manufacturers and contractors be considered as to avoid the issues that Princeton's Municipal Light Department experienced.

INTERVIEWS: GEOTHERMAL HEAT PUMPS

MIDDLESEX COMMUNITY COLLEGE

Founded in 1970, Middlesex Community College has two distinct campuses, one in Bedford and one in Lowell, MA. As part of the school's program "Greening of MCC" the college installed a geothermal heat pump system in 2012 to "replace the heating/cooling equipment in Trustees' House, a three-story, 9,800-square-foot building on the Bedford campus" (Bedford). The project is a collaboration between Middlesex Community College and the Division of Capital Asset Management (DCAM), which is the agency responsible for public building construction and real estate services in Massachusetts. Without state help, the project would not have been possible.

Middlesex Community College's project included a Geothermal GSHP energy retrofit to replace existing heating and cooling systems at the Trustee's House on the Bedford Campus in Massachusetts. They redesigned the existing system of the 9,800 square foot Trustees House, which consists of mostly offices, to incorporate a geothermal heat pump system and reduce its total natural gas energy consumption during the winter and electricity consumption for air conditioning during the summer. The process included the drilling of the borefield retrofit of the building for the geothermal heat pump equipment and the testing of the system.

I spoke with Ms. Gina Spaziani, the Assistant Vice President for Administration and Finance at Middlesex Community College about the geothermal heat pump system's design and installation. She explained that when the project was first proposed in 2008, the heat pump system was going to be installed into a different building, Henderson Hall. This is the campus's science building, but this plan was eventually shifted to the Trustees' House, as will be explained later in the paper. Representatives from MCC contacted Congressman John Tierney and set up an appointment at his office in Washington D.C. to discuss possible funding for the installation of the geothermal system. Congressman Tierney's support for the project helped MCC to obtain federal grants, securing $34,000 in federal funding. In addition to the federal grant, Middlesex was awarded a $75,514 state grant from the Department of Energy Resources' Lead by Example program to support the $300,000 Trustees' House geothermal project. DCAM paid for the engineering design of the project. Maintenance costs are $1,500 per year, by Coneco Energy to ensure the heat pump is functioning properly. However, environmental science students monitor it over the course of the year as well as part of their courses and education.

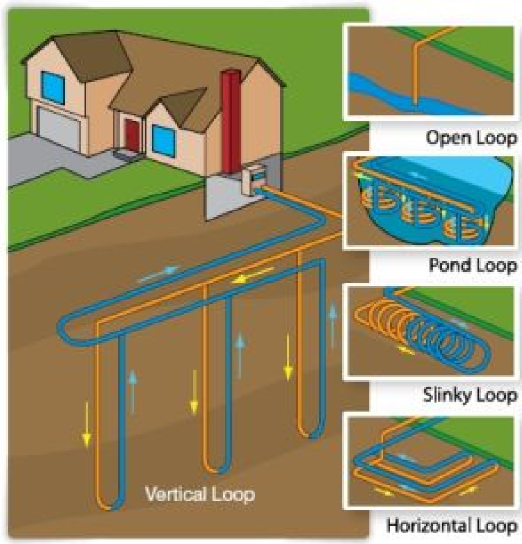
With these grants, the school was able to start designing and installing the new geothermal heat pump system. The technology provided to MCC was a way to "green the campus" in a manner that had not previously been used at the campus. "Middlesex spokesman Patrick Cook said the college initially looked into solar systems for the century-old Trustee's House, but sun exposure and the reinforcement of the roof required did not make it cost-effective" (Sato). According to College Vice Executive President, James Linnehan, "MCC has "implemented several "green" projects over the years, and energy audits showed they are saving the college $600,000 annually in energy cost…" (Sato). The school was excited for the technology because it would reduce the school's carbon footprint, while providing them with a replacement for the old heating and cooling systems. In 2012, Matthew Sepe, MCC's dean of facilities management stated, "The geothermal technology will help us in terms of energy reduction and sustainability by replacing cooling equipment that was at the end of its life…It will also cut our reliance on fossil fuels, reducing our carbon footprint" (Trustees).

As mentioned earlier, the initial plan was to heat and cool Henderson Hall on the Bedford campus, which acts as the school's science building. The idea was that the heating system would be convenient for environmental science students to study and demonstrate the importance of renewable energy sources to students. As renewable energy technology industries grow and use of these increases, students can see the importance of scientific research in the environmental and energy fields. However, according to Ms. Spaziani, Henderson Hall is approximately four times the size of the Trustees House and the cost of retrofitting this building was projected to be over a million dollars. MCC contacted DCAM for help with the preliminary design to lower this cost, but Henderson Hall is larger than other buildings on the campus and would require more wells, and thus more money. Additionally, upon drilling, they discovered that there was a large difference between the water table of Henderson Hall and Trustees House. Ms. Spaziani explained that even though the two buildings are only about three football fields away from one another, the bores showed that the Trustees' House hit water at a much shorter depth than did Henderson Hall. This would also increase the costs of the geothermal heat pump system in Henderson Hall as compared to the Trustees' House. According to Ms. Spaziani, as the geothermal heat pump would not cover the full cost of heating and cooling the building, MCC decided that they could not justify the installation of a project costing over a million dollars. The engineers started working on a retrofit for the Trustees House, which was already in need of an updated heating and cooling system.

The Division of Capital Asset Management (DCAM), as noted earlier, paid for the design of the geothermal heat pump system. They contacted and worked with multiple design and engineering companies including ARUP, Coneco Engineers & Scientists, and Haley & Aldrich. Coneco Engineers & Scientists was the contractor that installed the system and Ms. Spaziani provided me with Mike McGonigle's contact information to discuss geothermal heat pump economic feasibility at Assumption College, which will be discussed in a later section. ARUP also helped in the design of the system and Haley & Aldrich contributed additional technical review.

Several structural engineers worked on the project and conducted technical studies of the system, including Patrick McCafferty and Mark Walsh-Cook from ARUP and John Chrisley at Haley and Aldrich. The final design included seven " 'wells,' or holes in the ground, and 3,500-foot-long horizontal underground pipe connecting the wells with the building…the college's system has a 22-ton heating capacity, or the ability to generate 264,000 BTU of energy" (Sato). Matthew Sepe explained that MCC installed a vertical, closed-loop system, which uses a network of high-density polyethylene pipes to transfer heat to and from the earth. The various types of geothermal heat pumps systems can be seen in the Figure 2.

Figure 2: Geothermal Heat Pump Designs



(Geothermal).

For MCC, the pipes are buried in vertical wells behind Trustees' House. The system works through a groundwater heat pump that recovers heat stored in the ground which transfers heat to and from the building into the ground to either cool or warm the facility. The temperature in the ground is more stable because it retains more heat than the atmosphere (Trustees). The Department of Energy filed an initial assessment of the project and explained the design process. They state that MCC's geothermal system "utilizes municipal water with propylene glycol (non-toxic/ non-corrosive antifreeze solution) added in a 20% ratio to the municipal water working fluid" (Middlesex). This solution ensures that the solution does not freeze while exchanging heat in the winter months. The 17.5 ton system required seven boreholes to an average depth of 500 feet. The Department of Energy conducted an erosion control plan using siltation fencing and hay bales, which are often used for erosion and sediment control. The total area of the borefield was expected to be 420 square feet. A trench (approximately 140 feet by 3 feet) was planned to connect the geothermal wells with each other and the building components. The system would utilize both High Density Polyethylene and Thermally Enhanced Bentonite Grout to eliminate the risk of fluid leakage from the system. Any leakage could be potentially harmful to the local groundwater. The system would comply with all Ground Source Heat Pump Association's (GSHPA) design and installation standards. This requires that wetlands and/or floodplains are not present at the proposed project location (Middlesex).

Coneco projected the annual savings to be $6,524 or 5,392 therms saved. This unit measures the amount of heat and is equivalent to 100,000 Btu. Unfortunately, as the building is one among many, it is impossible to say with certainty how much money has been saved by the geothermal heat pump system. There are many other factors on campus which could raise or lower costs. "One Btu is the heat required to raise the temperature of one pound of water by one degree Fahrenheit" (Frequently). The four-month work to retrofit the building for the new system was completed in September of 2010. However, installation did not only include the construction of the wells. The equipment inside the Trustees House needed to be installed, including "three water furnace water-to-air heat pumps, an expansion tank, air separator, expansion tank, and duty-standby pumps" (Middlesex). Coneco also installed a monitoring system with web access to ensure the geothermal heat pump would function properly. Additional work included "ductwork in the mechanical room, cleaning of all existing ductwork and coils, commissioning and training" (Middlesex).

Ms. Spaziani stated that there were no legal obstacles to the project, but they had to go to the town to receive approval from the zoning board of appeal and receive "environmental sign offs", but this required no official legal action. Zoning board approval was necessary for the project, but this was just following due process, not because there was legal opposition to the project. The only problem according to Ms. Spaziani was trying to schedule when the drilling would occur because the school could not allow it to be a distraction during class days. Thus, the installation company had to schedule it around finals and during vacations. Not only did they have to schedule it around the students, but to avoid disrupting the neighbors, construction could only take place during the day. There were no complaints received about construction and the neighboring community did not have any concerns about how the project would affect their property. Ms. Spaziani explained that the neighbors were not apprehensive because there was no risk of contaminating the local water supply, affecting the neighbor's energy bill, or obstructing the neighbors' enjoyment of their own property. The project was contained on the campus and has not disrupted the neighbors.

On October 9th, Congressman Tierney visited the campus to see the project, but according to Ms. Spaziani, it was barely operational at that point in time. They were still working on the geothermal heat pump's operations inside the Trustees Building. Though the construction work was completed, the pump still required testing and balancing of the system. Once operational, MCC held a ceremony to celebrate the project's completion and thank the engineering companies and government agencies that helped with the geothermal heat pump. During the ceremony, the school's president, Carole Cowan, personally thanked the Division of Capital Asset Management (DCAM) for collaborating with the college for the project.

According to Ms. Spaziani, the heat pump covers a majority of the heating and cooling costs of the building, but buildings are not individually metered, so they do not know the amount of heating expenses saved from the building's previous gas system. However, Ms. Spaziani believes that the system was not economically cheaper to run than a gas heating system. She stated that the cost of installing a geothermal heat pump was much more expensive than simply updating the previous systems. The system has been running for two years and the college has yet to receive a return investment. Ms. Spaziani explained that over time there will be savings, but she cannot say for certain that they have seen or will see one soon. Unfortunately, they cannot accurately determine savings because many factors affected the consumption amounts of the school. For example, as the consumption went down due to the geothermal heat pump, campus nightly events increased and demanded more from the heating and cooling system in other buildings. Thus, they cannot accurately estimate the consumption of the Trustees Building and whether the heat pump has benefitted them economically.

Though the system has not been financially beneficial to the school, it has been reliable, an excellent educational tool for environmental students, and allowed for more efficient use of the building at night. There have been no problems with the system since installation. When asked how the students and community benefit from this project, Ms. Spaziani explained the educational opportunity to study the geothermal heat pump system was an invaluable part of the students' courses. "They get to say that Middlesex is doing its part to go green…it's a hands-on teaching tool for them." However, as many of the students were not present during construction, many students do not understand how the geothermal heat pump works. They do not see the machinery and thus, most students probably do not understand the project's environmental importance. The only direct impact that heat pump has is on the education of the environmental students that have the ability to monitor and learn this technology through hand-on experience. In terms of the community, Ms. Spaziani did not feel there was a large impact on them because it was contained to the campus. As it exists within a building on campus, the residents had little interaction with the project besides the noise associated with construction. The community can take pride in the fact that Middlesex is working to reduce their carbon footprint and trying their best to go green. However, they do not engage in its everyday processes and do not see it, which can cause many to forget about it.

Often times, people will be alarmed at development near their property such as renewable energy projects because of the possible effects it may have on their own property and how they enjoy it. Many people refer to "NIMBY" laws, which stand for "Not In My Backyard," where residents are protected from certain developments that could negatively impact their property. This attitude is generally associated with nuclear power (Waldo), but many oppose other renewable energy projects such as wind because of its possible effects on their lifestyle, economic benefit of their property, and possible nuisances. One study states, "As we have shown in the two case studies, the visual impact of wind power is one of the main causes of negative attitudes. The effective component of people's attitudes expresses strongly-felt and highly subjective aesthetic values; wind power is perceived as a threat to local landscape qualities, and to the emotional experience associated with the site" (Waldo). Also, a community resistance to projects is often based upon whether it serves a private or public use. If a community feels disconnected from a project, they may be less accepting: "In terms of process, our surveying of local residents suggested that more direct and substantial involvement of local people in a project also contributes to greater project acceptance and support, and there was evidence that this involvement could have a positive impact on local peoples' understanding of and support for renewable energy more generally" (Walker). Therefore, the lack of involvement of the community with geothermal heat pumps may cause a negative response to it. Wind turbines, based upon whether they are used for the public or private companies are opposed by some residents that anticipate nuisances. Geothermal heat pumps are not typically a nuisance to neighbors because they are contained and do not affect the neighbor's enjoyment of their property. Construction may disturb them temporarily, but there would be no permanent effects by the installation of the geothermal heat pump system. However, they could have a more positive impact, on the community if they are involved in its development and understand its benefit.

One initial concern that may prevent Assumption College from installing this technology in the proposed building is the high initial capital cost of geothermal power. Unfortunately, drilling into the earth is a delicate practice and the geology of the site could produce problems. “Wells are extremely expensive to drill; a 3 km well could cost 10 million dollars with a potential failure rate of 20%. Equipment and turbines for geothermal power are expensive. Drilling into the earth carries the same potential risks across all energy industries. There are a multitude of gasses and elements buried underground that can be dissolved in water coming through the production well” (Siting 59). As with all drilling practices, “open loop systems can allow these gasses and elements into the environment, but are often outfitted with emissions control systems to mitigate the byproducts of the open loop system. Gasses dissolved in the geothermal fluid can include ammonia, methane and carbon dioxide. Currently, the average plant allows only 122 kg of carbon dioxide to enter the atmosphere per MW-hour, which is a small fraction as compared to fossil fuel resources. Closed loop systems can possibly prevent the gasses and toxic elements from being able to escape the system into the environment altogether. As with any power plant, necessary steps must be taken to maintain clean emissions” (Siting 60). These concerns must be taken into account when planning a geothermal heat pump system. Drilling costs range depending on the geology of the site and cause the project to be more expensive than anticipated. It is imperative to hire engineers and installation companies that are experienced. Often times, institutions choose companies based solely on the inexpensive designs plans. I would urge against this because, design plans might be cheaper on paper, but could have more complications with less experienced engineering companies. It could benefit Assumption to hire the engineers are more equipped to handle the project, which may make them more expensive.

HASTINGS SCHOOL:

Built in 1970, Hastings Elementary School is a public school located in Westborough, MA, 13 miles from Assumption College. In 1997, it became the "First Successful 100% Geothermal School in New England." Hastings Elementary was the first school in New England to try geothermal technology. The project is annually saving the school thousands of dollars in heating and cooling costs. Not only has it been financially beneficial, but the school has reduced its CO_2 emissions by 577 tons annually (Geothermal). Similar to Holy Name High School and Mount Wachusett Community College, when Hastings Elementary School was first built in 1970, it was run completely on electric energy. Thus, their electrical bill was extremely high during the winter to heat the school. Also, it did not have a summer cooling system. Les Olson, the former Assistant Superintendent stated, "While there was the high operating cost, the original sense of a need to convert the building came one winter when one classroom's electric coils burned out and replacements were unavailable. As the building was 20 plus years old, we realized we had to convert the system." The original idea was to convert to a gas-fired hydronic heating system. However, Massachusetts Electric approached school officials with the idea of using a geothermal system rather than gas. Massachusetts Electric offered a grant to cover the design cost.

Geothermal usage in school systems has been growing, "As of the start of 2003 there were 1,200 schools in the US that were built new or were retrofitted with geothermal heat pumps." Unfortunately, I was unable to find data about the current uses of geothermal heat pump systems. This technology is not new, but it has improved over the decades. However, even an older system such as the one installed in Hastings has proved to be a valuable installation. Hastings School is a successful example of the technology, which has only improved with time. “Installed in 1995, the system saves the school approximately $75,000 annually in energy costs” (Geothermal). Hasting Elementary is an example of a successful project installed twenty years ago. The technology has since advanced, offering even more opportunity to Assumption College today.

The elementary school is 72,000 square feet and consists of 28 classrooms organized in 4 “pods,” or subdivisions centered around an outdoor courtyard. The school also contains a library, cafeteria, kitchen, office space, a gymnasium and a mechanical room. The heating load was determined to be 200 tons. Six standing column water wells were drilled to supply enough heat energy for the school. “The School heating load was estimated from a block load analysis and verified by a comparison against existing electric billing information” (Orio). The computed heating load was 2,400,000 British Thermal Units per hour and the cooling load was 1,500,000 BTUh. The BTU measures its capacity to cool or raise the temperature in an hour of running.

For geothermal heat pumps, both hydrology and geology of the site are important to determine the possible depth of wells and whether or not drilling will be impeded by certain types of bedrock. Massachusetts’ aquifers in particular, contain igneous and metamorphic rocks, predominantly of gneiss and schist. “Schists and gneiss and typically less strong than comparable igneous rocks. Crushing strength depends on the orientation of the foliations. Such rocks may be weak parallel to the foliations but resistant perpendicular. Schists may have elasticity that reduces the effectiveness of the drilling force” (Drilling 176). “The northeastern Appalachians region is a hilly to mountainous region characterized by glacial deposits underlain by igneous and metamorphic rocks. The glacial deposits are typically 10 ft (3 m) to 30 ft (9 m) thick (Randall et al. 1988)" (Orio). The common range of the depth of wells in Massachusetts is between 100-400 feet, but might exceed 1000 feet (Orio). Common well yield of a well in Massachusetts is 1-20 gallons per minute, but might exceed 300 gpm. This refers to the sustainable rate of water flow, so the well could draw this amount of water per minute (Orio). However, the Hastings Elementary's six standing column wells are each 1500 feet deep. The rate of water flow is 7 gallons per minute at a depth of 100ft. The depth to the bedrock is around 82-83 feet. As Assumption is within 15 miles of the school, this information could be useful in determining the type of drilling, the depth of the wells, and any problems associated with the bedrock. However, this is not definite because geology can vary, even across short distances. Also, depending on the type of well and system, it may not be necessary to study the hydrology. "The standing column well is advantageous during the design phase because the performance can be predicted without an extensive hydrogeological study." Hastings School used a standing column system, as will be explained.

HEC Corp. from Natick, MA served as design engineers and construction managers for the project. However, Enterprise Equipment Corp. from Weymouth, MA, installed the system. The initial operations analysis study was conducted by Vanderweil Engineers in 1994, but it was revised by HEC Corp. in 1995. Ken Anderson from HEC was the primary designer and Carl Orio from Water Energy Distributors Inc. was the primary equipment consultant. At the time, there were no state or federal grants available. The project cost a total of $860,000, not including the design costs. Les Olson stated, "Quite frankly, one thought we always kept in the back of our mind was that if the geothermal system failed we could then convert to the originally planned gas-fired system - the hydronic distribution system would still be in place." The school department appeared apprehensive of the technology in the beginning, but it has exceeded all expectations.

Based upon the data of heating and cooling loads of the school, engineers designed a system where "two centralized modular ten-ton water-to-water heat pumps fed a new two-pipe building-wide distribution system with a two-pipe distribution was selected for the retrofit. The building has two major distribution loops, which are combined in the equipment room. The central heat pumps are earth coupled by six (6) standing column wells" (Orio). A water-to-water system circulates water from a ground source through the unit, and the chilled or warmed water is circulated to fan coil units for cooling or heating. "Standing column wells consist of a borehole that is cased until competent bedrock is reached... A central pipe is dropped to form a core through which the water is pumped up, and an annulus into which the water is returned. The length of the central pipe at the bottom is perforated to form a diffuser. Water is drawn into the diffuser and up the central riser pipe" (Collins 4). 10 inch or 12 inch steel casing supports the shallow, soil portion of the borehole (Ross 28). An annulus is "The space around a pipe in a well bore, the outer wall of which may be the wall of either the bore hole or the casing; sometimes termed the annular space" (Annulus). Water in a standing column comes from fractures in the bedrock. Located away from the playground, the six standing column wells are adjacent to the playing field behind the school. "Each Standing Column Well (SCW) is a nominal six (6) inch bore fitted with a four (4) inch Porter Shroud, an internal sleeve and an over-ride bleed system. The bleed system allows the wells to be brought back to average earth temperatures should winter or summer requirements vary from statistical weather or building use standards" (Orio). The Porter Shroud is also referred to as the "straw" and is a "6-inch-diameter plastic pipe inserted into the completed borehole to the bottom" (Ross 28).

The well drilling was done by Wilmington Pump Co Inc. from Wilmington, MA and cost $180,000 in total. "Each well/bore required approximately one workweek to drill. This elapsed time period included set-up, drilling, area maintenance and relocation to next well/bore" (Orio). They drilled the six bore holes "in a linear array, with each well being approximately 75 feet from the next. The 75 foot separation is a generous design spacing and insures little, if any, thermal transfer from SCW to SCW" (Orio). The separation is important because "Closer spacing will affect the performance of the well field as the earth has a limited capacity to accept and reject heat" (Collins 25). After the drilling was completed, piping of the standing column system was installed.

As mentioned earlier, the HVAC Installer was Enterprise Equipment Co. Inc, from Weymouth, MA. "Piping from the SCWs to the school are high density polyethylene (HDPE) of a 3408 resin with high abrasion resistance specifications. This piping has identical characteristics as piping used for natural gas lines. All piping is joined by heat fusion" (Orio). Possible leaks were considered and safety standards were met to ensure that chemicals do not escape from the well. "Should a refrigerant leak occur and in order to meet the requirements of ASHRAE Standard 15, 'Safety Standard for Refrigeration Systems' a refrigerant sensor and an automatic high volume exhaust system was installed in the mechanical room" (Orio). Enterprise Equipment Co. also installed a system to control the geothermal heat pump. "Control of each of the heat pumps is by a Johnson 'Metasys' direct digital control (DDC) system. The DDC system has a central keyboard and display in an area accessible by the School's maintenance personnel. The heat pumps can either act as a boiler, producing heated water or as a chiller producing cold water" (Orio).

The system had to be installed in the mechanical room and classrooms were retrofitted from the previous heating system to the geothermal heat system. "Each classroom console had an electric heater, blower, blower motor and outside air louver. The geo retrofit involved removing the old electric coil, validating the integrity of the existing blower and motor, cleaning and repairing the 25-year-old console as needed. The old electric element was replaced with a new custom-made hydronic coil" (Orio). The coils normally consist of a "three row deep configuration. While this is a common coil thickness for an air conditioning application, the lower heating water temperature developed by a geothermal heat pump also required a three-row coil. Since the three-row requirement was common to both the heating and cooling water temperatures a single coil was all that was required. This in lieu of the common console, fan coil or large air handling unit that normally required two water coils, one for hot water and one for cold water. This characteristic of a geothermal system allowed a less costly single hydronic coil configuration" (Orio). Hastings' retrofit allowed for a unique coil system, and saved some installation costs. As Assumption College has proposed a new building, designing the geothermal heat pump system would not require a retrofit.

According to Mr. Garbarino, the HVAC technician of Westborough Public Schools, the geothermal heat pump system has reached its life expectancy of 20 years and the school is looking to replace it in the near future with higher efficient EPA compliant refrigerant R410A units. As of 2015, it is the new standard for U.S. residential air conditioning systems. The refrigerant is "a hydro-fluorocarbon (HFC) which does not contribute to ozone depletion" (Thien). Previously, the refrigerant R22, (a hydro-chlorofluorocarbon or HCFC) was used, but it was banned in the United States in 2010 for contributing to ozone depletion. R-410A systems can withstand higher pressures, and absorb and release heat more efficiently than R-22 refrigerants (Thien). The original system that was installed did not have an auxiliary boiler back up. Mr. Garbarino stated that he felt the boiler back up system was necessary "on exceptionally cold days because the system is only capable of producing 118 degree water to each of our classroom units." Some newer systems can run as hot as 160° F.

Mr. Olson agreed that the "major operating deficiency" was the main entrance area because as the children entered the school in the morning, the temperature of the foyer could drop to 50 degrees. The system unfortunately took a long time to re-heat the foyer back to an "acceptable temperature." Mr. Olson stated, "Adjacent classrooms were always colder than the rest of the building. Building a well-insulated entrance was considered but never implemented." This is an issue that should be considered in the design process to allow for more heating in the entrance of any similarly used building.

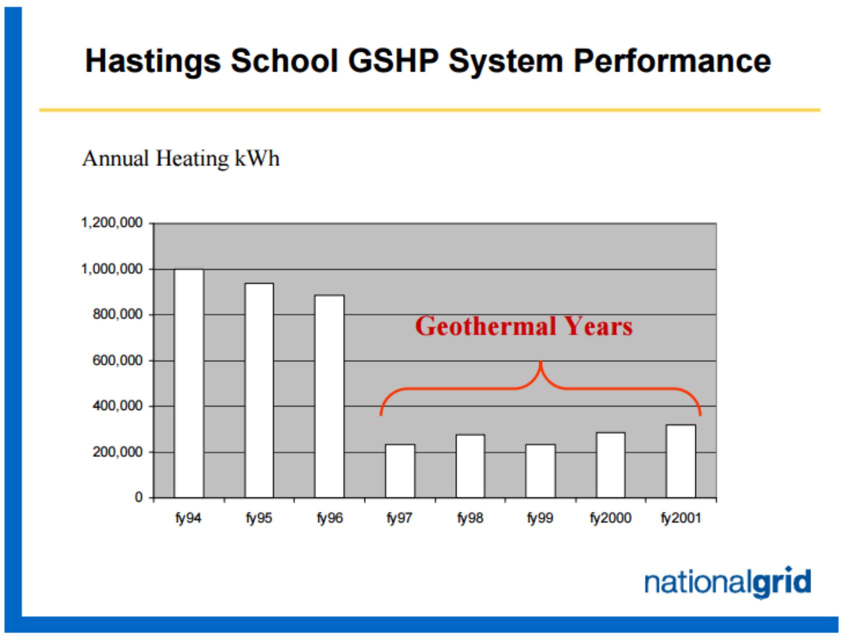
Though the geothermal heat pump was successful, it did require maintenance and upkeep over the past twenty years. Mr. Garbarino mentioned updates such as adding an outdoor reset of the indoor water loop temperature and adding well water flow control valves on each heat pump to balance. Anticipated problems with the system include replacements of equipment parts and worn-down equipment. For example, the compressor and well water pump required replacements. Newer systems now have longer lasting scroll compressors and energy efficient variable frequency drive technology to ensure a longer lifespan of the compressor and water pump. The system has experienced heat exchanger failures due to sand in the well water. Mr. Garbarino noted that a dirt separator should be added during any new system's installation. The air separator on the well water side of the system has rotted-out three times because it is made of ferrous material. Mr. Garbarino notes that it should have been PVC or stainless steel to prevent this problem. Unfortunately, Mr. Garbarino does not have exact costs of the repair work, but he estimated the costs based upon usual replacement amounts and the amount of times they each were done. The compressor was replaced 10 times and each was ~ $1500, totaling around $15,000 over the twenty year period. The water well pumps were replaced 4 times and each cost $3500, totaling at $14,000. The air separator was replaced 3 times, each costing $3000 and totaling $9,000. The well water expansion tanks were replaced twice and each cost $600, totaling the cost to $1,200. These costs include only equipment replacements, excluding labor. These best estimates can be observed in the table below, Table 1.

Table 1: Maintenance and Upkeep Costs of Geothermal Heat Pump System

Replacement Necessary	Cost per replacement ($)	Times Replaced	Totals ($)
Compressor	1,500	10	15,000
Well Water Pump	3,500	4	14,000
Air Separator	3,000	3	9,000
Well Water Expansion Tank	600	2	1,200
Overall Total ($)			39,200

Though the total initial construction cost was $860,000, Hastings Elementary has benefitted greatly from the installation of their geothermal heat pump system. It is one among many schools in the U.S. that have used the technology to save heating and cooling costs. “The use of a geo-exchange heat pump offers many advantages for the academic building manager and operator. Flexible use, low cost operational and maintenance budgets, savings on the newly adopted fresh air requirements and newly required “12 month” schools all make the geo-exchange heat pump an attractive space conditioning system for all school at all levels.” Hastings Elementary did not have a cooling system previous to the project and the geothermal system allows the building to be used all year-round. Mr. Olson, the Assistant Superintendent of the School District cited the $75,000 per year savings, but it is unknown how the geothermal heat pump savings or electric rates changed over the past two decades. Though the costs of maintenance over 20 years have totaled at ~$39,200, the savings have more than covered these expenses. This is demonstrated in Figure 3 below. This information was provided by Mr. Robinson, a former employee of National Grid.

Figure 3: Hastings School Heating Cost Comparison Pre and Post GSHP Installation



(Robinson).

As previously noted, the Hastings Elementary School has benefitted financially from the project and successfully reduced their carbon footprint by 577 tons of CO_2 emissions yearly. However, it does not appear to have had a large impact on the students or the community. As the technology was installed twenty years ago, many today do not know of its existence. There is limited information about it online and the principal herself was uninformed of the technology in the school. I was directed to Mr. Richardson, the Director of Building and Grounds of Westborough Public Schools for more information. From there, Mr. Richardson directed me to

Mr. Garbarino to answer questions about the installation and maintenance of the geothermal heat pump. My “wild goose chase” to find information about the system was eventually successful, but demonstrates the lack of public awareness about the system in the community. It is not acknowledged on the either Hastings’ Elementary’s or Westborough Public School’s websites. Hopefully, when the new system is installed, there will be more interest about the project through newspapers and other media.

BOWDOIN COLLEGE:

The only private liberal arts college that undertook a geothermal heat pump system is Bowdoin College, located in Brunswick, Maine. The geothermal heat system was installed in the summer of 2005 when the college created two new freshman dormitories, West and Osher Hall. The college needed to expand to accommodate increased enrollment. Completed in August, “Each dorm features 80 beds, common social spaces at the entries and distributed smaller social spaces throughout the buildings” (Bowdoin). The total cost of the new dorms with the engineered systems was $14 million. The system was created using standing column wells, as seen at the Hastings Elementary School. However, this system is unique because it also has a water collection system. These projects were developed for two reasons. The first reason was that the town mandated that new projects could not contribute any runoff from the additional impermeable surfaces that would be created by the dorms because the existing stormwater collection system adjacent to the campus was near capacity. Secondly, “Bowdoin’s central steam system did not have the capacity in its existing distribution system to take on the new buildings” (Greim). The school could have updated the stormwater infrastructure, but this would have been costly. Instead, a creative solution was designed by engineering consultants at Harriman Associates of Auburn, Maine, and architect, Kyu Sung Woo from Cambridge, MA.

Rainwater runoff from the new residential building was controlled by a collection tank to reuse the water for flushing residence hall toilets. In order to provide heating and cooling and domestic hot water for the residence halls, a geothermal heat pump system was installed. Seven 1,500 ft. deep, standing column wells were drilled for the two residence halls. “Each well has its own variable-speed, submersible well pump installed to accurately match pumping with the load of the associated heat pump” (Greim). As explained earlier, standing column wells tap into bedrock crevices filled with groundwater. “The wells bring the groundwater into the buildings, where heat pumps extract 15-20 degrees to heat or cool the building, depending on the time of year. A heating/cooling loop system takes the heated and/or cooled water and circulates it through the building to individual dorm rooms. The water then returns to the ground, where it is naturally re-heated” (Osher). Some of the heat pumps have different uses: “Five of the heat pumps are dedicated to the heating or cooling of the living spaces, and the remaining two pumps trade off generating the first stage of domestic hot water. Since heat pumps have an upper temperature limit in the heating mode, a direct-vented condensing gas boiler covers the final stage of domestic water heating” (Greim). The boiler and the emergency generator act as back-ups for heating and power should a heat pump fail. Any bleed from the system was incorporated into the rainwater storage tanks to prevent additional runoff in the stormwater. These systems work together to ensure that all water is put to use and all heating and cooling is covered.

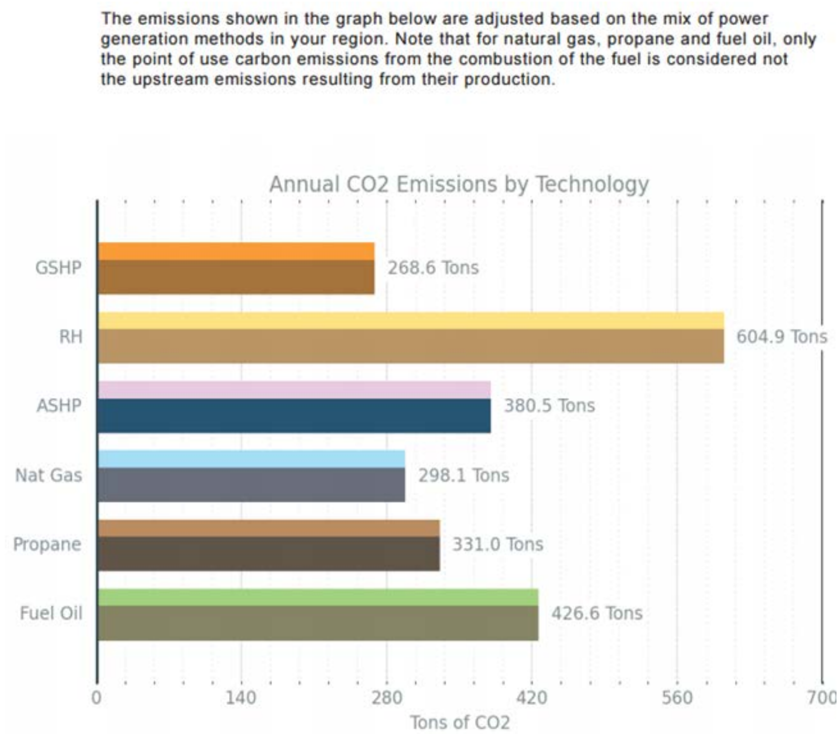
The college financially benefits from this technology. Additionally, it is a positive environmental advertisement. Economically, the project was helpful because the cost of fixing the stormwater collection to allow for the new residential halls was high. Using this system, the school was able to save money on heating oil rather than spend additional money to fix the stormwater situation. “The geothermal heating system allows Bowdoin to save over 40% of the energy per year that students would normally consume in a residence hall. While the initial cost is more than that of a normal heating and cooling system, the savings generated by features such as the geothermal system and the rainwater collection system are expected to be paid back in three to four years" (Osher). Not only was it economically beneficial, but "Both solutions earned the project LEED points, and Bowdoin College was awarded Silver LEED certification for the Coffin Street Residence Halls" (Greim). LEED certification is explained later on in the paper. The geothermal heat pump systems and "green image" are good publicity for the school, and Bowdoin College advertises the new technology on several of their websites.

Since this project, geothermal heat pumps systems have been added to Bowdoin campus for Studzinski Recital Hall and the Walker Art Building (Waxman). In 2007, the school had an unfortunate crack in the bedrock which required contractors to drill down an additional five feet to fix it (Waxman). The school has embraced their role in green technology through many other projects including increased efficiency systems and conservation programs, such as those that encourage minimizing waste, etc. They have switched from burning #6 fuel oil to #2 fuel oil, reducing their sulfur dioxide and particulate matter emissions by 57%. Another residence hall, the Ladd House, burns B20 BioHeat fuel, which is a mixture of 20% vegetable oil and 80% petroleum (Beem).

The green projects undertaken by the college were part of a movement at the school to be environmentally aware and work towards reducing their carbon footprint. "In April of 2002, Bowdoin adopted an Environmental Mission Statement that states, 'The College shall seek to encourage conservation, recycling, and other sustainable practices in its daily decision making processes, and shall take into account, in the operation of the College, all appropriate economic, environmental, and social issues'" (Beem). Bowdoin College has invested in these technologies and realizes the importance of sustainability in today's society. By undertaking a mission statement and incorporating these technologies, the school demonstrates the endless possibilities available for society to be "green" now. "Colleges and universities, dedicated as they are to the advancement of knowledge, have increasingly become laboratories for sustainable living. Bowdoin, with its historic commitment to what its first President Joseph McKeen referred to in 1802 as the Common Good, clearly wants to be a leader in establishing best environmental practices…Green design and sustainable development have become mainstream best practices and Bowdoin has adopted them, for the good of the College and for the common good" (Beem).

Assumption College's mission statement encourages stewardship and citizenship of their students, but does not expressly state an environmental goal or mission. The mission statement reads, "Assumption College, rooted in the Catholic intellectual tradition, strives to form graduates known for critical intelligence, thoughtful citizenship and compassionate service." Undertaking environmental projects may initially be more costly investments, but they can have enormous paybacks. Bowdoin College's efforts to become green not only have saved the school money, but they have also positively promoted the school, reduced their dependence on fossil fuels, and increased their efficiency. If Bowdoin College can take that first step towards sustainability and their green identity, Assumption College can do the same. By demonstrating forward-thinking practices of sustainability and conservation, it could positively promote the school and reduce our dependency on fossil fuels and foster "thoughtful citizenship," as referred to in the Assumption College Mission Statement. Figure 4 was provided by Mr. Nowak from Coneco Energy and it demonstrates the carbon dioxide emissions of various heating and cooling systems, including geothermal heat pumps, electrical energy, air source heat pumps, natural gas, propane, and fuel oil. Geothermal heat pump systems produce the least amount of carbon dioxide emissions, and installing one would show Assumption College's dedication to reducing the school's carbon footprint.

Figure 4: CO_2 Emissions of Different Fuel Types



(Nowak).

LEED CERTIFICATION:

LEED stands for Leadership in Energy and Environmental Design. The LEED label is an important one for businesses and companies because it demonstrates their dedication to building "green." "Supported by the United States Green Building Council (USGBC), LEED Certification recognizes a subset of buildings that were designed, built, and/or maintained with sustainability in mind" (What). There are different levels, but the "LEED plaque on a building is a mark of quality and achievement in green building" (This). It is the most widely used green building rating system in the world. They alone certify 1.7 million square feet of construction space every day. LEED certification takes into account many factors, including the “design, construction, operations and maintenance of resource-efficient, high-performing, healthy, cost-effective buildings” (This). LEED certification encourages energy and resource-efficient buildings, which reduces the stress on the environment, but also benefits business because of savings from increased building value, higher lease rates and decreased utility costs. “In fact, 88 of the Fortune 100 companies are already using LEED” (This). These companies have invested in the LEED certification because it endorses their buildings and businesses and attracts positive attention for the public.

The different levels and programs include LEED Green Associate, LEED AP Building Design and Construction (LEED AP BD+C), LEED AP Operations and Maintenance (LEED AP O+M), LEED Credential Maintenance Program (LEED CMP) (What). Each has their own tests to determine for which type of certification the building, company, and/or employees are eligible. The first program, LEED Green Associate, validates the company’s understanding of green building and sustainability. “The LEED Green Associate credential is the mandatory first step for pursuing a LEED credential, regardless of your experience” (What). The exam prep course available on LEED Green Associate’s website is designed to give companies a valuable overview of topics related to green design, construction, and operations. It “includes a complete review of the LEED Rating Systems, LEED credit categories, LEED certification process, hundreds of simulated exam questions, and strategies for passing the exam” (What).

The second program is the “most popular LEED AP specialty among accredited professionals” (What) is the LEED AP Building Design and Construction (LEED AP BD+C). It shares many similarities to LEED Green Associate but “takes a closer look at concepts related to new construction and major renovations" (What). The website explains that "LEED AP BD+C is directly applicable to professionals who work on constructing new buildings. This specialty highlights opportunities during the design phase that can result in greater energy savings later" (What). This program would be one to consider if Assumption College undertook a renewable energy construction project for its design process.

The next specialty is LEED AP Operations and Maintenance (LEED AP O+M) designation. This "focuses on the performance of green buildings and is perfect for facility managers and sustainability officers responsible for measuring and tracking a building's energy consumption" (What). This program evaluates the performance of the LEED's project in terms of sustainability. "Professionals with this designation are accountable for ensuring that a building's operations are as efficient as were designed" (What).

These specialties are important for the building's certification, but in addition, "All LEED professionals are required to participate in ongoing professional development training. Known as the LEED Credential Maintenance Program (LEED CMP), this requirement stipulates that all LEED Green Associates and LEED APs with Specialty acquire a set number of continuing education hours every two years to maintain their credential" (What). This ensures that associates are up-to-date on sustainability and green building technology. They can satisfy each program's hour requirements in a variety of ways, but "the most convenient solution for satisfying this requirement is to purchase a comprehensive LEED CMP package" (What).

By LEED certifying employees, projects, and buildings, businesses establish their reputation for sustainability. Whether it be construction, design, or maintenance, the certifications can endorse the business's dedication, while also improving the building's efficiency and saving money in the long term. These certifications are a positive way to advertise the business. Assumption College would benefit because they could publicize the projects and promote the school's efforts towards efficiency. Bowdoin College has several certifications from multiple projects on their campus and it has helped to establish their "green identity." It professionally recognizes the efforts of the school in terms of sustainability and efficiency of their green technology and programs. Other colleges in the Worcester area have invested in LEED certification of buildings, such as Worcester Polytechnic Institute. Four LEED buildings exist or are planned for WPI's campus. The buildings have different certification levels based upon the credits the building achieves. The different conservation and efficiency features of the building determine the credits it received. Table 2 below demonstrates the credit system and the certifications available based upon the amount of credits (Building).

Table 2: LEED Credits and Certification Available

TOTAL LEED CREDITS ACHIEVABLE	
Site Planning	14
Water Management	5
Energy Management	17
Material Use	13
Indoor Air Quality	15
Innovation & Design Process	5
Total Credits	**69**
LEED CERTIFICATION LEVELS	
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

(Building).

WPI is not the only school that has LEED certification; "Clark University, the College of the Holy Cross, University of Massachusetts Medical School, Worcester State University and Worcester Polytechnic Institute have all earned the Leadership in Energy and Environmental Design (LEED) green building certification" (Semon). The certifications encourage ingenuity and efficiency in buildings. "LEED addresses all building types, emphasizes state-of-the-art strategies, and promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. LEED is a practical rating tool for green building design and construction that provides immediate and measurable results for building owners and occupants" (Building).

SECTION I CONCLUSION:

After interviewing the schools about their wind turbine or geothermal heat pump projects, the next step was to interview installation companies to determine the possibility of similar projects for Assumption College. The information provided by the schools demonstrates the pros and cons, the success stories and the unfortunate outcomes that are possible when investing in renewable energy. Private and public schools, private towns, private and public colleges were all involved in the interview process. While some were unsuccessful and others were beneficial, all could agree that the design process is the most important aspect in the projects. It is important to consider every possibility and outcome before undertaking an extensive renewable energy project. Engineering expertise can make or break a project and thus, it is important to properly invest in the initial design processes before any installation is considered.

I contacted several engineering and wind turbine installation companies through contacts provided by the schools and communities in the first section. However, many of these efforts were unsuccessful as companies were unwilling to give estimates of cost on a hypothetical project. Fortunately, one company was cooperative and provided me with the rough estimates of a geothermal heat pump project for Assumption College. While one wind turbine company would not give estimates, they suggested that a cost analysis be conducted off Holy Name's wind turbine as that project would be the most similar.

SECTION II: COST-BENEFIT ANALYSES

This section consists of a cost-benefit analysis of each of the hypothetical projects. Of the several wind turbine companies contacted, only Gamesa Corp. was willing to provide some information for the analysis. As mentioned, they are a Spanish company that provides maintenance to the Holy Name High School wind turbine. This was only possible through the efforts of my contact, Johanne Sermania (an aftersales manager), who introduced me to Luisa Vidal (a pre-sales engineer). Ms. Vidal determined the best wind turbine specifically for Assumption College based upon several factors. First, she used the historic data available through the company's records of wind speeds for Holy Name High School. Second, she used the orography conditions of Assumption College. As we are in a highly populated area with many obstacles and high, dense vegetation, according to Ms. Vidal this "implies, normally, a high turbulence intensity and shear. A small rotor is less dependent on these parameters and the operation will be smoother." Her advice was to install a G47 wind turbine on the hill north of Assumption's Multi-sport Stadium.

Similarly, I contacted several geothermal heat pump engineering and installation companies and only one was willing to give rough estimates of cost for a geothermal heat pump system. As Assumption is tentatively planning to construct a new 58,000 square foot building, I based the geothermal heat pump system in the new building rather than retrofit an existing building. It is easier to design and install geothermal heat pump systems in new buildings than to incorporate them into already-existing structures. Mike McGonigle was given as a contact by

Middlesex Community College for Coneco Engineers and Scientists Inc. He connected me with their expert engineer on GSHP designs, Chris Nowak. Mr. Nowak was willing to give extremely rough estimates based upon what little information I could provide on the new building. As it is only now moving into the design phase, the heating and cooling loads for the new building are currently unknown. However, based upon typical heating and cooling loads and the square footage of the building, Mr. Nowak provided a feasibility report.

These estimates would not be possible without the help and time of contributors of Gamesa Corp and Coneco Engineers and Scientists. The following section consists of the cost-benefit analysis provided by the engineers and sales representatives based upon their estimations and advice.

WIND TURBINE COST-BENEFIT ANALYSIS:

Gamesa Corp. suggested that the best estimation of pricing would be based off Holy Name's wind turbine expenses. In her professional opinion, Luisa Vidal, an engineer at Gamesa suggested the G47 turbine for Assumption College. The 600 kW turbine was manufactured by Gamesa Corp. However, it is no longer in production. This would require the company to find a wind turbine in use and refurbish it for Assumption College. According to Ms. Sermania, this would lower the price by up 10%. However, based upon the location of the turbine, shipment and delivery costs could be expensive. The turbine could be across the country or across continents. These shipment expenses are impossible to determine because of the unknown location of the turbine. It is unknown whether warranties would still be applicable with the refurbished turbine.

Unfortunately, Gamesa could not give exact cost estimates of the turbine. Ms. Sermania explained that in order to determine the possible energy production of a turbine, extensive studies are required. She assured that, without these studies, it is impossible to give any accurate determination of prices and savings from the turbine. She estimated that these studies would cost approximately $100,000 to provide an estimate for the turbine's costs, energy production, and projected savings. Based upon rough wind speeds and available space, the G47 was determined to be the best option for Assumption College. However, without the design preliminary studies, Ms. Vidal cannot be completely certain of the best turbine. Ms. Sermania's suggestion was to base the costs of a wind turbine on Holy Name High School's wind turbine project. While the two turbines have different manufacturers, both are 600 kW turbines. As Holy Name is also located in Worcester, the wind speeds can be expected to be relatively similar to Assumption College's wind speeds, especially up on the hill above the Multi-Sport Stadium.

The wind turbine at Holy Name High School produces between 675,000 and 800, 000 kW hours per year. This would reduce Assumption College's electric bills. Currently, Assumption College pays an electric rate of $0.0930/kWh. Holy Name's wind turbine cost $2,000,000 in total, including studies, construction, and installation. However, this project began in 2001 and was finished in 2008. It is difficult to determine the inflation rates of the cost of the turbine, but inflation rates are projected to be approximately 2% from 2015 to 2019. Using this information and the available discount factor, the real rate of interest was used to determine the net present value of the income stream. This can be viewed in the provided table on page 63.

Available below, Map 1 and Figure 5 demonstrate how the cost of electricity decreases as wind speed increases. The map shows the average wind speed for Massachusetts. Assumption College's average wind speeds are 5.5- 6.0 m/s. Other records have verified the speeds to be approximately ~5.9 m/s at a height of 50 meters (wind). On the graph, the pink lines are the wind speeds at height of 50 m versus the blue which show wind speeds at a height of 10 m.

Map 1: Massachusetts Wind Speeds

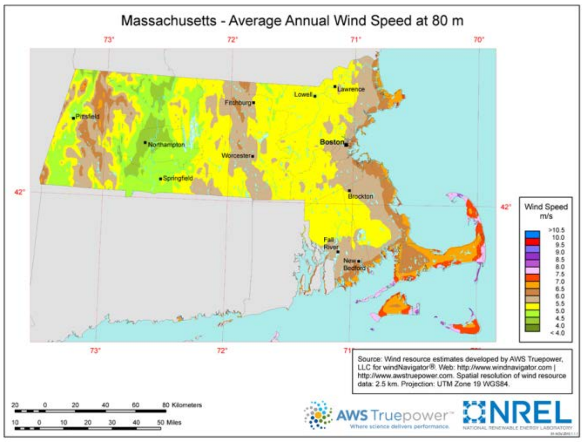
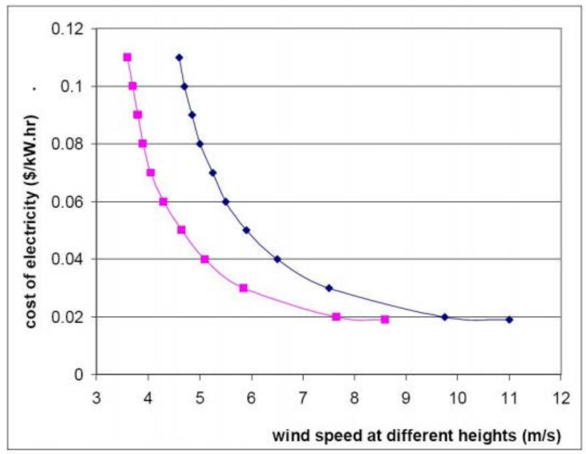


Figure 5: Electricity Costs based upon Wind Speeds



(Ragheb)

The average expected lifetime of a wind turbine is 20 years (Ragheb). If the turbine cost and installation comes to $2,000,000, as Holy Name's wind turbine project did, we can project the repayment. If we assume Gamesa would handle the maintenance of the turbine for the same amount as Holy Name's wind turbine, the yearly maintenance costs come to $25,000. The following cost-benefit analysis is guided by Dr. Ragheb's paper, "Economics of Wind Energy." Following this format, I was able to insert information provided from Gamesa Corp. and Mr. Reynolds from Holy Name High School to create an estimation of savings from a G47 turbine.

Assumption's Electricity Budget for 2015:

=(kWh purchased X supply cost) + (kWh purchased X delivery cost)

=(8,621,000 kWhr purchased X $0.070) + (8,621,000 kWh X $0.039)

= $1,000,036 cost of annual electricity

Note: The utility budget information was provided by Ms. Prizio from Business Services at Assumption College.

Total Expenditure of Turbine: total turbine cost + maintenance costs over expected lifetime

=$2,000,000 + ($25,000 per year X 20 years)

=$2,500,000

Capacity factor: 28.54% or 0.2854

This capacity factor was provided by Dr. Ragheb's paper. He explains that for energy generating technology, the capacity factor, "…is equal to the ratio of the annual energy production to the theoretical maximum energy production. " He states, "Depending on the wind statistics for a particular site, the ideal capacity factor for a wind turbine is in the range of 25-40 percent, because that capacity factor minimizes the cost per kWhr of energy produced… Capacity factors will be very different for different turbines, but likewise the prices or costs of these turbines will be very different. Overall, what counts is the cost per kW hr of energy produced, not the capacity or intermittence factor" (Ragheb).

Energy produced/ year: kW produced per year X capacity factor

600kW X 365.25 days X 24 hours X 0.2854 = 1,501,089.84 kWhr/year

Gross yearly income from electrical sale: 1,501,089.84 kWhr/year X $0.0930/kWh= $139,601.36/year

Net income stream per year: gross yearly income – maintenance costs

=$139,601.36/year – $25,000 = $114, 601.36/year

Table 3: Expenditures and Income Streams of G47 Turbine

Year (n)	Expenditures ($)	Gross Income Stream ($)	Net Income Stream ($)	Present Value Factor $1/(1+r)^n$ r=0.05	Net Present Value of Income Stream ($)
0	-2,000,000	-	-	-	-
1	-25,000	139,601.36	114,601.36	0.95238	109,144.15
2	-25,000	139,601.36	114,601.36	0.90703	103,946.81
3	-25,000	139,601.36	114,601.36	0.86384	98,996.96
4	-25,000	139,601.36	114,601.36	0.8227	94,282.82
5	-25,000	139,601.36	114,601.36	0.78353	89,793.16
6	-25,000	139,601.36	114,601.36	0.74622	85,517.30
7	-25,000	139,601.36	114,601.36	0.71068	81,445.05
8	-25,000	139,601.36	114,601.36	0.67684	77,566.71
9	-25,000	139,601.36	114,601.36	0.64461	73,873.06
10	-25,000	139,601.36	114,601.36	0.61391	70,355.29
11	-25,000	139,601.36	114,601.36	0.58468	67,005.04
12	-25,000	139,601.36	114,601.36	0.55684	63,814.33
13	-25,000	139,601.36	114,601.36	0.53032	60,775.55
14	-25,000	139,601.36	114,601.36	0.50507	57,881.47
15	-25,000	139,601.36	114,601.36	0.48102	55,125.21
16	-25,000	139,601.36	114,601.36	0.45811	52,500.20
17	-25,000	139,601.36	114,601.36	0.4363	50,000.19
18	-25,000	139,601.36	114,601.36	0.41552	47,619.23
19	-25,000	139,601.36	114,601.36	0.39573	45,351.65
20	-25,000	139,601.36	114,601.36	0.37689	43,192.05
Total	-2,500,000	2,792,027.20	2,293,027.20	-	1,428,186.25

Net Present Value of Income Stream: at r = 5 % per year real rate of interest: $1,428,186.25

The net present value represents the income worth based upon the discount factor and inflation rate of the net income stream. “The real rate of return is a measure of the real interest rate earned on a given investment” (Ragheb). The real rate of interest is found by combining the discount rate and the inflation rate. Inflation rates are expected to raise prices approximately 2 % over the next four years (Projected). His paper conducted a similar economic benefit estimation of a 600 kW wind turbine, which helped to develop this cost-benefit analysis. I used the same real rate of interest, or r value of 0.05 for this paper as Dr. Ragheb. “The computation of the real rate of return requires an iterative procedure to find the roots of the expression for the present value. One approach is to make a guess that is substituted into the equation. If the guess is too high, the net present value will be negative. If the guess is too low, it becomes positive. The Newton- Raphson iteration method can make the iterative approach converge rapidly" (Ragheb).

Yearly net real rate of return:

= (Net Present Value of Income Stream / Total Turbine Cost) X (1/ Turbine Lifetime)

= ($1,428,186.25 / $2,000,000) X (1/ 20 years) = 0.0357 X 100% = 3.57 % per year

Present Value of Electricity per kWhr:

= Net Present Value of Income Stream/ (Yearly Energy Production X Turbine Lifetime)

= $1,428,186.25 / (1,501,089.84 kWhr/year X 20 years)

= $0.047571644 / kWhr

= 4.76 cents per kWhr

Table 4 demonstrates the savings possible from a 600 kW turbine at Assumption College. The gross income stream of $139,601.36 per year is the yearly electric savings to Assumption College. If the electric rates rise at an expected rate of 3%, the savings rise as well. I used Assumption College's current electric rates locked in $0.0930 per kWhr, but increasing yearly at a rate of 3%. The hypothetical turbine costs ~$2,000,000 in total for the design studies and installation. However, maintenance costs are $25,000 each year. From Table 4, it is projected that after 13 years, the yearly energy savings of the wind turbine exceed the investment cost. This allows Assumption College to fully benefit from the wind turbine and save on electric costs for the next seven years. This seven year period would save the college a total of $1,823,011.56.

Table 4 :Wind Turbine Cost- Benefit Analysis

Year	Expected Electricity Costs per year ($)	Turbine Savings per year ($)	Electricity Costs with Turbine Reduction ($)	Accumulative Turbine Savings ($)	Turbine Costs ($)	Turbine Costs- Accumulative Yearly Savings ($)
0	1,000,036	139,601.36	860,434.64	139,601.36	2,000,000	1,860,398.64
1	1,172,111.16	143,789.40	1,028,321.76	283,390.76	2,025,000	1,741,609.24
2	1,207,274.49	148,103.08	1,059,171.4	431,493.84	2,050,000	1,618,506.16
3	1,243,492.73	152,546.17	1,090,946.5	584,040.01	2,075,000	1,490,959.99
4	1,280,797.51	157,122.56	1,123,674.9	741,162.57	2,100,000	1,358,837.43
5	1,319,221.43	161,836.23	1,157,385.2	902,998.80	2,125,000	1,222,001.20
6	1,358,798.08	166,691.32	1,192,106.6	1,069,690.12	2,150,000	1,080,309.88
7	1,399,562.02	171,692.06	1,227,869.9	1,241,382.18	2,175,000	933,617.82
8	1,441,548.88	176,842.82	1,264,706.0	1,418,225.00	2,200,000	781,775.00
9	1,484,795.35	182,148.10	1,302,647.2	1,600,373.10	2,225,000	624,626.90
10	1,529,339.21	187,612.55	1,341,726.6	1,787,985.65	2,250,000	462,014.35
11	1,575,219.38	193,240.92	1,381,978.4	1,981,226.57	2,275,000	293,773.43
12	1,622,475.96	199,038.15	1,423,437.8	2,180,264.72	2,300,000	119,735.28
13	1,671,150.24	205,009.30	1,466,140.9	2,385,274.02	2,325,000	-60,274.02
14	1,721,284.75	211,159.58	1,510,125.1	2,596,433.60	2,350,000	-246,433.60
15	1,772,923.29	217,494.36	1,555,428.9	2,813,927.96	2,375,000	-438,927.96
16	1,826,110.99	224,019.19	1,602,091.8	3,037,947.15	2,400,000	-637,947.15
17	1,880,894.32	230,739.77	1,650,154.5	3,268,686.92	2,425,000	-843,686.92
18	1,937,321.15	237,661.96	1,699,659.1	3,506,348.88	2,450,000	-1,056,348.88
19	1,995,440.79	244,791.82	1,750,648.9	3,751,140.70	2,475,000	-1,276,140.70
20	2,055,304.01	252,135.58	1,803,168.4	4,003,276.28	2,500,000	-1,503,276.28

A wind turbine project could save the college in electric costs, but it does not cover the total electricity bill. It would require a large initial investment and it must be noted that these estimates are not exact prices. The turbine could have a lower capacity factor than expected or might have technical problems. These are not factored into the analysis because of limited economic information.

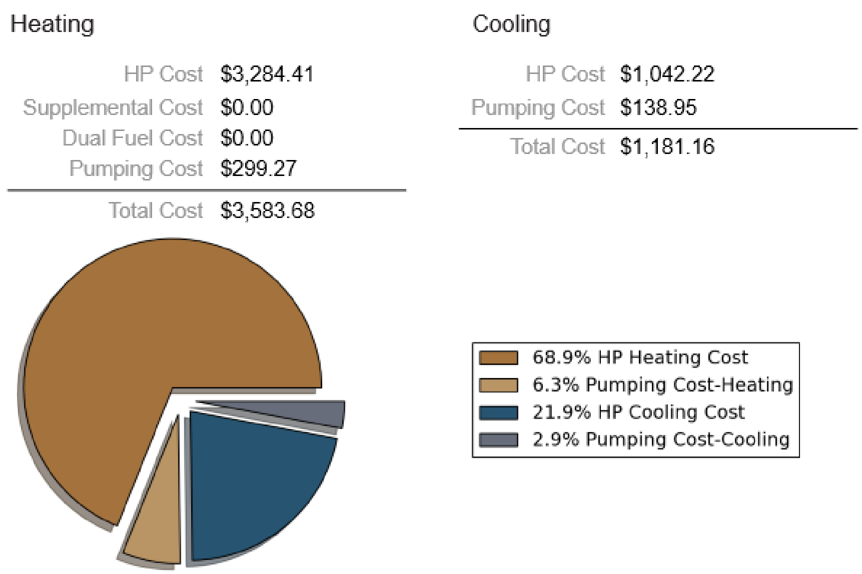
GEOTHERMAL HEAT PUMP COMPARATIVE COST ANALYSIS:

Mr. Nowak from Coneco Energy, a division of Coneco Engineers & Scientists, Inc. created a preliminary design for a closed loop heat pump for Assumption College. The proposed building has a vague layout, consisting of 14 classrooms, an auditorium, rehearsal space, 1500 square foot atrium, 39 offices, and 2 conference rooms. According to Todd Derderian, the Director of Building and Grounds at Assumption College, the plan is to heat the 58,000 square foot building with high efficiency condensing gas fired hot water boilers. To cool most of the building, high efficiency air cooled packaged equipment has been proposed. According to Mr. Derderian, the school is planning to install energy efficient systems in the building. However, he did not specify as to the type of energy efficient systems. Also, according to Mr. Derderian, the Director of Building & Grounds, Assumption is not planning to invest in LEED certification. While the building would qualify for LEED credits, the school feels the cost of LEED certification is not worth the investment.

Based upon this information, Mr. Nowak used general design software to determine a block base heating and cooling load for the building based upon the school's geographic location and the general labelling as "School Classroom." The estimated cooling load is expected to be 240,000 Btuh. The peak heating load is expected to be 190,000 Btuh. This would require 60 boreholes at a depth of 450 feet. The layout can be seen in Figure 8 on page 71. Large hydronic water-to-water heat pump units would be installed to provide hot and cold water to the building. Based upon the information provided of the current proposed heating and cooling system, Mr. Nowak expects that the interior installation costs of a geothermal system and conventional system would be similar in price. They would use the same interior distribution system, but geothermal heat pump units would probably be more expensive than boiler units. Both systems heat and cool, so there is no additional cost of cooling equipment to factor in either system. The interior installation costs are expected to be similar, but the exterior ground loop installation is the main additional cost which would make the geothermal heat pump system initially more expensive.

The system, or peak loads are used to "calculate the total amount of heating and cooling capacity required for a space based on the set points and the climate data…" (Nowak). Peak loads are calculated based on several factors, including, "assumed occupancy levels, the number of appliances operating, the number of doors & windows and the tightness of the construction all contribute to the amount of energy required to maintain the thermostat set points given the historical extreme weather conditions in the area" (Nowak). The peak heating load for Assumption College was determined to be 190,000 Btu/hr with a heating set point at 70°F. The peak cooling point is 240,000 Btu/hr and cooling set point is 75°F. Normally, the design would separate different sections of the building into zones and determine the heating and cooling low capacity and high capacity for both heating and cooling in a zone. The zones would be based upon the architectural design, the layout of the building, and the use of the each zone. However, this information is currently unavailable at this point of the design process. Thus, as a majority of the building is going to be offices and classrooms, Mr. Nowak created a zone for a generic classroom to use for the entire building. Thus, the low and high heating capacity for the entire building is between 126,600 and 233,607 Btu/hr. The low and high cooling capacity for the building is between 137,267 and 259,538 Btu/hr. It was estimated that high capacity heating hours would be 414 hours, low capacity heating would be 1,979 hours, high capacity cooling would be 372 hours, and low capacity cooling would be 739 hours per year. Based upon the annual power consumption of the geothermal heat pump system and price per kilowatt hour, the heating cost totaled to $3,583.68 and the cooling cost totaled to $1,181.16. This can be seen in Figure 6 below. The supplemental cost refers to back up systems that run when the space load is greater than the system capacity. In other words, the load required to heat or cool the building is too high or low for the GSHP system to handle alone. It requires a backup system in these cases. This was not taken into account for this project because this cost ranges based upon the back-up system and its prices. The temperature 20 feet below the ground is expected to be 52°F based upon Assumption College's location.

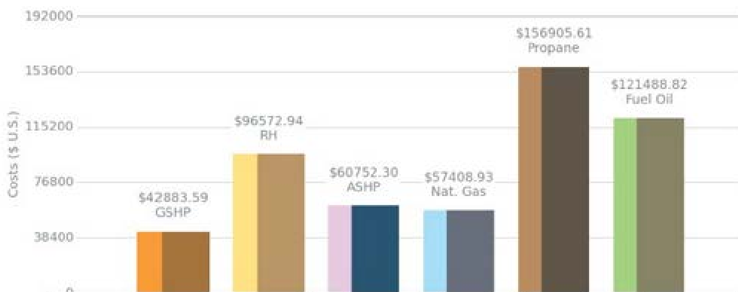
Figure 6: Heating and Cooling Costs of Geothermal Heat Pump System



(Nowak).

The costs of heating and cooling by different mediums can be seen in Figure 7 on the following page. The average annual cost of heating and cooling can be seen in the bar graph. Geothermal heat pumps provide the cheapest heating and cooling option, followed by natural gas. The annual cost of natural gas is $14,525.34 more expensive than a geothermal heat pump system. The cheapest option after natural gas is an air source heat pump (ASHP), which relies on the temperature of the outdoor air to cool and heat indoors. However, this costs $17,868.71 more on average than a geothermal heat pump system and is more suited for moderate climates. Fuel oil, propane, and electric (RH) are all between $50,000 and $114,000 more expensive than the geothermal heat pump design. It should also be noted that, as a non-profit organization, Assumption College is ineligible for federal tax credit available for help in geothermal heat pump projects.

Figure 7: Comparison of Costs of Fuel Types

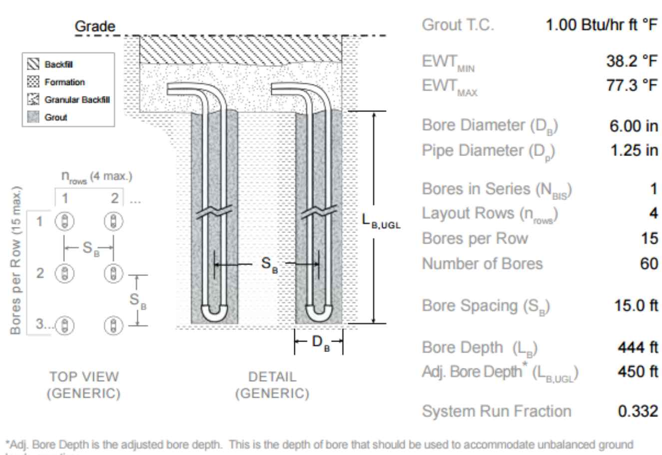


System Type	Heating	Cooling	Total	vs. GSHP
Ground Source Heat Pump (GSHP)	$32,253.12	$10,630.47	$42,883.59	———
RH	$83,046.30	$13,526.64	$96,572.94	$53,689.35
ASHP	$47,225.66	$13,526.64	$60,752.30	$17,868.71
Nat Gas	$43,882.29	$13,526.64	$57,408.93	$14,525.34
Propane	$143,378.97	$13,526.64	$156,905.61	$114,022.02
Fuel Oil	$107,962.18	$13,526.64	$121,488.82	$78,605.23

(Nowak).

The total estimated installed cost of the geothermal heat pump system is $2,425,000. This includes the exterior ground loop design and installation of $425,000 and the interior GSHP distribution system design and installation would require $2,000,000. The exterior costs include many factors such as site visits, reviews of existing site conditions and local geology, location and study of well sites, and permitting work by the city/ town (legal approval by zoning board). Once preliminary design and planning is finished, construction of the boreholes begins. Haybale/silt fencing and berming are provided for site protection. These act as temporary sediment barriers and "consist of filter fence, straw or hay bales, a berm of erosion control mix, or other filter materials" (Maine). Sediment barriers intercept and retain small amounts of sediment from disturbed or unprotected areas. They are used when "sedimentation can pollute or degrade adjacent wetland and/or watercourses, sedimentation will reduce the capacity of storm drainage systems or adversely affect adjacent areas…" (Maine). Next, sixty 6 inch closed loop geothermal bores would be drilled to a depth of 450 feet with 15 feet separation between each one. Each bore would have 1 ¼ inch piping with approved thermally enhanced bentonite grout. "Grout is used inside of all bores in order to protect the deep earth environment from surface contaminants and to provide a more effective contact surface with GHEX piping that optimizes heat transfer between the fluid pumped through your GSHP and the earth" (Nowak). The boreholes would be piped and connected to a HDPE vault, installed with clean sand fill as pipe protection. A layout of the wells can be seen in Figure 8 below. The system would then be flushed out of air and debris, and filled with a 20% propylene glycol/water mix and pressure test. The interior installation would include the installation of 9 separate reversible water-to-water heat pump units, the distribution system from construction plans, and full system installation.

Figure 8: Geothermal Heat Pump Design for Assumption College



(Nowak).

The installation of the conventional distribution system includes planning and design of the system, providing the natural gas and A/C units. Following the design, the interior distribution system would be installed. The interior installation of both the conventional system and geothermal heat pump system would each cost approximately $2,000,000. Thus, the geothermal heat pump system would cost approximately $425,000 more than the conventional heating and cooling system. Table 5 on the following page shows the cost analysis for this project in comparison with a conventional gas heating system, assuming an inflation rate of 3% for electricity and 4% for natural gas prices. Electric rates and gas prices are based upon Assumption's current rates of supply. The energy savings of the geothermal heat pump system yearly exceed the additional cost after 18 years of use, allowing the college to save on heating and cooling costs for the next several years. Geothermal heat pump systems have a typical life span of 25 years until they need to be replaced. By the 20th year, it is estimated that Assumption College will have saved $65,000 from energy costs.

Table 5: GSHP Cost Comparison with Conventional Gas Heating System

Financial Details When Paying Cash for the System

Year	System Cost Conventional	System Cost Geothermal	Marginal Capital Cost Difference	Energy Savings	Cumulative Cash Flow
1	$2,000,000	$2,450,000	$450,000	$14,456	$435,544
2	-	-	-	$15,328	$420,216
3	-	-	-	$16,244	$403,972
4	-	-	-	$17,205	$386,767
5	-	-	-	$18,214	$368,553
6	-	-	-	$19,273	$349,280
7	-	-	-	$20,384	$328,895
8	-	-	-	$21,550	$307,345
9	-	-	-	$22,774	$284,571
10	-	-	-	$24,057	$260,514
11	-	-	-	$25,402	$235,112
12	-	-	-	$26,813	$208,300
13	-	-	-	$28,292	$180,008
14	-	-	-	$29,842	$150,166
15	-	-	-	$31,467	$118,699
16	-	-	-	$33,170	$85,529
17	-	-	-	$34,954	$50,575
18	-	-	-	$36,823	$13,752
19	-	-	-	$38,782	$25,030
20	-	-	-	$40,833	$65,862
Totals	**$2,000,000**	**$2,450,000**	**$450,000**	**$515,862**	**$65,862**

Model Assumptions		
Electricity Cost	$0.093/kWh	Increases 3% every year
Heating Oil Cost	$1.218/THERM	Increases 4% every year
Geothermal Unit Efficiency (Seasonal Average)	2.69 COP	
Conventional Furnace/Boiler Efficiency	88% Efficient	

NOTE: Efficiencies Are Average Estimates For Entire System (Circulators, Fans, Zone Valves, Etc.) Not Just For The Heat Pump Or Boiler Units

(Nowak).

CONCLUSIONS:

With all large scale renewable energy projects, there are many factors to consider. There are moral, ethical, social, economic, and political effects that the projects can have. This paper has shown that successful renewable energy projects have benefitted schools and influenced campuses positively in multiple ways. The institutions in this paper have taken it upon themselves to explore the possibilities of green energy. While not all have been successful, most have benefitted either financially and ethically. For many of these schools, the project was the school's first attempt at renewable energy. Its success led Bowdoin College to other conservation projects and investment in other renewable energy designs on campus.

Renewable energy projects are positive publicity for the schools, demonstrating their forward-thinking ideals and social awareness. Both public and private institutions have taken on "green identities" by installing these technologies. The schools have shown their dedication to reducing dependence on fossil fuels and encouraging energy efficiency through their projects. They encourage their green identities by embracing programs such as signing the American College and University Presidents' Climate Commitment, LEED certifying their buildings, and incorporating environmental awareness in their mission statements. The moral and ethical benefits of a wind turbine or geothermal heat pump system have helped schools to stand out, influence current students, and attract new students.

Besides ethical reasons, the technology serves other purposes. It can be used educationally in environmental and natural science, global studies, and economics courses. By introducing students to the technology and providing them with the opportunity to have hands-on experience with the technology, they can be better-prepared for future "green careers." The renewable energy projects could provide students with a unique education that other schools cannot access. Any professor can teach about renewable energy projects, but as the saying goes, "Actions speak louder than words." By installing the technologies and demonstrating their potential, it can influence students to explore renewable energy options in their future.

Last, the economic benefits of the projects are an important factor because these technologies require large initial investments. While these projects can be expensive, this paper demonstrates the possible financial success of renewable energy projects. The cost-benefit analyses explain the payback periods of the projects and their financial potential for the college. Unfortunately, these technologies require extensive planning and construction. Renewable energy projects are an investment, and like any other investment, there is no guarantee that they will yield the expected amounts. However, the institutions in the paper have demonstrated their potential and proven that these can be a financially beneficial asset to the school.

In the end, the schools discussed have shown the benefits of either a wind turbine or geothermal heat pump system in more ways than one. At this point, I cannot unequivocally state whether one or the other is best for Assumption College. Personally, if asked, I would install a geothermal heat pump on campus because of its ability to lower heating and cooling costs, reduce carbon dioxide emissions, and its financial potential.

Though following in Holy Name Central Junior Senior High School's footsteps is an intriguing idea, there are some differences to the local high school and Assumption College. As Assumption is located in a thickly settled suburban area of Worcester, MA, it is likely that there would be resistance to a wind turbine project. Holy Name's neighbors are not as close and there was not resistance to the project. Assumption College is in a residential area in which many neighbors would be concerned about flicker and shadow. If they could prove that the turbine would be a nuisance, it is possible that the Zoning Board of Appeal would stop the project before it even begins. The legal implications of zoning would require time and money that might ultimately go to waste if the project is rejected.

Also, the turbine requires an initial $100,000 investment in pre-construction studies that could then show that a turbine is not feasible at the specified location. While DCAM might be willing to pay for the designs and environmental studies, it is possible that this would not lead to a finished product. There is no guarantee that the wind speeds at Assumption College would yield the same energy production as Holy Name's turbine. While using wind power is a wonderfully innovative idea, it may not prove useful at Assumption College if we do not have high enough and consistent enough wind speeds throughout the year.

Geothermal heat pump systems offer year-round heating and cooling and is contained in a building on campus. It is unlikely that a neighbor would complain about a nuisance because construction would take place during daytime hours and would not disturb nearby residences. Also, as the proposed building is in the design stages, now is the ideal time to explore geothermal heat pump technology. The technology is efficient and can be applied in all seasons, from the cold Worcester winters to its scalding summers. While a backup system will be necessary when the heating and cooling loads are beyond the geothermal heat pump's capabilities, the costs will be significantly reduced. The cost-benefit analysis shows the potential of significant economic benefit of such as system in the proposed building.

Assumption College has the opportunity to make a difference. Taking the first step towards renewable energy may be seen as a risky investment, or it can be seen as an opportunity to demonstrate the ideals of the college. While finances are important, a liberal arts education encourages moral and ethical decisions. As a Catholic institution, Assumption College strives to create well-rounded individuals that strive to better the world today through thoughtful citizenship and compassionate service. Climate change is not a problem the world can wait to address. Renewable energy technology on our campus is a step towards a solution. The technology is available, other institutions have successfully installed renewable energy projects with success, and the opportunity is now. What more is there to discuss?

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