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Whiting Farm Renewable Energy Report

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EXECUTIVE SUMMARY

Overview

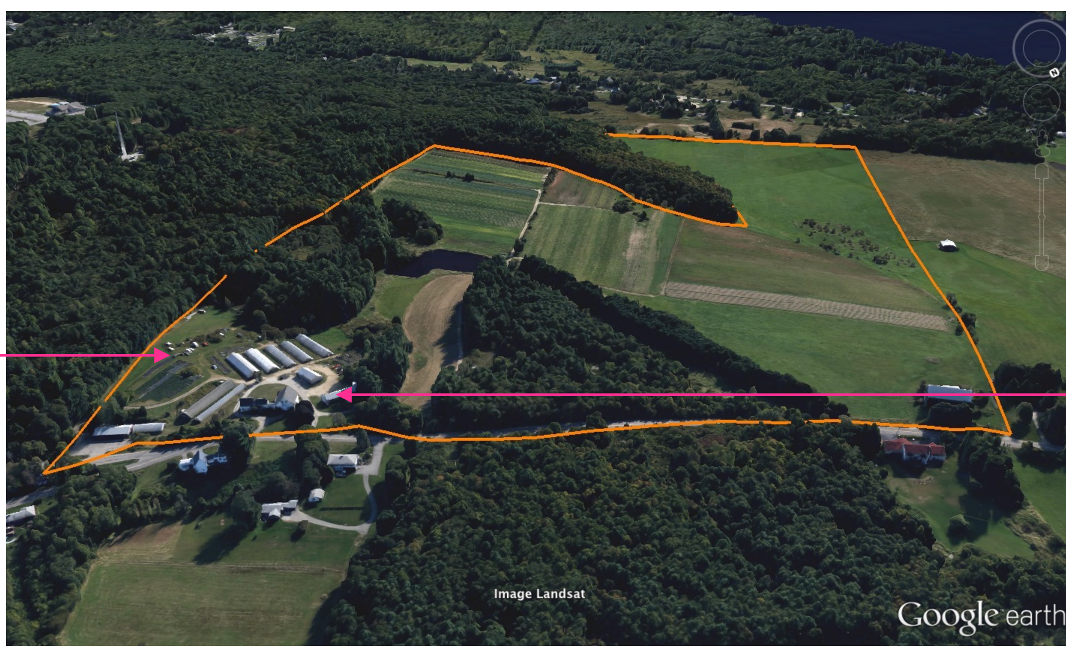
This report provides an analysis of the current electrical and heating usage at Whiting Farm. The data gathered from the analysis is used to evaluate the efficacy of alternative energy sources to offset or completely replace Whiting Farm's dependence on grid-drawn electricity and propane.

Findings

Solar power is the most cost-effective source of alternative electricity production so we recommend the installation of a 15 kilowatt (kW) array from ReVision Energy. A wind turbine produces far less electricity, but serves as a powerful educational tool, so we recommend a Pika T701 1.5 kW turbine from Pika Energy.

Geothermal heating systems are 300-400% more efficient than conventional propane-powered heating systems, Thus we recommend a mixture of air and ground source heat pumps be installed to heat the various buildings.

Type of Alternative Energy	What we Suggest
Wind	1.5 kW Turbine from Pika Energy
Solar	15 kW PV solar array by Revision Energy
Geothermal	A combination of systems depending on building location



OVERVIEW

Introduction

Whiting Farm was once a family owned and operated farm and a cornerstone of the Lewiston/Auburn community. After two non-operational years, the farm was purchased and revitalized by John F. Murphy Homes, a non-profit company that offers services for people with developmental disabilities. John F. Murphy Homes established Kim Finnerty as the onsite program director and effective chief of operations. The ultimate goal for Whiting Farm is to host John F. Murphy Homes programs for individuals with developmental disabilities and provide them with an environment to learn, improve confidence, increase self-reliance, and expand community participation by improving social and practical skills. Currently, Whiting Farm is a blank canvas that will one day be recognized as a model of a sustainably fueled, four-season farm powered by alternative energy sources such as wind power, solar power, and geothermal heating.

Background

In order for Whiting's to fulfill its potential as an educational destination for schools and farmers alike, the farm hopes to sustain its day-to-day farming operations with sources of alternative energy. Whiting Farm would like to potentially source electricity from a combination of wind turbines and solar arrays, in addition to a geothermal system that will heat water. This combination of power sources should suffice for all of Whiting Farm's current and future energy needs as well as serve an educational purpose. Because of the desirability that these systems be paid for using grants, it is important that all three systems are implemented in order to create a display-like environment for farmers to learn about the feasibility of implementation on their respective farms.

We, as a group, have acted as consultants and proponents for the installation of alternative energy sources on Whiting Farm. As amateur consultants in collaboration with professional and product specific consulting firms, we have provided the research necessary to implement any combination of the three sources of energy onto Whiting Farm. By analyzing Whiting Farm's energy bills from the past six months we were able to extrapolate the amount of energy used for both electrical and heating needs. This analysis allowed us to approximate a calculation of the amount of power that the farm draws from the grid. This information is crucial in order to determine a reasonable recommendation for the potential integration of wind power, solar power, and geothermal heating into the farm's current energy infrastructure.

AUDIT

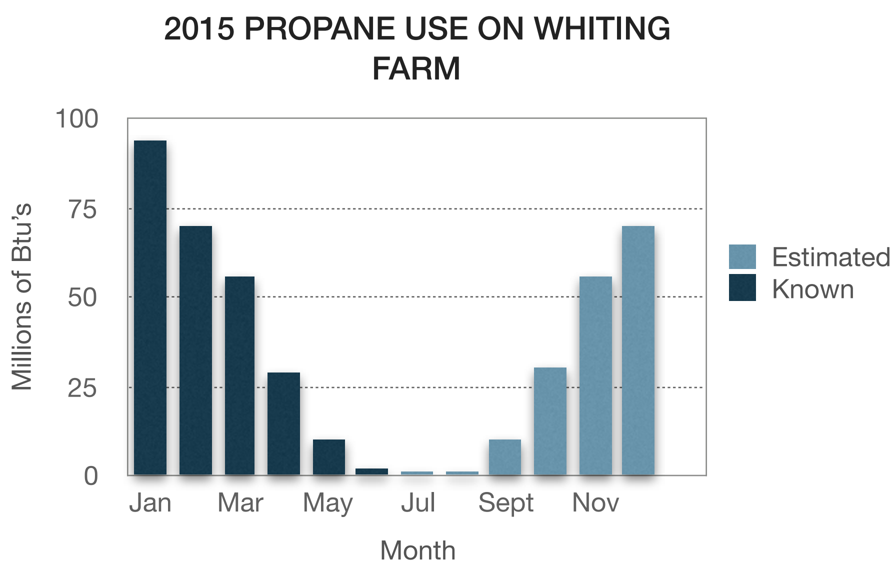
Introduction

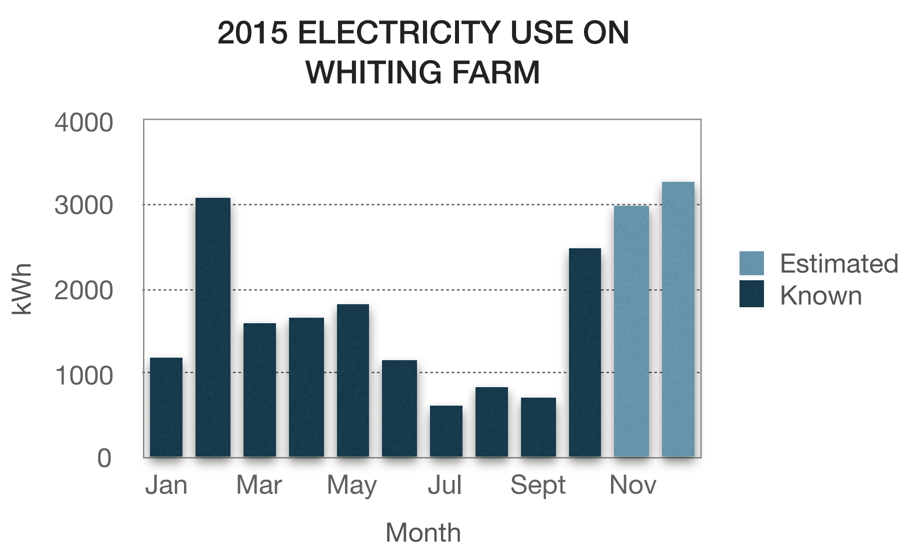
An energy audit is an essential management tool in developing a comprehensive understanding and plan of energy usage on a property. By establishing a baseline of energy usage through inspection, survey, or inventory of existing energy-consuming systems, an audit can be used to locate areas of considerable energy loss or systematic inefficiencies in order to pinpoint wasted costs and measures to counteract them.[1] A successful audit will not only highlight areas to improve operational efficiency, but also identify the potential for the integration of renewable energies. The information received from a successful audit allows for the prioritization of efficiency improvements based on economic factors such as production capabilities, payback periods, operational lifespan, complexity of installation, and frequency of required maintenance.

Our analysis varied from a traditional audit in that we were given past energy bills from Whiting Farm in order to extrapolate the amount of energy used in that period. By analyzing Whiting Farm's electrical and propane bills from the past six months we were able to estimate the amount of energy required to operate the farm for a full calendar year. Because Whiting Farm already had the intention of installing sources of renewable energies, our calculation of total energy usage can be used to gauge the necessarily capacity and combination of sources implemented.

Results

The following graphs visually represent the energy used per month by Whiting Farm over the past six months. Despite the incomplete scope of data, it was helpful that the months included were the coldest





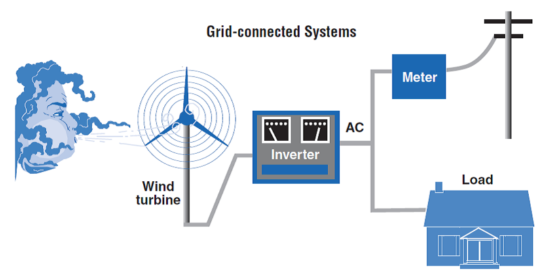
[1] National Center for Appropriate Technology, 2009.

and warmest months of the year. For months without data we predicted estimates based on weather data for propane and scaled electricity data from Whiting Farm. As displayed by the graphs there is a strong correlation between increased propane and electrical use on the farm with the darker and colder months such as January and February, as well as harvesting months like October. The most important findings from the analysis are the total monthly energy usage numbers that we were able to derive from Whiting Farm's bills. These numbers guided us in determining the necessary capacities of alternative energy sources in order to match or exceed the current amount of energy required operate the farm.

WIND ENERGY

Introduction

Harnessing the wind through a turbine-like structure in order to convert it to usable energy is an idea with roots in farming. Historically, across agrarian cultures, wind mills were used to grind grains and pump water.[2] Over the past decade small-scale wind generated power has become the fastest growing source of energy production in the technology sector with a consistent 35% increase in small-scale wind turbines installed per year. A small-scale wind turbine is an apparatus with a production capacity that ranges from less than 1 kW up to 100 kW.[3] Because wind is caused by uneven distributions of heat in the atmosphere, harnessing its power is environmentally and ethically clean, as well as sustainable in a long-term scenario. During a meeting, Chip Means of Pika Energy informed us that the approximate costs to install a 1.5 kW small-scale wind turbine with an inverter is $15,000. The inverter is necessary to condition the harnessed electricity from DC to AC, a format that is compatible with the the grid and thus most technology is formatted so. Despite the sizable economic investment, wind power has the potential to produce electricity around the clock with very few subsequent monetary investments needed.



http://en.openei.org/wiki/File:GridConnectedSystems.png

Whiting Farm is interested in the potential for the implementation of wind power as a sign of their commitment to sustainably minded education. The prospect of harnessing wind to power at least a small portion of daily operations on Whiting Farm is a powerful idea that could prove invaluable in terms of educating children and farmers of the greater Maine community on innovative types of alternative energy. There are two potentially viable locations for a small-scale wind turbine on the Whiting Farm property. The first, and optimal location, is on the hill above the greenhouses. The prominent elevation of the hill would allow for unobstructed and less turbulent wind to reach the turbine creating maximum efficiency in

[2] US Department of Energy, 2015.
[3] American Wind Energy Association, 2015.

terms of wind harnessed. The second location would be the back corner of the farm in an unused field. Both serve as viable installation locations that require further research to differentiate.

Results

After analyzing regional wind maps and weather data, and consulting with various wind power turbine installers, we have concluded that the average wind speed on Whiting Farm is approximately 9 mph at 100 vertical feet and 9.5 mph at 120 vertical feet. We used these heights because those are the two options for the tower size that the turbines can be installed on. Wind consultants consider a steady 10 mph wind speed to be a low but adequate speed. This puts Whiting Farm on the lower end of the wind power efficacy spectrum in terms of the cost-efficiency of installing a wind turbine. Whiting Farm's wind speed allows the option of three turbines, all varying in their cost, output capacity, and spacial efficiency.

The first option is a Pika T701 1.5 kW turbine. It will cost $15,000 to install at Whiting Farm and it would produce 106 kWh/month (1,277kWh/year) of electricity. The turbine would stand on a 100 ft. tower and would include an inverter, guide wire, and monitoring software to track wind input and electrical output over time. This is the smallest of the three turbines and thus only produces a fraction of Whiting Farm's energy needs. However, any wind turbine would be serving a primarily educational purpose due to the sub-optimal wind speed on the property. We therefore recommend this turbine because it is the most cost-efficient option with no maintenance required for its 20+ year life span and contains the greatest educational potential because it is small enough to be located close to the farmhouse and not in the back field. It is also the quietest of the three turbines and the supplier, Pika energy, is a Maine based company.

A Pika T701 Turbine installed on a farm.
https://www.emarineinc.com/Pika-T701-Wind-Turbine

The Three Turbine Options

Turbine Option	Rated Energy	What it would produce on the farm	Cost
Pika T701	1.5 kW	106 kWh/ month	$15,000
Bergey Excel 6	5.5 kW	429 kWh/ month	$60,000
Bergey Excel 10	10 kW	600 kWh/ month	$70,000

The second option is a Bergey Excel 5.5 kW turbine. It will cost about $60,000, including full installation, and would produce about 429 kWh/ month (5,148 kWh/year) of electricity, meaning that over the course of a year it would offset about 2 months of Whiting Farm's electrical needs. This is a medium sized turbine that would stand on top of a

120 ft. tower in order to take advantage of the slightly greater wind speed. Although this turbine apparatus could be installed on the hill near the farmhouse, we recommend that it be installed in the back field due to the necessity of guide wires for stability.

The third option is a Bergey Excel 10 kW turbine. Made by the same company as the medium sized turbine, this large turbine will cost about $70,000, including full installation, and given our wind speed estimations would produce 600 kWh/month (7,200 kWh/year) of electricity. To harness the maximum wind speeds available on Whiting Farm, this turbine should stand on a 120 ft. tower. This turbine has the ability to produce exponentially more electricity than the two smaller options when it is working at full capacity; however, it would only be efficient under sporadic and atypical wind conditions found at Whiting Farm. This turbine would have to be placed in the back field due to its size and necessity of guide wires for stability.

SOLAR

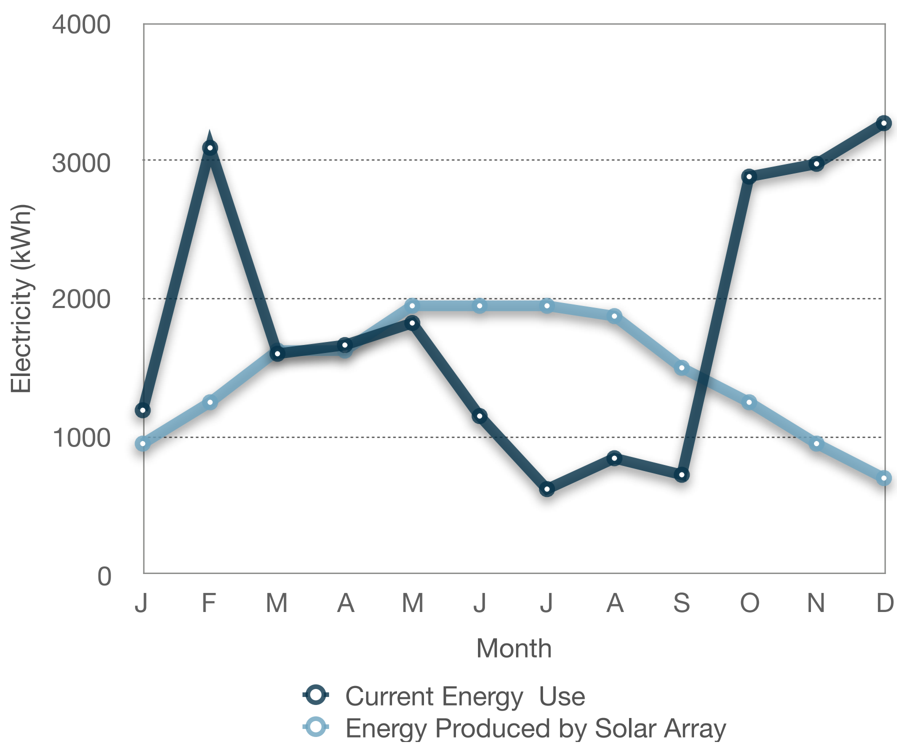
Introduction

Solar energy has experienced phenomenal growth in recent years due to both technological improvements, resulting in cost reductions, and government policies supportive of renewable energy development and utilization. Solar has emerged as the most stable source of alternative energy because it undergoes the least amount of seasonal fluctuation. This has made solar power the most favored and effective way for farms to reduce usage of conventional energy sources.[4] Because running utility lines to far and remote corners of a farm is not always practical, given the tendency for every square inch to be plowed and utilized, solar panels have become a popular choice on farms because they can be installed as a cohesive unit or as remote arrays. Their prevalence is also due to low maintenance costs and rapid payback rate.[5] The two types of solar energy relevant to Whiting Farm are photovoltaic (PV) and solar thermal. Photovoltaic is the direct light-to-electricity conversion through PV panels. This created energy is not easy to store and thus is sent back to the grid if not immediately used. Solar thermal uses the sunlight to heat a body of liquid stored inside cylinders within a thermal panel. Depending on the intended use, it is either pumped through a heat exchanger to transfer the heat to a body of water or creates steam within the thermal panel cylinders to spin a turbine which in turn creates electricity through a generator.[6] Solar energy, like any source of renewable energy, can help stabilize energy costs, decrease pollution and greenhouse gases, and postpone, if not completely deter, the need for electric grid infrastructure improvements.

Installing solar panels would not only serve as a serious sign of Whiting Farm's dedication to a sustainable farming model, but would also be an intelligent investment for operational and economic reasons. Whiting Farm is more suited to accommodate photovoltaic solar power due to the field space that has been designated for this purpose. Solar thermal energy requires a great deal of stable and reinforced roof space, which is currently limited at

[4] Xiarchos et al., "Solar Energy Use in U.S. Agriculture Overview and Policy Issues," 2011.
[5] Nate Bowie, ReVision Energy Site Evaluation, 2015.
[6] Gage et al., "Concentrated Solar Thermal vs. Photovoltaic Solar," 2012.

PROJECTED ENERGY CONSUMPTION VS. ENERGY PRODUCED BY 15 KW SOLAR ARRAY



Whiting Farm. Electricity produced by photovoltaic panels can easily and efficiently be transported to every corner of the farm with minimal energy loss.[7] Depending on the magnitude of Whiting Farm's vision and budget, a combination of the two methods of solar energy production could operate symbiotically to create electricity and heat the water to pump through the greenhouses.

Results

By working with ReVision Energy, a company that was recommended to us by Tom Twist, the sustainability officer at Chewonki Semester School and incoming Environmental coordinator at Bates, we determined that solar energy has the greatest potential of all the alternative energy sources to offset Whiting Farm's reliance on grid-drawn electricity. After a site visit from Nate Bowie, ReVision Energy's Solar Experience Manager, we concluded that to completely offset Whiting Farm's projected yearly electrical use it would be necessary to install 15 1kW PV systems (comprised of 4 panels each). A complete 15 kW system would cost roughly $45,000 and would last approximately 25 years with low maintenance requirements.The most efficient way to install PV solar panels is to place them directly onto the rooftops where the generated electricity will be used, so that the least amount of distance has to be covered between source and use. Nate Bowie identified Barn 1 as a structure that meets the criteria for a rooftop installation: it is oriented such that a side of the roof is facing south, the roof appears to be structurally sound and able to bear additional weight, there are no skylights, and there is no chimney. Other than Barn 1, there are no other structures that meet all the criteria. This means that the majority of panels would have to be freestanding, ideally close to where the produced electricity would be used.

We recommend working with ReVision Energy because of the Solar Power Purchase Agreement (SPPA) that they offer. This financial agreement would allow Whiting Farm to install a full PV array without any upfront cost. ReVision Energy

[7] Bowie, ReVision Energy Site Evaluation, 2015.

facilitates the purchase and installation of solar equipment hosted by Whiting Farm. This allows ReVision, or an outside investor, to benefit from a suite of federal and state incentives that are unavailable to Whiting Farm because it is a nonprofit organization. Whiting Farm, in turn, purchases the clean, solar-generated electricity back at a competitive rate. After an agreed upon amount of time, usually 6-8 years, of purchasing the electricity from ReVision, Whiting Farm would be given the opportunity to purchase the solar array at a substantial discount. The SPPA would work especially well with Whiting Farm because it is a realistic model for other farms to follow if they are searching for ways to afford a solar power system.

GEOTHERMAL

Introduction

Geothermal is a broad term that literally means "earth heat," and encompasses high, medium and low temperature heat sources. Whiting Farm has a low temperature heat source, meaning that below 30 ft. the soil temperature remains a constant 50˚F. In general, low temperature geothermal works by utilizing the relatively constant temperature of the ground as a heat source or as a sink to dump excess heat. In a closed-loop system, fluid is circulated through underground pipes, where the liquid exchanges heat with the earth.In an open-loop system, water is pumped from a well and then circulated. A ground-source heat pump (GSHP) then extracts, concentrates and transfers this heat to the desired location. The same process occurs when cooling a space except in reverse: the heat pump transfers heat from your home to the geothermal liquid which releases it into the ground. A geothermal system with a GSHP has the potential to replace both furnaces and boilers in providing hot air and hot water,

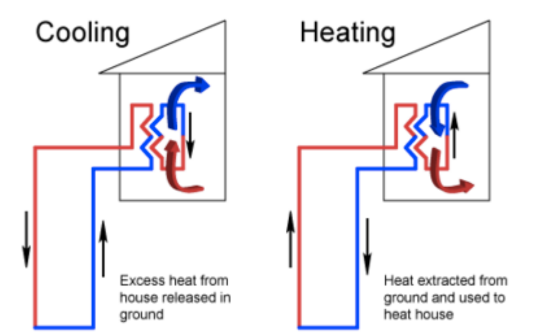


Diagram shows the heating and cooling process of a vertical ground source heat pump system.

respectively. They can also provide hot water for radiant floor-heating. According to the US Environmental Protection Agency (EPA) installing a geothermal system is the most energy-efficient, environmentally clean, and cost-effective space conditioning method available. A geothermal system in a medium sized home typically costs between $15,000-$30,000 but could be triple this in a greenhouse due the extensive heating demands. The seemingly expensive initial investment is quickly offset by low maintenance and operational costs.[8] Ground source heat pumps boast a lofty 300-400% higher efficiency and double the lifespan (18-23 years) of traditional heating systems. With an average payback

[8] John Bartok, "Geothermal Heat for Greenhouses," 2012.

period of 10 years, such a significant increase in efficiency could save 50-70% on Whiting Farm's monthly heating bill and markedly decrease reliance on fossil fuels.[9]

There are many potential uses for a geothermal heating system on Whiting Farm. Such uses include thermoregulation of the farmhouse, farm stand, and new conference center; as well as providing heat and hot water for seed germination in the greenhouses. The greenhouses in particular have the most potential for significant savings using a geothermal system because they have such high heating requirements.

We evaluated air-source heat pumps (ASHP) for buildings that do not meet the criteria for geothermal systems. ASHPs are less efficient than GSHPs at low temperatures, but they are a fraction of the price. Overall ASHPs operate at one-third of the cost of conventional fossil fuel heating sources, are relatively inexpensive to install, are highly efficient and retrofit easily into older buildings. The average payback time is 3.5 years.

Results

Working with geothermal consultants and contacting farmers in Maine already utilizing geothermal energy has allowed us to provide general heating system recommendations for each building and establish a resource base for moving forward. All buildings must undergo their planned renovations before an accurate heating load and system size can be determined. For the farmhouse we recommend improving the insulation and installing Mitsubishi or Fujitsu air-source heat pumps, supplemented by the oil furnace in place, in order to meet the estimated heating load of 76,000 BTUs. Three ASHP units each with a 24,000 BTU capacity would meet this demand and cost between $2,000-$3,000 each without installation factored in. We were unable to include the installation cost in our estimate because it depends on whether the ductwork requires modification in order to account for the increased forced air flow rate of an ASHP. If the ductwork presents a problem, ductless split system ASHPs pump air directly into the building and thus bypasses the need for duct modification.

The market place and attached greenhouse have limited surrounding space and thus would require either a vertical closed loop or open well system. Additionally, a soil analysis found bedrock at a depth of 3 feet in this area, eliminating the possibility of a horizontal loop, which would require trenches with a depth of at least 6 feet. The marketplace has a concrete floor making it relatively easily to retrofit with hydronic radiant heat tubing installed in a slab of cement that could be poured on top the existing floor along with insulation. Hydronic radiant heat tubing can also be used in the adjacent greenhouse sharing the same underground loop or well if sized accordingly to support both hydronic systems. However radiant heat flooring cannot provide cooling due to condensation. The attached greenhouse is about half the size of the restored dual poly greenhouse and thus estimated to have a heating load of 220,280 BTUs. The marketplace is approximately 2,450 square feet with an estimated heating load between 29,400-49,000 BTUs. Thus, the combined heating load is between 249,680-269,280 BTUs.

The greenhouses could be heated by a variety of GSHP systems. Shallow bedrock is also found here, prohibiting a horizontal closed-loop

[9] ELCO Electric, 2015.

system. Shallow bedrock is conducive to an open loop system due to the high water table and a reduced required drilling depth. Both would enable the installation of a water-air heating system, a water-water radiant floor heating system, or a water-water bench heating system. It would be cheapest to install a water-air system since the greenhouses are already equipped with fans to circulate air, so minimal modifications would be necessary to accommodate this system. However, a water-air system is less efficient than both water-water systems that provide root zone heating. Heat is delivered directly to the roots of the plant so the inside air temperature can be kept cooler without affecting the plant's growth, thus decreasing the necessary output capacity of the GSHP installed and decreasing heat loss. Radiant floor heating systems can be installed in concrete or buried in sand, either option would require a sizable modification to a current greenhouse. A water-water bench heating system is similar to radiant floor heating in that hot water is run through pipes to radiantly heat the space, but it is installed directly in or below the seed beds. A smaller GSHP could be installed to heat the two beds with bench heat already in use, along with water-air coils to provide supplemental heat from the propane heaters. This would demonstrate both geothermal options at a lesser cost, not accounting for increased propane use. We also recommend that a root zone heating system is installed in the new hydroponics greenhouse when it is constructed and that a geothermal system is installed in the conference center.

Chewonki Semester School installed a 3-ton GSHP vertical closed loop system with radiant floor heat for $45,000 that operates with a system coefficient of performance (COP) of 3 (for each unit of energy in, 3 units of heat are produced). In January Whiting Farm used 1,114 gallons of propane to produce 94 million BTUs of heat in one greenhouse. At the going rate of $2.70/gallon, this amounts to a bill of $3,008.50. A geothermal system can produce the same amount of heat using 9,183 kWh with a COP of 3. This amounts to an average monthly saving of $2,000 for the four months of intensive heating. It would cost Whiting Farm approximately $95,000 to install a 10 ton GSHP, horizontal looping, and two hydronic radiant floor systems similar to those used of Cozy Acres Greenhouses, and would take approximately 8 years to pay off.

Heating System Cost Comparison

Heating Option	COP	BTU/unit	BTU/$*
Propane	1	91,500/gal	33,888
Geothermal	3	10,200/ kWh	170,000
Air source	2	6,824/kWh	113,733

SOURCES

American Wind Energy Association. 2015. Small Wind Facts. http://www.awea.org/Issues/Content.aspx?ItemNumber=4592&navItemNumber=723

Bartok, John. “Geothermal Heat for Greenhouses”. eXtension, 23 Mar. 2012. Web. Accessed October 4, 2015. http://www.extension.org/pages/27790/geothermal-heat-for-greenhouses#.VjzsWxCrSRu

Bowie, Nate. “ReVision Energy Site Evaluation.” Personal interview. 05 Nov. 2015

ELCO Electric. “Geothermal Heating”. 2015. Web. Accessed October 24, 2015. http://www.elcogeothermal.com/

Gage, Brett T., and Rick Borry, PhD. “Concentrated Solar Thermal vs. Photovoltaic Solar.” TECHNOLOGICAL NICHES (2012): n. pag. Principle Solar Institute. 2012. Web. 28 Oct. 2015

Svejkovsky, Cathy. "Small-Scale Wind Energy on the Farm." National Sustainable Agriculture Information Service, 2007. Accessed September 1, 2015.

US Department of Energy. 2015. History of Wind Energy. http://www.energy.gov/eere/wind/history-wind-energy

US Environmental Protection Agency. 1993. The Potential for Advanced Residential Space

Conditioning Technologies for Reducing Pollution and Saving Consumers Money. http://nepis.epa.gov/

World Wind Energy Association. 2012. Small Wind World Report. www.wwindea.org/webimages/WWEA%20Small%20Wind%20World%20Report%20Summar%20 2012.pdf

Xiarchos, Irene, and Brian Vick. “Solar Energy Use in U.S. Agriculture Overview and Policy Issues.” 2011. Accessed September 22, 2015. http://www.usda.gov/oce/reports/energy/Web_SolarEnergy_combined.pdf