Feasibility of Alternative Energies in Municipal Buildings

A Major Qualifying Project Report:

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by

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Table of Contents

List of Figures

List of Tables

1. Photovoltaic Solar Energy and Solar Water Heating:

1.1 Background

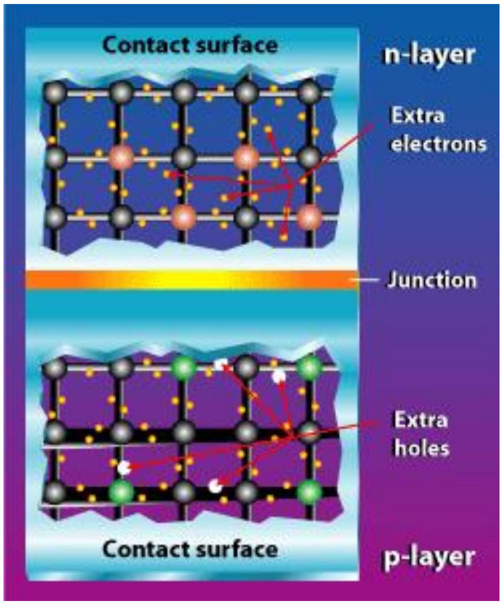
Solar technology is the process of taking energy that comes from the sun and turning it into electricity. Solar energy can be broken into two different categories: Photovoltaic and solar water heating.

Photovoltaic energy is the process of converting light energy into electrical energy. When the light from the sun shines down on a PV cell three things happen; the light is absorbed, reflected or passes through. Only the light that is absorbed by the cell can be converted to electricity. When the PV cells absorb the light, it is then transferred into electrons in the atoms of the cells. Due to an excess of energy from the sun's light these electrons are able to leave their original location where they are then forced into the flow of an electrical circuit.

1.2 Photovoltaic Technological Process

In PV cells there is what is known as a "built-in electric field." This built in field takes the extra electrons that enter the electrical circuit and provides a force that transfers the electrical current into an external circuit that can be used as power. PV cells are made out of two layers of silicon which is a semi-conductive material. In a PV cell there are two different types of silicon layers that are used to create this electrical field. One layer is known as the "n-type" layer and the other is the "p-type" layer. The "n-type" layer has extra electrons with a negative electric charge. The "p-type" layer has a positive charge with extra electron holes on its contact surface. When these two layers are put into contact with each other the extra electrons from the negative type layer are transferred to the positive type layer. This process creates an excess amount of positive charge on the n-type layer and an excess of negative charge on the p-type layer. The transfer of electrons to the other layer creates an electric field that causes electrons to move toward the negative surface which is now available to provide the electrical current for external use. The positive side functions in the opposite way as goes to the surface to complete the circuit. A group of PV Cells that are connected together make up a solar panel. A group of solar panels together is known as a solar array.

Figure 1.1: PV Cell

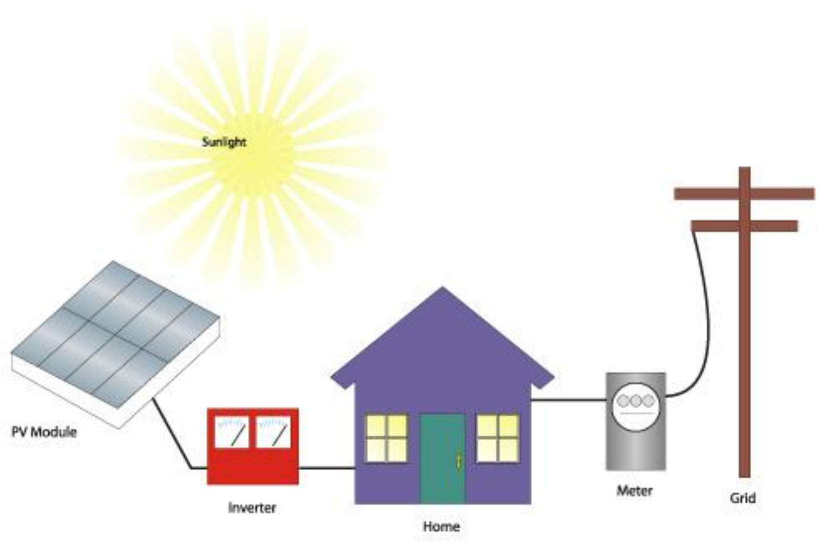


(The Photoelectric Effect, 2008)

Solar panels produce direct current (DC) electricity. Buildings however are typically powered by alternating current (AC) electricity. A DC/AC inverter is installed into the system before it can be used as electricity. After the inverter there are two options for the electricity.

One option is the excess output from the panels can be directly connected into the utility grid, or the excess output can be used for charging batteries that will be used when the sun isn't shining.

Figure 1.2: Solar Energy Process Showing Excess Power Provided to Grid



(Solar Energies Technologies Program, 2008)

A combination of these two options is also possible. The benefit to being connected to the utility grid is that it is possible to sell the extra energy back to the grid and have the utility company pay for the solar system.

1.3 The Sun's Light

When the sun's light reaches Earth's surface it is either direct or diffuse light. Direct light includes the light that comes directly from the sun without reflecting off of clouds, dust or the ground. Diffused light however, consists of light that is reflected off clouds, the ground or any other object. This is important when dealing with PV collectors because of the two types of collectors, flat plate and concentrators, only the flat plate can use both forms of light while concentrators can only use direct light (Solar Energy Technologies Program: Light and the PV Cell). About 21% of the solar flux reaches the surface as direct light, while 29% reaches as diffuse light. Even though there is a lot of lost solar energy, the light that does reach us is a significant amount. (Tester et al., 2005).

Flat plate solar water collectors operate in that they intercept solar radiation on an absorber plate in which passages for carrier fluid are integral. The carrier fluid, which is either liquid or air, passes through the flow channels and has its temperature increased by heat transfer from the absorber plate. The energy transferred to the carrier fluid determines the instantaneous collector efficiency. In order to achieve maximum capacity, the flat plate collectors usually have one or more optically transparent cover plates that are intended to minimize heat lose from the absorber plate. Usually they are capable of heating carrier fluids up to 82°C with efficiencies between 40 and 80 percent. For applications such as air conditioning and other industrial heat requirements, flat plate collectors generally can't provide carrier fluids at temperatures that are high enough to be effective. They can be used as first stage heat input devices and then the temperature of the carrier fluid is increased by other conventional heating means.

A more complex and expensive device called concentrating collectors can be used. Concentrating collectors optically reflect and focus incident solar energy onto a small receiving area. With this concentration, the intensity of the solar energy is magnified and the temperature that can be achieved at the receiver, also known as the target, approaches several hundred or even several thousand degrees Celsius. In order to work effectively the concentrators must move to track the sun. Concentrators use devices called heliostats to track the sun. (Discovery Education Science Connection)

1.4 Solar Panel Orientation

The orientation of the solar panels is very important in order to maximize the incident energy and in turn optimize the effectiveness of the solar panel. Panels can either be fixed or the tilt can be adjusted seasonally. In rare cases where the panels track the sun's movement througout the day, it can receive 10% (winter) and 40% (summer) more energy than fixed panels. Solar panels should always face true south in the northern hemisphere and should face north in the southern hemisphere. The winter season has the least available incident energy but in order to achieve the most energy, the solar panels must be oriented of the latitute of the location multiplied by .9 and 29 degrees added to it. Some examples of this are in table 1.1. Solar panels should be adjusted during the change of each "solar season." The solar season are as follows: Winter is from October 13th to Februrary 27th, Spring is from February 27th to April 20th, summer is from April 20th to August 22nd, and Autumn is from August 22nd to October 13th. The adjustment needed on the panels for maximum efficiency is as follows: for the spring and autumn seasons the tilt should be the latitute minus 2.5 degrees, and for the summer the optimum angle is 52.5 degrees less than the winter angle. See table 1.2 for examples of the adjustments (Landau, 2002).

Table 1.1: Winter Solar Panel Angle

Latitute	Angle	% of optimum
25° (Key West, Taipei)	51.5°	85%
30° (Houston, Cairo)	56°	86%
35° (Albuquerque, Tokyo)	60.5°	88%
40° (Denver, Madrid)	65°	89%
45° (Minneapolis, Milano)	69.5°	91%

(Landau, 2008)

Table 1.2: Spring, Summer, Autumn Solar Panel Angle

Latitude	Spring/Autumn angle	Insolation on panel	% of optimum	Summer angle	Insolation on panel	% of optimum
25	22.5	6.5	75%	-1.0	7.3	75%
30	27.5	6.4	75%	3.5	7.3	74%
35	32.5	6.2	76%	8	7.3	73%
40	37.5	6.0	76%	12.5	7.3	72%
45	42.5	5.8	76%	17.0	7.2	71%
50	47.5	5.5	76%	21.5	7.1	70%

(Landau, 2008)

Note 1: The % of optimum is based off of how well the angle orientation will do compared with the best possible tracker that always keeps the panel pointed directly at the sun.

Note 2: These calculations are based off ideal situations. This means that there is no obstruction of the sky, with no trees or clouds ever blocking the sun.

1.5 Solar Water Heating

Solar water heating systems are made up of two parts, the first being a solar collector and the second is a storage tank. Most solar collectors are made up of a thin, flat, rectangular box known as a 'flat-plate collector.' This flat plat collector has a transparent cover and usually sits on the south-side of the building. This collector has small tubes that run through the collector to an absorber plate; these tubes carry either water or antifreeze that will be heated. This absorber plate is painted black and continues to build up heat that will heat the fluid that runs through the tubes. The process of moving the liquid from the collector to the tank can be one of two methods, either a passive or active system. An active system involves using pumps to transfer the liquid from the collector to the tank. The other option, passive systems, depends on gravity to circulate the water as it is heated. The storage tank holds hot water that is ready for use.

1.6 Solar Energy Feasibility

There are a lot of variables to take into account when determining whether solar energy is technically and economically feasible for a home or building. A few factors that need to be determined are; the amount of energy that is used over the year by the building or home, the size of the roof, location of the building (this will be used to figure the tilt of the panel and solar radiance), if the roof is flat or pitched, and if the system can be connected to the energy grid. Once all of these factors are determined it is possible to do a feasibility check. The solar radiance at the buildings location is constant year to year and is already known. However, this does not take into account any trees, buildings or any other objects that may be obstructing the sun from reaching the building's roof. In order to do a more accurate evaluation there is device called the solar pathfinder that can help tell how much solar radiance a roof will get throughout the entire year.

1.7 Solar Pathfinder

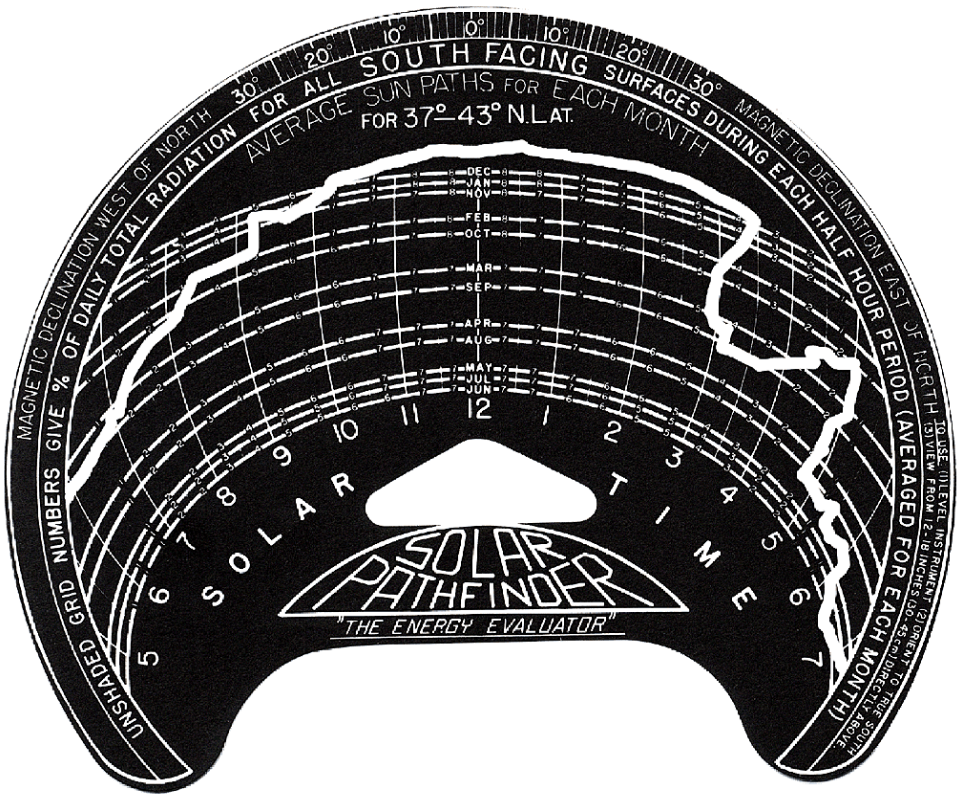
Figure 1.4: Solar Pathfinder

Above is a picture of a solar pathfinder. The solar pathfinder as well as the solar pathfinder assistant is manufacture by the Solar Pathfinder Company and is based out of Linden, TN. The device works by putting it up onto a roof and standing at the north side of the pathfinder (there is a compass on it). Hover directly over the pathfinder and take a picture of it (if the roof is small, one picture in the center of the roof is sufficient, if it is large a shot at all four corners might be necessary).

Figure 1.5: Solar Pathfinder Overhead

Above is a picture being taken from the north side, directly over the pathfinder. It can be seen that there are buildings that will be blocking some sunlight throughout the year. The reason that the picture is taken from the north is because a solar panel that would be installed here will be tilted down to the south, therefore anything that is being obstructed from the north is neglected. Once this process is finished, the pictures will be uploaded into the Solar Pathfinder Assistant. The Solar Pathfinder Assistant can tell how much sun is expected at this site and will also be able to say the exact month, day, hour and minute the panels will be receiving sun and also will tell the same for when the panel will not be receiving sunlight (Solar Pathfinder).

Figure 1.6: Solar Assistant



(Solar Pathfinder)

Above is a picture of a traced outline after the solar assistant has been used. This has all the months in the year and every hour in a day. For example, in the case study above it can be seen that in this location from 3pm to 4pm, from December to September, there is something obstructing the sun and little to no energy will be produced by the panels at this specific time.

1.8 Determining costs

When figuring out the costs of a solar panel system, there are many different terms that need to be understood and determined, including Net Capacity Factor (NCF), Simple Payback and Net Present Value.

The net capacity factor determines the ratio of actual power produced at a site as compared to the amount of energy that could potentially be produced at full sun for a duration of time. When investigating net capacity factors for different areas in the country, Connecticut has an average net capacity factor of approximately twelve or thirteen percent, while in Arizona the average is approximately nineteen percent (Laumer, 2008). The comparable net capacity factors demonstrate that although Massachusetts would not be as efficient in terms of energy production, the differences in climate do not have an overly dramatic impact on the net capacity factor.

$$NCF = \frac{Net\ Actual\ \ Generation}{(Period\ Hours\ *\ Max\ Capacity)}$$

The Simple Payback calculation determines how long it will take for a home or building to make back all of the money they initially invested on the installation. This figure is a preliminary estimate of whether the investment is worth making. The smaller the simple payback is, the better the investment. Although this simple payback does not take into account inflation and the cost to barrow money (if necessary).

$$Simple\ Payback = \frac{Energy\ Costs\ Savings}{Initial\ Cost}$$

The Net Present Value (NPV) of a solar project quantifies how much a project is currently worth. This includes the initial costs for the project as well as the current amount of money saved from electricity production.

Eq 1.1: Net Present Value

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

Where:

t - the time of the cash flow

N - the total time of the project

r - the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)

C_t - the net cash flow (the amount of cash) at time t (for educational purposes, C_0 is commonly placed to the left of the sum to emphasize its role as the initial investment.)

The following equations will help one to find the feasibility check for a home or building.

Eq 1.2: Estimated KW Production

$$\textit{Estimated KW Production} = \frac{40\%\ \textit{Roof Area}}{6.3m^2 / KW}$$

Eq 1.3: Approximate Number of Panels

$$\textit{Approximate Number of Panels} = \frac{40\%\ \textit{Roof Area}}{16.3m/panel}$$

Eq 1.4: Annual Net Capacity Factor

$$\textit{Annual Net Capacity Factor} = \frac{\textit{Actual AC Power with Shading}}{0.195KW \times \textit{Approximate Number of Panels} \times 8760\ hrs/yr}$$

Eq 1.5: DC Watt Production

$$DC\ Watt\ Production = \frac{\left(\frac{Actual\ AC\ \ Power\ with\ Shading}{0.8}\right) \times 1000\ W/KW}{8760 hr/yr}$$

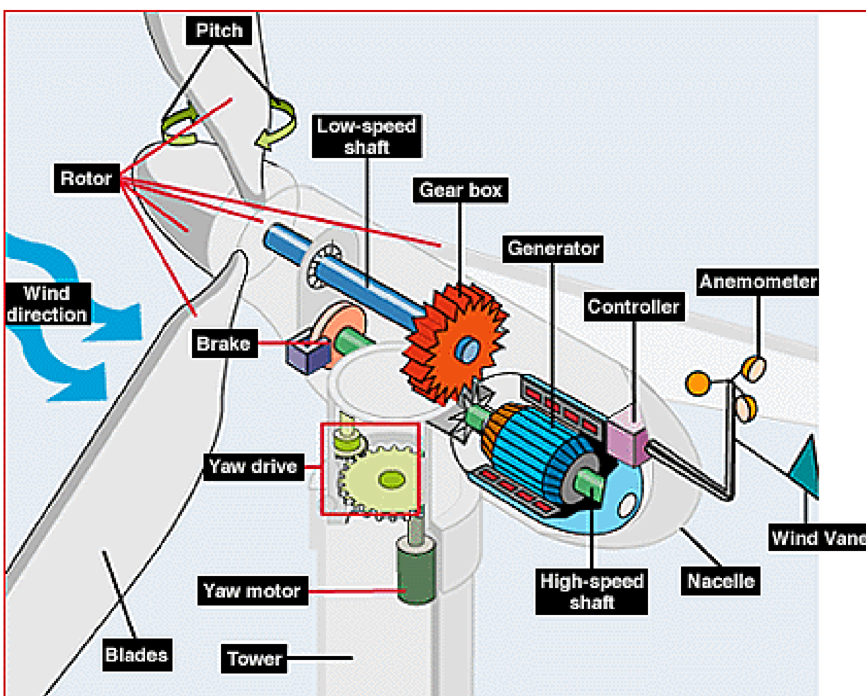
Using the formulas above help define feasibility formulas below. The variables that need to be known are energy used/ year, the average annual incident radiation, I, in specific area and size of roof usable for panels.

2: WIND ENERGY

2.1: Background

Electrical energy may be created from wind energy with a wind turbine. A wind turbine is made up of multiple blades that are fixed to a rotor. The wind turns the blades around the rotor which in turn creates electricity. The rotor is connected to a metal tower that has a sturdy base. Wind turbines come in different sizes depending on the demand of energy. The larger the turbines and the higher in elevation they are located the more electricity will be produced because the wind is generally faster and circulates in a more consistent direction as altitude is increased.

Figure 2.1 Wind Turbine Mechanics



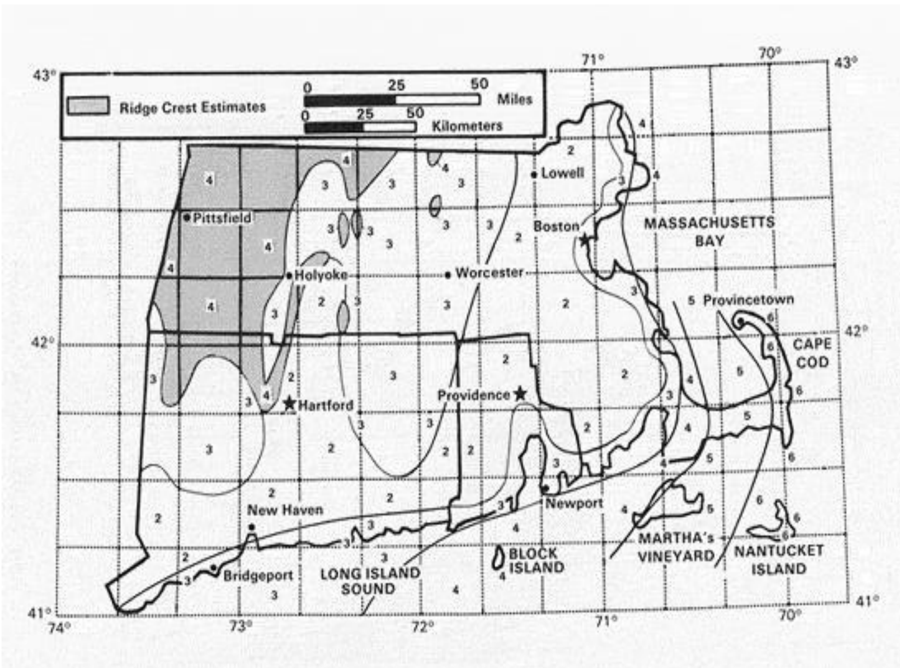
(Wind and Hydropower Technologies Program: How Wind Turbines Work, 2006)

Wind energy is one of the cheapest renewable energies. It generally costs between 4 – 6 cents per kilowatt hour (KWH) to operate and receive capital costs. There is also an abundant amount of energy available from wind. Wind energy does not emit any green house gasses when operational and is not depended on foreign fossil fuels. Unlike solar panels, a wind turbine generates AC electricity which means it can be directly put in the energy grid without an inverter. Solar panels create DC electricity that needs to be converted to AC electricity. A disadvantage to wind power is a fairly large initial capital expenditure is needed to purchase and construct a turbine. Also, when the wind isn't blowing there won't be any electricity generated. Once the wind is blowing there is a low constant sound that can bother the public. Another disadvantage is something known as the flicker affect. When the turbine spins with the sun shining down on it, the turbine casts a flicker like shadow down on the ground. If the turbine is a residential area the flicker can bother people by casting a constant flicker. With capital not being an issue, the best places for wind turbines with minimum to zero disadvantages are rural areas and farms. (Wind and Hydropower Technologies: Advantages and Disadvantages of Wind Energy, 2005)

2.2 Wind Power in Connecticut:

The map below shows the different wind classes in each region. This is just a generalization, for local areas the wind class could be larger or smaller depending on the specific area and weather.

Figure 2.2: Wind Map Class



(Massachusetts Wind Map)

2.3: Wind Classes

The reason one would use these generalizations for a feasibility check is so that there can be an approximation of how much wind a turbine might receive over the course of a year. If the check is still unclear, one will need a more precise wind reading for the specific location. A wind monitor will be needed and placed at the precise location of the possible wind tower.

Figure 2.3: Wind Monitor

200-05305 Wind Monitor-AQ

(200-05305 Wind Monitor-AQ, 2008)

The wind monitor above can calculate winds up to 112 mi/hr with an error of only 0.4 mi/hr. This monitor also calculates the wind direction within 3°. Table 2.1 defines what a wind power class is. Each wind power class should span two power densities. For example, Wind Power Class = 3 represents the Wind Power Density range between 150 W/m^2 and 200 W/m^2. The offset cells in the first column attempt to illustrate this concept.

Table 2.1: Wind Power Classes

Classes of wind power density at 10 m and 50 m [(a)].				
Wind Power Class*	**10 m (33 ft)**		**50 m (164 ft)**	
	Wind Power Density (W/m^2)	**Speed [(b)] m/s (mph)**	**Wind Power Density (W/m^2)**	**Speed [(b)] m/s (mph)**
1	0	0	0	0
	100	4.4 (9.8)	200	5.6 (12.5)
2				
	150	5.1 (11.5)	300	6.4 (14.3)
3				
	200	5.6 (12.5)	400	7.0 (15.7)
4				
	250	6.0 (13.4)	500	7.5 (16.8)
5				
	300	6.4 (14.3)	600	8.0 (17.9)
6				
	400	7.0 (15.7)	800	8.8 (19.7)
7				
	1000	9.4 (21.1)	2000	11.9 (26.6)

(a) Vertical extrapolation of wind speed based on the 1/7 power law.

(b) Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions.

(NREL, Wind Map)

Wind speed changes as elevation changes and the average wind speed increases with height as the 1/7th power. An equation to show this is $v_2/v_1 = (h_2/h_1)^{1/7}$ (Sustainable energy, 622). A turbine that is put at 90 feet vs. a turbine put at 50 feet might get a lot of extra power. Using that formula the turbine at 90 feet will get an average higher speed by 8.8% than the turbine used at 50 feet. What that means in power is that the higher turbine can generate up to 28.6% more electricity than the lower turbine due to power varying as velocity cubed. This formula is ideal for a smooth plane surface however the flow of wind above hills does not follow this formula. Other areas such as crests of treeless hills are great but do not necessarily follow the 1/7th power rule. When dealing with multiple turbines one must take into affect how each turbine will alter the wind flow for other turbines. Generally, a few units that are adjacent to each other will only power 82% of what one turbine powers when standing alone. Utility companies need to take this into account when building a wind turbine power plant because the original wind that is analyzed from the wind monitor is accurate but will be altered when more than turbine is present.

Air density also plays a large role when determining the power generated by a wind turbine. More dense air creates more power than less dense air. This can be found true in the wind quality formula that defines the power per unit area transported by a fluid system. (Tester et al, 2005)

Eq 2.1: Power per unit area

$$P''(v) = (\rho / 2)v^3)$$

Above shows that power per unit area is proportional to air density.

2.4: Wind Turbine Efficiency

When looking at wind turbine efficiency the power of the turbine is proportional to the force of the turbine blades. The force of the blades is equal to the total area the blades cover (A_t) times the air density (ρ) times the velocity of the wind as it hits the blades (v_t) times the difference of the upstream velocity and downstream velocity ($v_u - v_d$). Upstream velocity is the speed of the wind moving towards the turbine and the downstream velocity is the speed of the wind after it has moved through the turbine. This gives us the equation;

Eq 2.2: Force produced by the blades

$$F = \rho A_t v_t (v_u - v_d)$$

The power produced by the blades is the force times the velocity;

Eq 2.3: Power produced by the blades

$$P = \rho A_t v_t^2 (v_u - v_d)$$

In optimal conditions V_t, V_u and V_d are all in proportion to each other. V_d= 1/3 V_u= ½ V_t. This shows us that 2/3 of the winds speed was taken up by the turbine.

The powers of different wind turbines in the New England area:

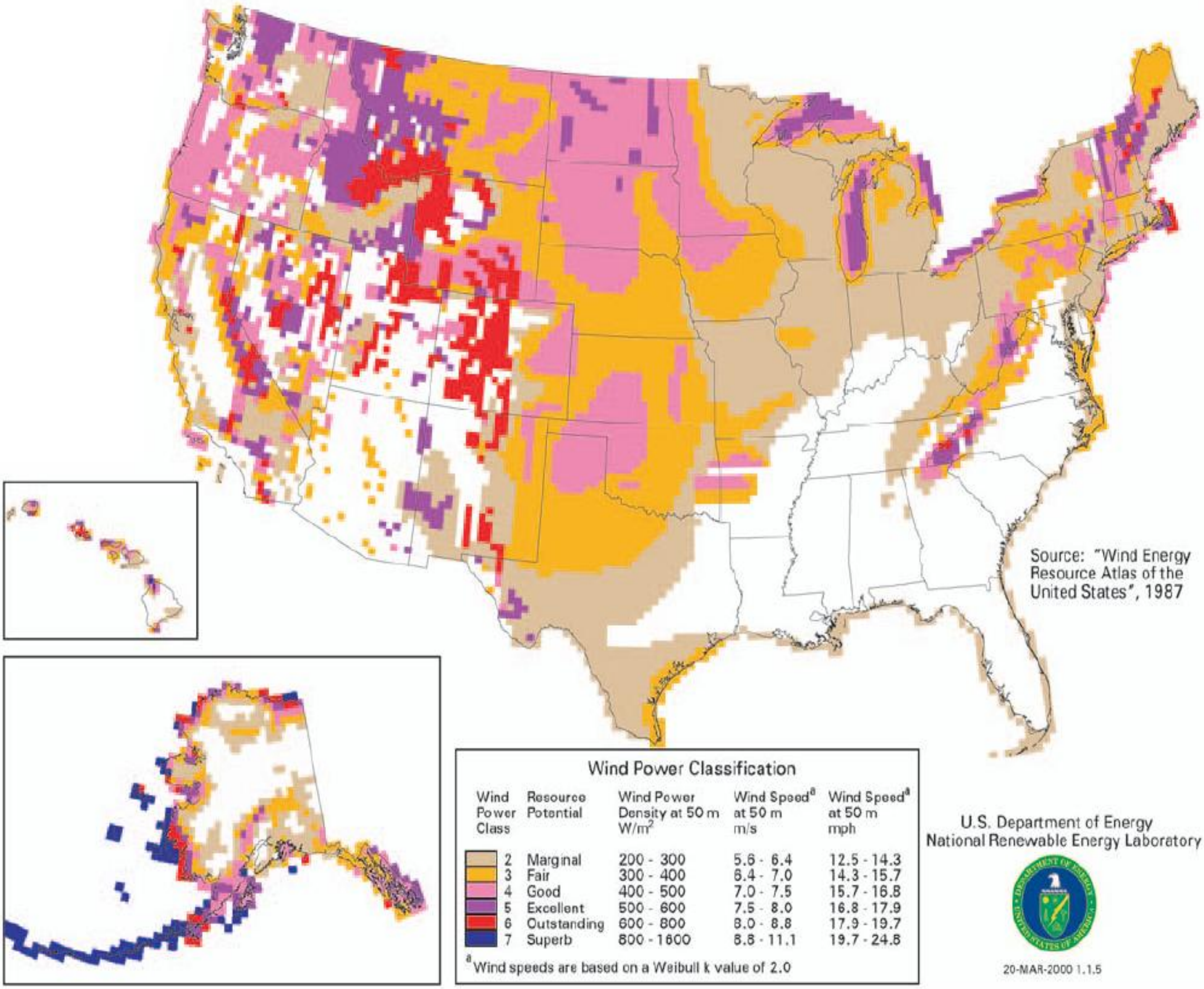
Known averages per year- Wind speed = 4.3 m/s at 10 m from ground or 9.619 mph at 32.808 ft

Temperature- 8.3 °C or 46.94° F.

Atmospheric Pressure= 97.9 kPa (Ret screen International)

With this information we can determine the force and power of different sized wind turbines using the formulas above (2.2 and 2.3) and also the 1/7th power theory $v_2/v_1 = (h_2/h_1)^{1/7}$ that was explained above. Knowing the wind speed at a specific height and the air temperature and atmospheric pressure we can look at the power output of a few different sized wind turbines.

Figure 2.4 US Wind Power Classifications



(Wind Energy Resource Atlas of the United States, 1987)

2.5: Wind Energy Feasibility

Germany, United States, and Spain are the top three countries that generate the most amount of wind power. There is huge push for wind power in the future for our world. Wind power plants will play a large part in energy sources to come in the future.

There are many variables to take into account when determining whether wind energy is feasible and makes economic sense for a home or building. The first factor that needs to be determined is the amount of energy that is demanded. With this information it will give one an idea on how large the wind mill needs to be. When installing a wind turbine, it needs to be determined whether or not one wants to be connected to the energy grid. The energy grid is a way for an electricity company to supply or take away energy from a house as it is needed for that house. The benefits of being connected to the grid with a wind or any energy generator is that when the wind creates an excess amount of energy that is not needed for the building, and will be put back on the energy grid and in the end the electricity supplier will pay for that excess energy. Essentially, by being on the grid, little energy is lost because the energy is being used instantaneously by the building and others on the energy grid. Disconnecting from the energy grid makes one self sufficient. The advantage to being off the grid is that one is not dependent on electricity companies. An issue with being off the grid is storing the excess energy. Wind doesn't consistently blow to move the turbines therefore energy will not be provided at all times. However when there is an excess of energy provided by the turbine, it will be stored for later use. Energy storage has been a consistent problem in this world. Yes, energy can be stored, but energy is also lost in the storage process.

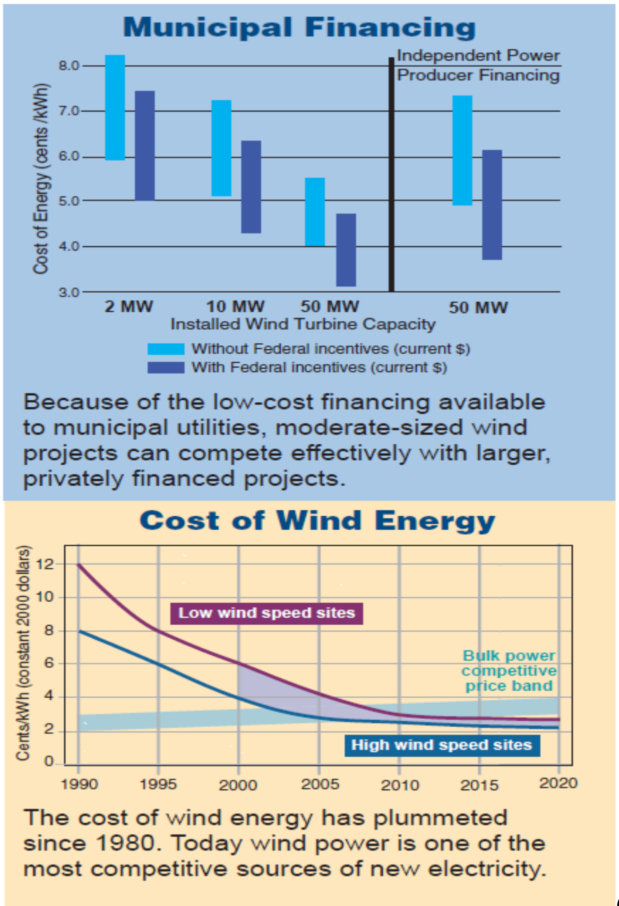
2.6: Rated Power

There are different sizes of turbines that have a certain rated power. Rated power is the power output of a device under specific or nominal operating conditions (RATED POWER). To understand what size turbine a building needs, one will need the energy used in the building. From here the rated power can be found and in turn the size of turbine can be determined. The formula that can be used is by taking rated power (RP) and multiplying it by the Rough Capacity Factor (RFC) which the rated power, times 24 hours, times 30 days, and provides the amount of energy produced per month. The average Rough Capacity Factor is approximately 30%, (this number varies as location varies). So if the building needs 100,000 kWh per month then the formula will be RP * RFC * 24hr * 30 Days = 100,000 kWh (Electricity used per month). Solve for Rated Power; 462 kw system is needed or a 500 kw system for RCF=30%. This formula assumes the RCF and does not take into account variables that can affect the rated power.

2.7 Wind Power Costs

Smaller wind turbines have a smaller initial cost than a larger turbine however it has been determined that the larger turbines have a less expensive kWh the smaller turbines. As the size of the turbine increases the more cost effective the turbine becomes. There are many variables when determining how much a wind turbine will initially cost and how long it will take until the investment pays itself off. The payback period is dependent on the system, wind speeds at turbine location, costs of electricity, government incentives and green energy credit worth.

Figure 2.5: Cost of Wind Energy



(NREL,2008)

Table 2.3: Small Wind Turbine Costs

Comparison	**Small Wind Turbine Category**		
	Battery Charging & Light Seasonal Loads	**Residential & Heavy Seasonal Loads**	**Commercial, Institutional, Farm, Remote Community**
Typical Power Rating	300 to 1,000 W (0.3 to 1 kW)	Above 1 kW to 30 kW	Above 30 kW to 300 kW
Average Capital Cost of Turbine only per unit Power	$2,800/kW	$3,000/kW	$2,200/kW
Average Total Installed Cost per unit Power	$5,000-$6,400/kW	$6,000/kW	$3,300/kW
Average Annual Operations & Maintenance (O&M) Cost	$40-130/yr	$1,150/yr	$3,300/yr
Typical Installation by	User	Professional	Professional
Typical Lifetime	10-15 yrs	20 yrs	25 yrs with major component replacement typically after 15 yrs
Comments		Larger machines in this range may require a crane to raise/lower, making more difficult and costlier to maintain than smaller turbines	Requires crane to raise/lower, making more difficult and considerably costlier to maintain on rough terrain or in remote areas

(CanWEA: SmallWind: Costs)

Turbine costs differ depending on turbine size. A turbine with a rated power of 1 MW can range from $1.2 million to $2.6 million. Turbines with a rated power under 100 kilowatts cost approximately $3,000 to $5,000 per year kilowatt.

3. Biomass Technologies

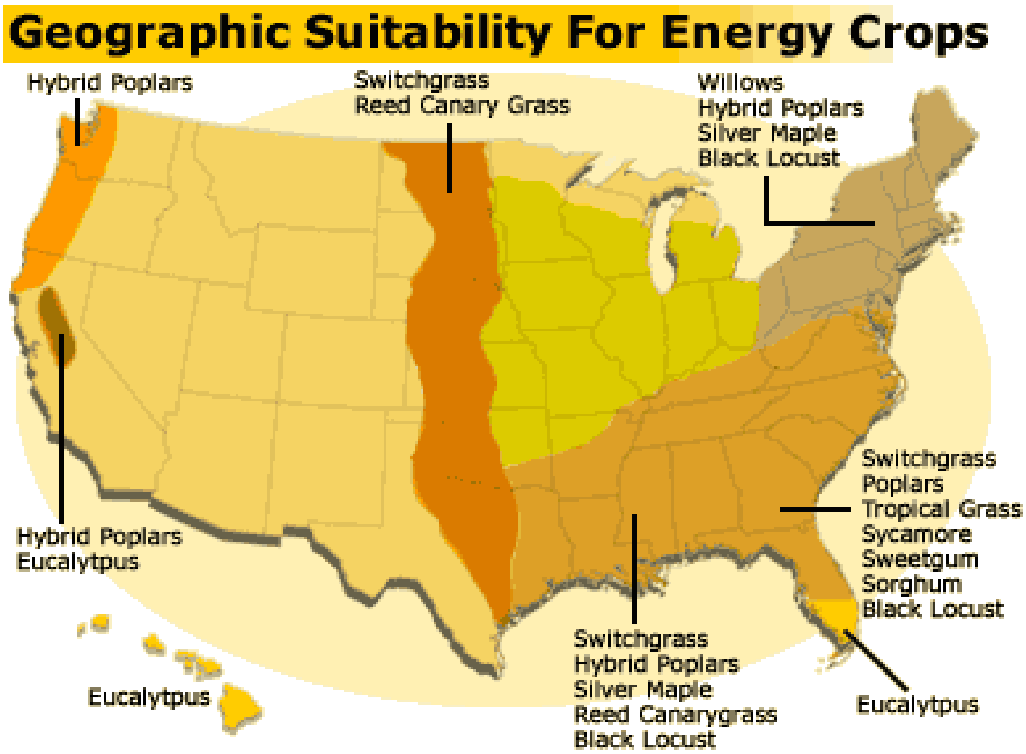
3.1 Background

As a renewable energy biomass involves using the sun's energy through the process of photosynthesis. Photosynthesis involves the chlorophyll in plants to absorb the sun's energy by taking the carbon dioxide in the air and the water in the ground and turning it into carbohydrates. When these carbohydrates are combusted for heat energy they are then turn back into water and carbon dioxide and with that release the sun's energy for use. This process is a constant cycle and will be around forever as long as this technology has sustainable development.

3.2 Energy Crops

Biomass is broken up into two different categories. The first is growing crops that are specific to energy use and the other is using residues from plants that are used for other purposes. Certain factors affect which approach should be used such as climate, soil, and geography.   The energy crops are generally trees and grasses that can be grown in large amounts on generally large farms. Currently corn is used as an energy crop, but it is less sustainable than trees and grasses. Trees are generally harvested on a periodic basis. Specific climate conditions use certain types of trees. An example would be in the warmer southeast regions, sycamore and sweetgum trees are most effective. The types of grasses that are used depend on region as well as climate.   Throughout the prairie land of the Midwest switchgrass, and big bluestem grasses grow quickly and can be harvested for up to 10 years before replanting occurs. The crops that are used most for energy are crops that were grown for food, such as corn. These food crops must be replanted every year and thus require more attention than the tree's and grasses. Figure 3.1 shows what parts of the country are geographically suitable for which energy crops.

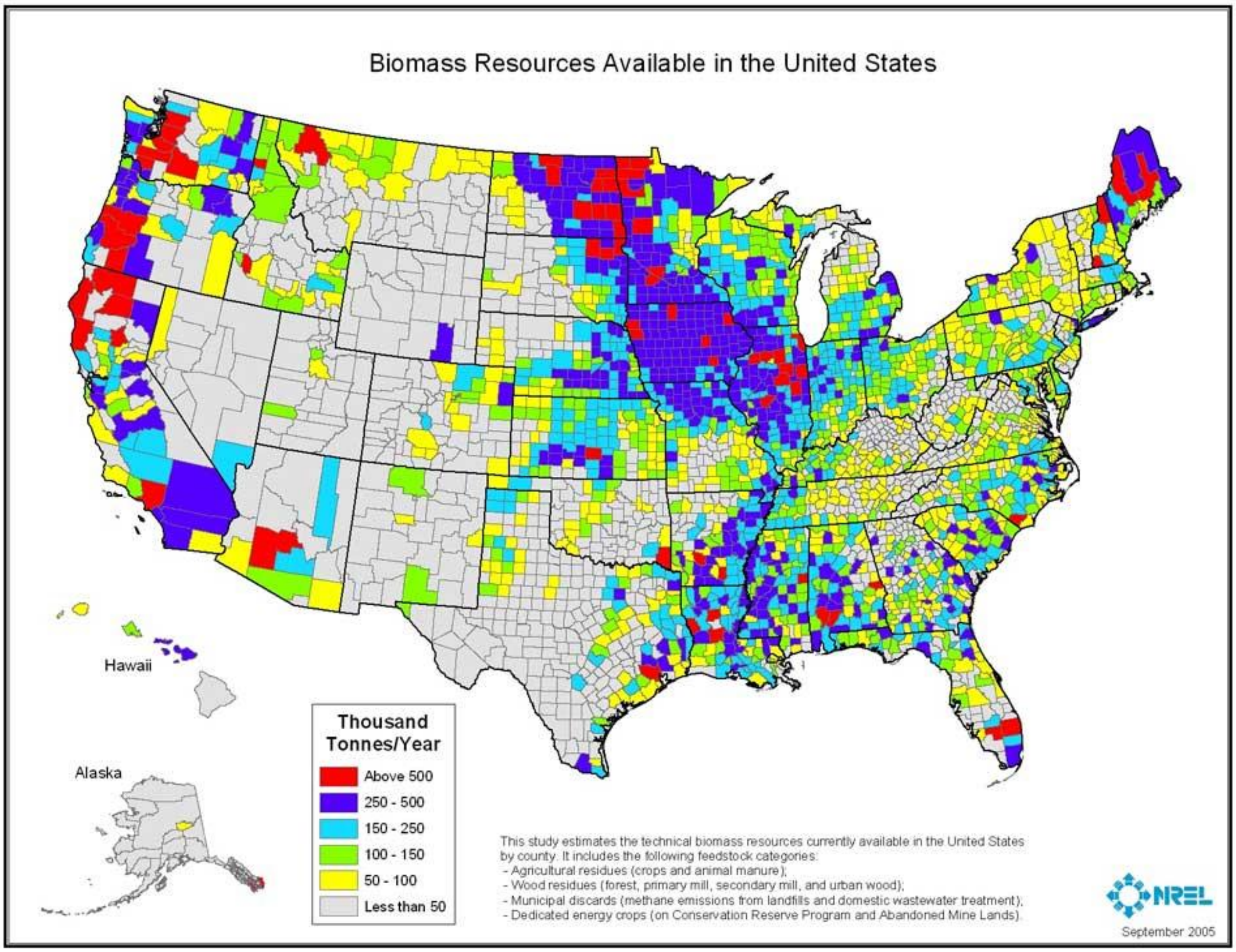
Figure 3.1: Geographic Suitability for Energy Crops



(http://www.cbsnews.com/htdocs/energy/renewable/map_bioenergy_image.html)

The biomass residue uses the leftover waste when its initial use is finished and uses it for energy. It is broken up into three categories; forestry, agriculture and cities. Forestry waste is the largest source of heat and electricity. A large source of forestry waste is tree tops and branches left over from when lumber companies chop down the trees. Another large source of wood waste is from sawmills or anywhere that produces sawdust or wood shavings. The agriculture industry produces its usable waste in the form of manure. Another is when crops are made into food they create a lot of usable waste. As a society we produce a great deal of usable waste. This can be in the form of garbage such as paper or food. Sewage treatment plants also create energy through the process of capturing methane that is given off by the sewage and then burning it into heat and power. Figure 3.2 shows the biomass that is available throughout the United States. (Larson, 2006)

Figure 3.2: Biomass Resources Available in the United States



(Dynamic Maps, GIS Date, & Analysis Tools, 2008)

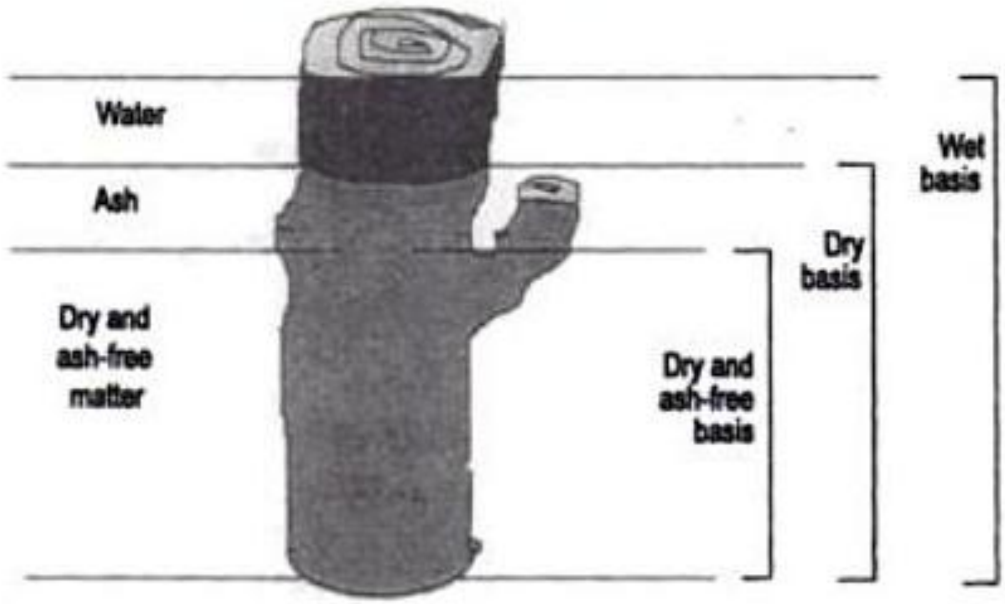
3.3 Biomass Properties

Throughout history the process of converting biomass to energy has been through burning the biomass to create heat. This heat can be used to cook, produce electricity, or heat buildings. Although this causes a lot of wasted energy and produces pollution.

Every type of biomass has certain properties that determine how well it performs as a fuel in either combustion or gasification processes. The most important properties during this thermal conversion process are; moisture content, ash content, volatile matter content, elemental composition, heating value, and bulk density.

The moisture content in biomass is the amount of water in the material. This is expressed as a percentage of the material's weight. The weight of material is referred to on a wet basis, dry basis, and on a dry and ash free basis. The difference between the three is that the wet basis is expressed as a percentage of the sum of the weight of the water, ash, and dry and ash free matter. The dry basis is the expressed as a percentage of the sum of the ash and the dry and ash free matter. Lastly for the dry and ash free matter the water weight is related to the weight of the dry biomass. The basis of which the biomass moisture content is measured must always be mentioned. This is because the moisture content affects how the biomass will perform as a fuel and also because moisture content has a wide range of values. Such as for cereal grain straw, the wet basis moisture content is less than 10 percent where it is 50 to 70 percent for forest residues. Figure 3.3 shows typical biomass composition.

Figure 3.3: Biomass Ash Content



(Quaak, 1999)

The ash content is expressed in the same form as moisture content, with the wet, dry, or dry and ash free basis. For the most part it is expressed on a dry basis. The composition of the ash affects its behavior under the high temperatures of the combustion and gasification processes.

Volatile matter content is what is released from the biomass when it is heated. The temperature is usually around 400 to 500 degrees. When biomass is heated it is decomposed into volatile gases and solid char. Volatile matter is around 80% for a most biomass compared to around 20% for coal.

The elemental composition of biomass is relatively uniform. The major components include carbon, oxygen, and hydrogen. Also nitrogen and sulfer have a small weight percentage. Table 3.1 shows the elementary composition of typical biomass.

Table 3.1: Elemental Composition of Typical Biomass

Element	*Symbol*	*Weight percent (dry and ash-free basis)*
Carbon	C	44–51
Hydrogen	H	5.5–6.7
Oxygen	O	41–50
Nitrogen	N	0.12–0.60
Sulfur	S	0.0–0.2

(Quaak, 1999)

The heating value is an indication of the energy chemically bound in the fuel with reference to a standardized environment. Temperature, state of water (whether it is gas or liquid) and the combustion products (CO,H_2O) are the standard conditions in the environment. The energy that is chemically bound in the fuel is determined by the heating value of the fuel in energy (J) per amount of matter (kg). This energy cannot be measure directly, only referenced. The best known references are the lower heating value, LHV, and higher heating value, HHV. For the LHV the reference state of water is its gaseous state, while for the HHV the reference state of water is its liquid state.

Bulk density is the weight of material per unit of volume. The bulk densities in biomass range from 150-200 kg/m^3 in cereal grains to 600-900 kg/m^3 in solid wood. Energy density can be determined from the bulk densities and the heating values. The energy density is the potential energy available per unit volume of the biomass. Although biomass energy densities are approximately one-tenth of fossil fuels like petroleum. (Peter Quaak, Energy from Biomass, 1999)

Table 3.2 shows a summary of some of the mentioned characteristics in typical types on biomass fuels.

Table 3.2: Characteristics of Biomass Fuels

Type	*LHVw (kJ/kg)*	*MCw (%)*	*ACd (%)*
Bagasse	7,700–8,000	40–60	1.7–3.8
Cocoa husks	13,000–16,000	7–9	7–14
Coconut shells	18,000	8	4
Coffee husks	16,000	10	0.6
Cotton residues			
Stalks	16,000	10–20	0.1
Gin trash	14,000	9	12
Maize			
Cobs	13,000–15,000	10–20	2
Stalks			3–7
Palm-oil residues			
Fruit stems	5,000	63	5
Fibers	11,000	40	
Shells	15,000	15	
Debris	15,000	15	
Peat	9,000–15,000	13–15	1–20
Rice husks	14,000	9	19
Straw	12,000	10	4.4
Wood	8,400–17,000	10–60	0.25–1.7
Charcoal	25,000–32,000	1–10	0.5–6

LHV=lower heating value MC=moisture content AC=Ash content

(Quaak, 1999)

3.4 Conversion to Electricity

Biomass can be converted into many forms of energy including heat, electricity and fuel. This conversion is broken up into two categories: thermochemical and biochemical. Thermochemical is broken down even further into direct combustion, gasification and pyrolysis. Biochemical breaks into anaerobic digestion and fermentation. Figure 3.4 shows the typical conversion routes for biomass.

Figure 3.4: Biomass Conversion Routes

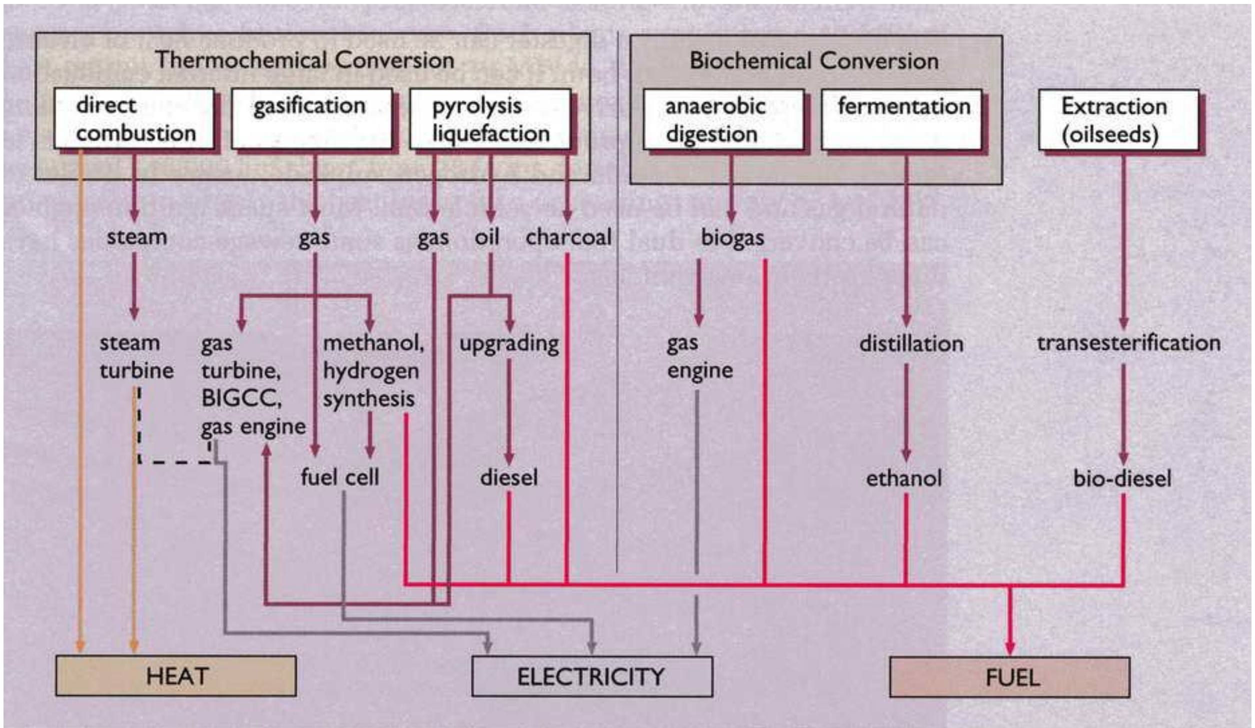


Figure 4.13 Main bioenergy conversion routes

(Zafar, 2008)

3.4.1 Combustion

Combustion is the most direct and fundamental process when converting biomass to electricity. Biomass needs to be heated to at least 550°C for combustion to take place. In simplest terms biomass only needs ignition along with sufficient air supply for combustion to take place, although it is not that simple with the need to meet current emissions and efficiency standards.

During combustion a number of stages take place. The first is drying which involves evaporation of the contained water. Next is pyrolysis and reduction which is the thermal decomposition of the fuel into volatile gases and solid char. From here the volatile gases that are produced during the pyrolysis and reduction are burned above the fuel bed, and show yellow flames. Also the solid char is combusted in the fuel bed and it produces a small blue flame or glowing of char pieces.

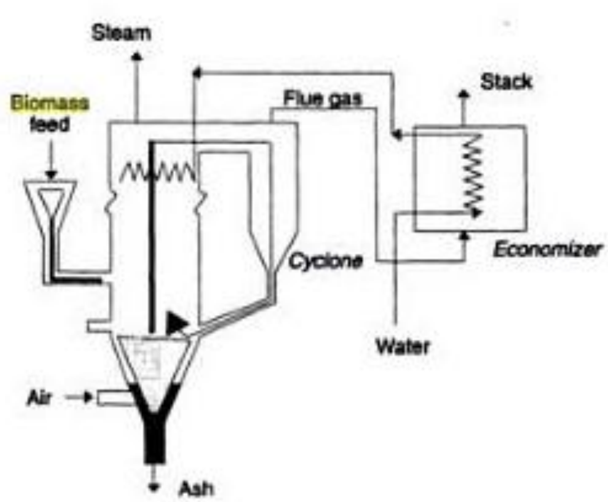
The actual process of combustion takes place in the furnace and what happens is chemically bound energy in the fuel is converted to thermal energy. The thermal energy is available in the form of hot flue gas, and the rest of the energy created is lost. Some of this lost energy can be attributed to the heat lost to the environment through the furnace walls or in the release of hot ash. The efficiency of the furnace is defined in Eq 3.1.

Eq 3.1: Efficiency of the Furnace

$$\eta = \frac{thermal\ energy\ available\ in\ the\ flue\ gas}{chemical\ energy\ in\ the\ \sup plied\ fuel}$$

The two types of furnaces for combustion systems are fixed bed or fluidized bed. Fixed bed systems, in the simplest form, consist of a grate in a combustion room, which is the furnace. Primary air which is used for the combustion of the char is supplied under the grate. Secondary air is used for the combustion of the volatile gases and is located above the grate. The combustion of the char on the grate provides the heat for the continuing pyrolysis of newly added fuel above the char. The typical combustion temperatures in the grate range from 850° to 1,400°C. For years, all ash was removed by hand but, new automatic ash removal systems have become available. In a fluidized bed system the biomass is burned in a bed of sand, limestone, or another noncombustible material at a temperature range of 700° to 1,000°C and is kept in turbulent suspension by fans. A typical fluidized bed system has a combustion chamber which contains a sand bed that acts as a heat-transfer medium. This sand bed is fluidized by blowing air through a perforated bottom plate, which forces the sand upward. The heat exchange rates during this process are high and complete combustion can be realized using low excess air factors. (Peter Quaak, Energy from Biomass, 1999)

Figure 3.5: Typical Fixed Bed System



(Quaak, 1999)

3.4.2 Gasification

Gasification is the process that converts biomass into carbon monoxide and hydrogen. This is done through reacting the biomass at a high temperature, 800° to 1000°C, along with a controlled (usually none or very small) amount of oxygen, and results in syngas. Syngas, short for synthetic gas, is a gas mixture that contains varying amounts of carbon monoxide and hydrogen, and is used as a fuel. Gasification is potentially more efficient than combustion of the same biomass material due to if using gasification it can be combusted at a higher temperature which means Carnot's efficiency rule is higher or not even applicable. Carnot's rule is defined in Eq 3.2.

Eq. 3.2: Carnot's Rule

$$\eta_{th} \equiv \frac{W_{out}}{Q_{in}}$$

When using gasification, the upper limit (W) is higher resulting in higher efficiency. Also when using higher temperatures corrosive ash elements, like chloride and potassium, are eliminated allowing for a cleaner gas production. There are currently four types of gasification units for commercial use: counter-current fixed gasifier, co-current fixed bed gasifier, fluidized bed reactor, and the entrained flow gasifier. (Zafar, 2008)

3.4.3 Pyrolysis

Pyrolysis is another way of converting biomass to fuel. Pyrolysis is thermal degradation with either none or a limited supply of an oxidizing agent. It works on a lower temperature than gasification, 500° to 800°C, where as stated before gasification is around 800° or 1000°C. Three products are usually produced; gas, pyrolysis oil and charcoal. In order to reach the high yields of liquid biomass it must undergo fast pyrolysis. (The reaseach progress of biomass pyrolysis processes) This process is characterized by rapid heating of the biomass particles and a short resistance time of product vapors, usually .5 to 2 seconds. Since it is a rapid heating process, the biomass must be ground into small fine particles and, the char layer that forms at the surface of the reacting biomass must be continually removed. There are several methods that provide heat for the reaction; one is partial combustion through an air injection, another is direct heat transfer with a hot gas but it is a problem to provide enough heat with a reasonable gas flow-rate. Two of the most used technologies for using pyrolysis are using a fluidized bed and a circulating fluidized bed. In a fluidized bed biomass particles are introduced into a bed of hot sand fluidized by a gas, which is usually a re-circulated product gas. Heat is usually provided by heat exchanger tubes through which hot combustion gas flows. There is some dilution of the products, which makes it more difficult to condense and then remove the bio-oil mist from the gas exiting the condensers. In a circulating fluidized bed biomass particles are introduced into a circulating fluidized bed of hot sand. Gas, sand and biomass particles move together, with the transport gas usually being a re-circulated product gas. High heat transfer rates from sand ensure rapid heating of biomass particles and ablation is stronger than with regular fluidized beds. A fast separator separates the product gases and vapors from the sand and char particles. The sand particles are reheated in fluidized burner vessel and recycled to the reactor. (The research of biomass pyrolysis processes)

3.4.4 Anaerobic Digestion

Anaerobic Digestion is another process that converts biomass into fuel and or electricity. Anaerobic digestion is a natural process that converts organic material into methane and carbon dioxide without oxygen. The process of anaerobic digestion produces three main products: biogas, fibre and liquor. Biogas is mixture of carbon dioxide and methane and it can be used to generate heat and or electricity, fibre can be used as a nutrient-rich soil conditioner and liquor can be used as a liquid fertilizer. This process takes place in a digester which is a warmed, sealed airless container. The digester tank is warmed and is mixed thoroughly to create the ideal conditions for biogas conversion. During this digestion process 30-60% of the organic material is converted into the biogas and from there it can be burned in a conventional gas boiler for heat. It can also be burned in a more efficient combined heat and power system (CHP), where heat and electricity can be generated. (Seadi)

3.5 Wood Pellets

Wood pellets seem to be the most feasible for all the different types of biomass materials for the Pomfre Connecticut town hall. Wood pellets are made from wood waste materials that are compressed into pellets under heat and pressure. Wood pellets have natural plant lingin which holds the pellets together without glues or additives. Wood pellets are of uniform size, about 1-1$^{1/2}$ inches and about 1/4 -5/16 inches in diameter, which makes them easy to store. Wood pellets have three different types of ash content: premium, standard, and industrial. Premium, which is ash content less than one percent, and standard, ash content between one and two percent, are the two prefered types of wood pellets due to the decrease in ash produced. Industrial is over three percent ash and should be avoided (Wood Pellet Heating, 2007).

4. GEOTHERMAL ENERGY

4.1 Background

Geothermal energy uses the thermal energy stored under the earth's surface. This stored thermal energy can be used in a few different ways however the most common way geothermal energy is used is to heat or cool a specific area.

4.2 Electricity Conversion Technologies

There are three main types of conversion technologies of turning hydrothermal resources into electricity and they include dry steam, flash steam and binary cycle.

4.2.1 Dry Steam

Dry steam is the oldest conversion technology, with the first power plant dating to over 100 years ago. This technology is particularly popular in areas where dry steam is prevalent such as at The Geysers in California. Dry steam power plants use very hot steam, greater that 235°C. The process works in that the steam produced directly from the geothermal reservoir runs the turbines that power the generator. Dry steam systems are, for the most part, simple with requiring only steam and condensate injection piping and minimal steam cleaning devices. The dry steam system requires: a rock catcher to remove large solids, a centrifugal separator to remove condensate and small solid particulates, condensate drains along the pipe-line and a final scrubber to remove small particulates and dissolved solids. The steam goes directly through a pipe to the turbine to spin a generator that produces the electricity (Shibaki, 2003). Dry steam plants make up around 40 percent of all the US geothermal electricity production and all plants are located at the Geysers in California. Figure 4.1 shows a typical dry steam power plant.

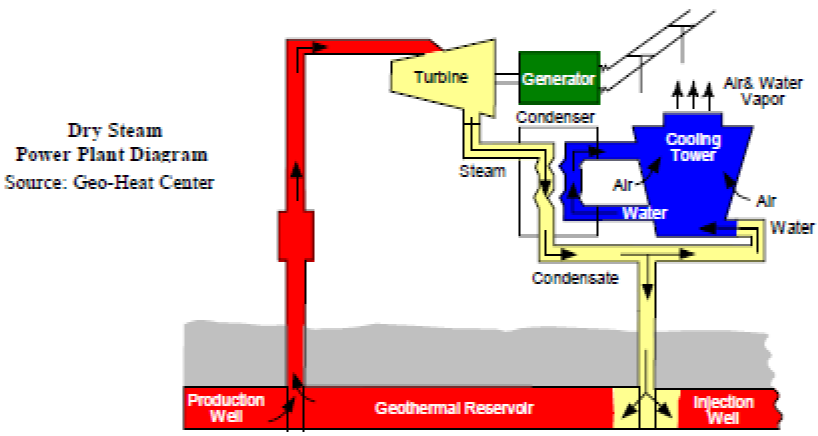
4.2.2 Flash Steam

Flash steam power plants are the most common type of power plant to convert geothermal energy to electricity. About 45 percent of geothermal electricity production in the US comes from flash technology. A flash steam power plant works in that hot liquid water from deep in the earth is under pressure and is kept boiling. When the hot water moves from deeper in the Earth to shallower levels, it quickly loses pressure, then boils and "flashes" to steam. The steam is separated from the liquid in a surface vessel (steam separator) and is used to turn the turbine and the turbine powers a generator that spins and produces the electricity. Flash power plants usually range from a temperature of 177 to 260 C. There are two types of flash technologies the first is the single flash, which was just described, and double flash. Double flash is more popular yet more expensive. Double flash uses a larger portion of the resources and is more effective due to it can concentrate the chemical components that exist in the geothermal water more efficiently. Figure 4.2 shows a single flash steam power plant, while figure 4.3 shows a double flash steam power plant.

4.2.3 Binary Cycle

The last conversion technology is binary geothermal plants. Binary works at moderate temperature of 107 to 182 C. Approximately 15 percent of all geothermal power plants use binary conversion technologies. The binary process is the geothermal fluid, which can either be hot water, steam or a mixture of the two, heats another liquid, known as the "working fluid", which can be either isopentane or isobutene, and the liquid boils at a lower temperature than water. The two liquids are kept completely separate through the use of a heat exchange that is used to transfer heat energy from the geothermal water to the working fluid. When heated, the working fluid vaporizes into gas and (like steam) the force of the expanding gas turns the turbines that power the generators. Geothermal fluids never actually make contact with the atmosphere before they are pumped back into the underground reservoir. Since the geothermal water never flashes in air cooled binary plants, 100 percent can be injected back into the system through a closed loop. This is important because this process serves a dual purpose of reducing already low emissions to near zero, and also maintain reservoir pressure and therefore extend the process continually. Figure 4.4 shows an example of a binary power plant. (Kagel, 2008)

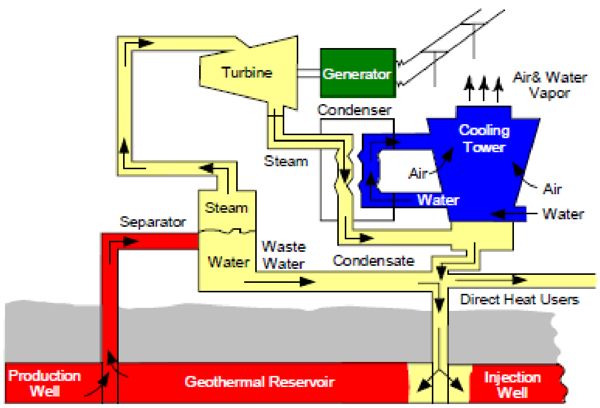
Figure 4.1: Dry Steam Power Plant

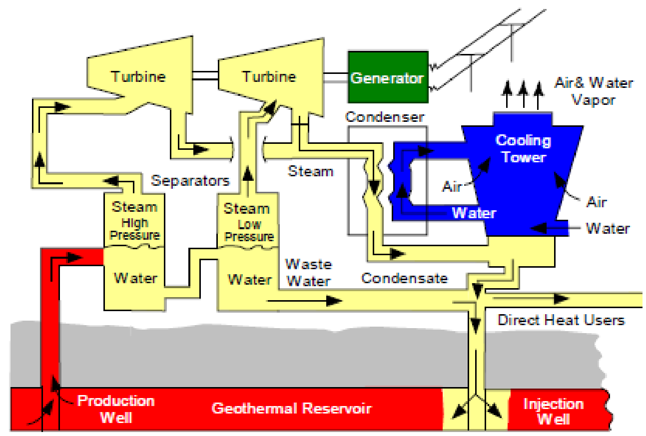


(Geo-Heat Center,2008)

Figure 4.2: Single Flash Steam Power Plant

Figure 4.3: Double Flash Steam Power Plant

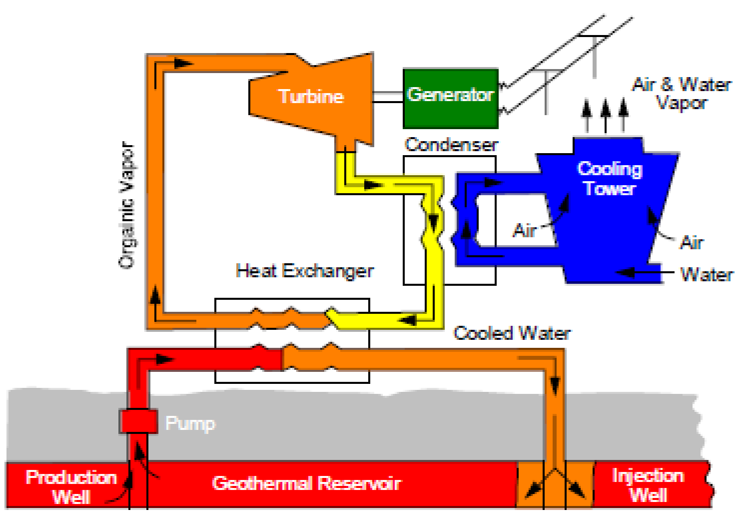




Source (Figures 28, 29): Geo-Heat Center

(Geo-Heat Center,2008)

Figure 4.4: Binary Power Plant



Source: Geo-Heat Center

(Geo-Heat Center,2008)

4.3 Ground Loop Systems

Geothermal heat pump systems are broken up into four basic types of ground loop systems. Three are closed loop systems and they include horizontal, vertical and pond/lake. The fourth type is the open loop option. All of these options can be used on residential and commercial buildings. The one that fits best depends on the climate, soil conditions, available land and local installation costs at the site.

4.3.1 Horizontal

The first of the closed loop is horizontal. This is generally the most cost efficient for residential installation, especially on new construction sites where sufficient land is available. It requires trenches that are at least four feet deep. The most common layouts either use two pipes, one buried at six feet and the other at four feet. Another common method is two pipes placed side-by-side at least five feet in the ground in a two foot wide trench. Another method of installation is The Slinky method, which requires looping the pipe. This allows for more pipe in a shorter trench, which cuts down on installation costs and makes horizontal installation possible in areas where it would not be available with usual horizontal installation. Figure 4.5 shows an example of this.

4.3.2 Vertical

Vertical closed loop systems generally are used at large commercial buildings and school because of the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching, and they minimize the disturbance to existing landscaping. Generally for vertical systems holes are drilled about 20 feet apart and are drilled down to anywhere from 100-400 feet. The holes that are drilled are roughly four inches in diameter. In these holes that are drilled are two pipes that are connected at the bottom with a U-bend to form a loop. The vertical loops are connected with horizontal pipe, are placed in trenches and connected to the heat pump in the building. Figure 4.6 shows an example of this.

If the location has an adequate water body, the pond lake loop system may be the lowest cost option. The pond lake loop system works by a supply line pipe is run underground from the building to the water and is coiled into circles at least eight feet under the surface to prevent freezing. The coils need to be placed in a water source that meets minimum volume, depth, and quality criteria's. Figure 4.7 shows an example of this.

4.3.3 Open Loop System

The open loop system uses wells or surface body water as the heat exchange fluid that circulates directly through the geothermal heat pump system. Once it has circulated through the system, the water then returns to the ground through a recharge well, or through surface discharge. The open loop system is only practical where there is an adequate supply of relatively clean water and all local codes and regulations regarding groundwater discharge have been met. Figure 4.8 shows an example of this. (Geothermal Technologies Program: Hydrothermal Power Systems, 2008)

Figure 4.5: Horizontal Closed Loop System

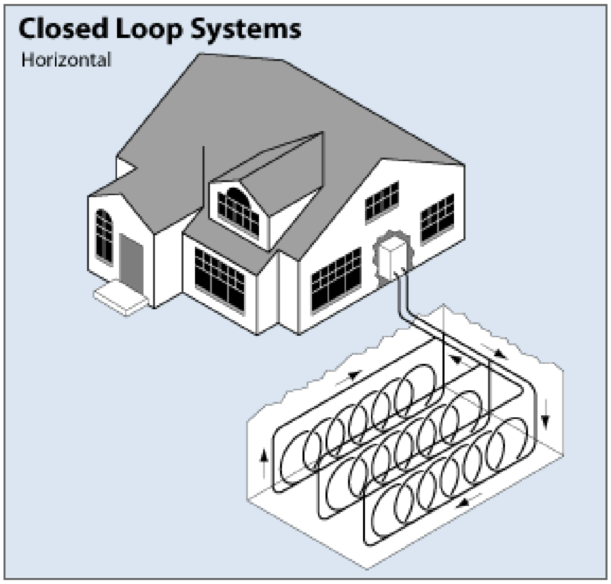


Figure 4.6: Vertical Closed Loop System

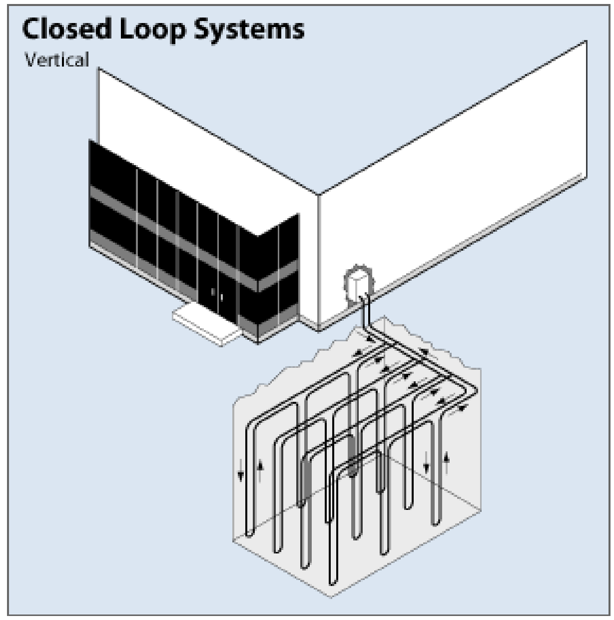


Figure 4.7: Pond Closed Loop System

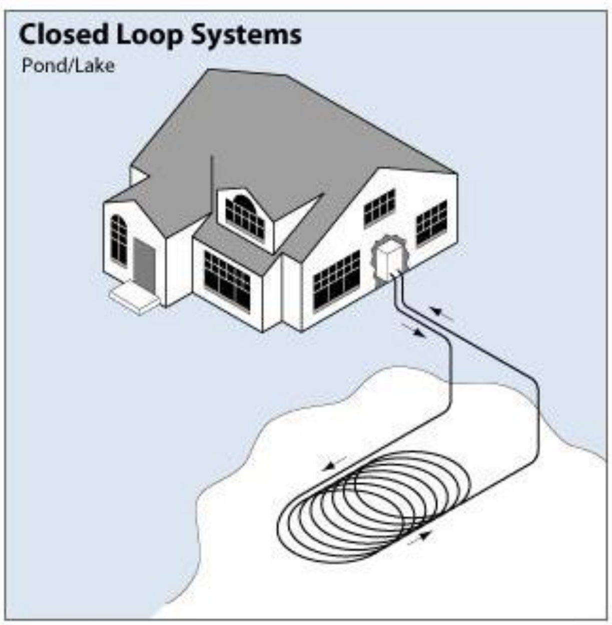
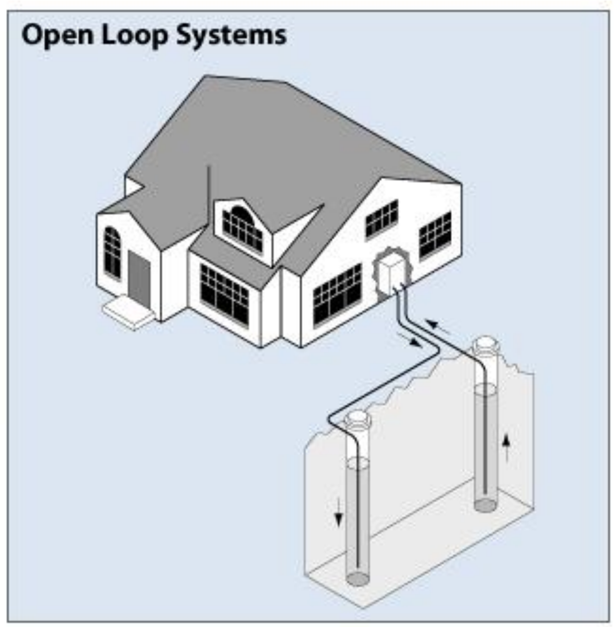


Figure 4.8: Open Loop System



(Types of Geothermal Heat Pump Systems, 2008)

5. Case Study: Pomfret, CT Town Hall

Our case study involved the town hall of Pomfret Connecticut. This is a small building which 32290 kwh of electricity a year as well as 2,460 total gallons of fuel oil in a year. Next to the building is open land which could be used to install a geothermal heat pump system, as well as a large roof, roughly a eight pitch, which could make for the use of solar panels. In the basement, the building is currently run on two 180,000 BTU boilers which would make for a relatively easy transition to biomass energy. Many trees and rough hill land would create a tough area to install a wind turbine. Below are the four analysis of each solar, wind, biomass, and geothermal which all provide a payback time period of when the owner will begin to make a profit on the alternative energy.

(Pomfret Connecticut)

5.1 Photovoltaic Energy Analysis

5.1.1 Is Solar Energy Right For Your Building?

With the equations below it can be found; the size of system needed to power your building, how much that system will cost, and how many years until the system payback its original investment.

5.1.2 Raw Data Needed

The raw data needed in order to calculate for the simple payback are; Kilo Watt Hours (kWh's) used per year, the average annual incident radiation in your area (Can be found by the National Renewable Energies Laboratory), size of roof (sq. m), and the current cost per KWH.

5.1.3 Assumptions Made

Due to these equations needing limited raw information there had to be some assumptions that affect the end result. We assumed (from research) the cost per watt of solar electricity is $9. We assumed that there are no trees or buildings would be blocking the sun from the panels throughout the day and finally that the panels have a 12% efficiency rate of producing power. Now that the assumptions are clear, if any of these change (like the efficiency) as research and development become better, the assumptions can be changed making the payback even more precise.

Solar Photovoltaic System

average annual incident radiation
(National Renewable Energy Laboratory)

$$I := 4.25 \quad \frac{kW \cdot hr}{m^2 \cdot day}$$

Panel surface area

$$A := 172 \quad m^2$$

panel efficiency

$$\varepsilon := .12$$

Energy produced in year

$$KWHproduced := I \cdot A \cdot \varepsilon \cdot 365$$

$$KWHproduced = 3.202 \times 10^4 \quad KWH$$

Power of system (in kw)

$$SystemSize := \frac{KWHproduced}{(365 \cdot 24 \cdot \varepsilon)}$$

$$SystemSize = 30.458 \quad kW$$

Cost of system ($9000 per kW from siemenssolar)

$$SystemCost := SystemSize \cdot 9000$$

$$SystemCost = 2.741 \times 10^5$$

Payback in years

$KWHused := 32290$ Per Year

$DollarPaidKWH := .19$

$ElectricBill := KWHused \cdot DollarPaidKWH$

$ElectricBill = 6.135 \times 10^{3}$ Dollars

$KWHproduced = 3.202 \times 10^{4}$ Per Year

$DollarsSavedWithSolar := (KWHproduced) \cdot DollarPaidKWH$

$BillWithSolar := ElectricBill - DollarsSavedWithSolar$

$BillWithSolar = 51.718$ Per Year

$$Payback := \frac{SystemCost}{DollarsSavedWithSolar}$$

$Payback = 45.061$ Years

Payback in years

$KWHused := 32290$ Per Year

$DollarPaidKWH := .238$

$ElectricBill := KWHused \cdot DollarPaidKWH$

$ElectricBill = 7.685 \times 10^{3}$ Dollars

$KWHproduced = 3.202 \times 10^{4}$ Per Year

$DollarsSavedWithSolar := (KWHproduced) \cdot DollarPaidKWH$

$BillWithSolar := ElectricBill - DollarsSavedWithSolar$

$BillWithSolar = 64.784$ Per Year

$$Payback := \frac{SystemCost}{DollarsSavedWithSolar}$$

$Payback = 35.973$ Years

Payback in years

$KWHused := 32290$ Per Year

$DollarPaidKWH := .285$

$ElectricBill := KWHused \cdot DollarPaidKWH$

$ElectricBill = 9.203 \times 10^{3}$ Dollars

$KWHproduced = 3.202 \times 10^{4}$ Per Year

$DollarsSavedWithSolar := (KWHproduced) \cdot DollarPaidKWH$

$BillWithSolar := ElectricBill - DollarsSavedWithSolar$

$BillWithSolar = 77.577$ Per Year

$$Payback := \frac{SystemCost}{DollarsSavedWithSolar}$$

$Payback = 30.041$ Years

The Payback with electricity costing \$ .19 = 45 Years

The Payback with electricity costing \$ .238 = 36 Years

The Payback with electricity costing \$ .285 = 30 Years

5.2: Wind Energy Analysis

5.2.1 Is Wind Energy Right For Your Building?

With the equations below it can be found how large of a turbine is needed for your home (Power of system), how much the system will cost to purchase and install, and the number of years it will take for your turbine to payback the original investment.

5.2.2 Raw Data Needed

The input parameters (raw data) needed to solve for the power of the system, system size, system cost, and payback years are; Wind speed at your area (Can be found in figure 2.4 on page 26 in this report) at a specific height (defined as h_2 in the equation), the density of air at specific location (Can be found- Density based on Average temperature in CT (46.95 F) and Elevation in CT (500ft) site calculated from weblink - http://www.denysschen.com/catalogue/density.asp), and KWH's used per year.

5.2.3 Assumptions made

In the process of solving the equations above we needed to make some general assumptions. When looking at the payback formulas we assumed a 40% efficiency rate for the wind turbine. With our research we found the costs to be $3,000 per KW to purchase and $6,000 per KW to Install. These numbers allowed us to finalize the cost and determine a simple payback.

Wind Turbine Formulas (Raw data is taken from RetScreen International and NREL)

$Vu := 5.3\frac{m}{s}$ $\quad h2 := 10m$ $\quad h1 := 75ft$ $\quad r := 22.5ft$

Vu is the given velocity at a given height (h2). h1 is a new height that determines a new Velocity V. r is the Radius of the blades.

$\rho := .0765\frac{lb}{ft^3}$ Density based on Average temperature in CT (46.95 F) and Elevation in CT (500ft) site calculated from weblink - http://www.denysschen.com/catalogue/density.asp

$At := \pi \cdot r^2$ At is the Area in which the blades cover.

$$\frac{Vu}{V} := \left(\frac{h2}{h1}\right)^{\left(\frac{1}{7}\right)} \qquad V := \frac{(Vu)}{\left(\frac{h2}{h1}\right)^{\left(\frac{1}{7}\right)}}$$

The 1/7 Power equation. The new Velcoity (V) is directly propotional to the velocity (Vu) at h2 and its new height h1.

$$V = 5.964\frac{m}{s}$$

$$Vt := \frac{2V}{3}$$

$$Vd := \frac{1V}{3}$$

Force of Turbine

$$F := \rho \cdot At \cdot Vt \cdot (Vu - Vd)$$

$$F = 2.384 \times 10^3 N$$

Power of Turbine

$$P := \rho \cdot At \cdot Vt^2 (Vu - Vd)$$

$P = 9.481 \times 10^3 W$ This is the actually amount of power produced by the size mentioned above. Efficiency is already taken into account.

Payback

It is \$3000 dollars / Kw system and 6,000/kw to install that system

We need a 6.3 kw system

$SystemSize := 9.25$ In Kw

$SystemCost := 3000 \cdot SystemSize$

$Installation := 6000 \cdot SystemSize$

$TotalCost := SystemCost + Installation$

$TotalCost = 8.325 \times 10^{4}$ Dollars

$KWHused := 32290$ KWH

$CostPerKWH := .19$ Dollars

$ElectricBill := CostPerKWH \cdot KWHused$

$Efficiency := .40$ (40%)

$KWHproduced := SystemSize \cdot 365 \cdot 24 \cdot Efficiency$

$DollarPaidKWH := .11$ The utility pays 11 cents per kwh put back into the utility grid

$ExtraElectricity := (KWHproduced - KWHused) \cdot DollarPaidKWH$

$ExtraElectricity = 13.42$ KWH Produced

$$Payback := \frac{TotalCost}{(ElectricBill + ExtraElectricity)}$$

$Payback = 13.54$ Years

Inforation from CanWEA:
SmallWind: Costs
http://www.canwea.ca/images/uploads/File/TipsheetsFINAL.pdf

Payback

It is $3000 dollars / Kw system and 6,000/kw to install that system

We need a 6.3 kw system

Inforation from CanWEA: SmallWind: Costs http://www.canwea.ca/images/uploads/File/TipsheetsFINAL.pdf

$SystemSize := 9.25$ In Kw

$SystemCost := 3000 \cdot SystemSize$

$Installation := 6000 \cdot SystemSize$

$TotalCost := SystemCost + Installation$

$TotalCost = 8.325 \times 10^{4}$ Dollars

$KWHused := 32290$ KWH

$CostPerKWH := .238$ Dollars

$ElectricBill := CostPerKWH \cdot KWHused$

$Efficiency := .40$ (40%)

$KWHproduced := SystemSize \cdot 365 \cdot 24 \cdot Efficiency$

$DollarPaidKWH := .11$ The utility pays 11 cents per kwh put back into the utility grid

$ExtraElectricity := (KWHproduced - KWHused) \cdot DollarPaidKWH$

$ExtraElectricity = 13.42$ KWH Produced

$$Payback := \frac{TotalCost}{(ElectricBill + ExtraElectricity)}$$

$Payback = 10.814$ Years

Payback

It is $3000 dollars / Kw system and 6,000/kw to install that system

We need a 6.3 kw system

Inforation from CanWEA: SmallWind: Costs http://www.canwea.ca/images/uploads/File/TipsheetsFINAL.pdf

$KWHused := 32290$ KWH

$Efficiency := .40$ (40%)

$$SystemSize := \frac{KWHused}{(365 \cdot 24 \cdot Efficiency)}$$

$SystemSize = 9.215$ In Kw

$SystemCost := 3000 \cdot SystemSize$

$Installation := 6000 \cdot SystemSize$

$TotalCost := SystemCost + Installation$

$TotalCost = 8.294 \times 10^{4}$ Dollars

$CostPerKWH := .285$ Dollars

$ElectricBill := CostPerKWH \cdot KWHused$

$KWHproduced := SystemSize \cdot 365 \cdot 24 \cdot Efficiency$

$DollarPaidKWH := .11$ The utility pays 11 cents per kwh put back into the utility grid

$ExtraElectricity := (KWHproduced - KWHused) \cdot DollarPaidKWH$

$ExtraElectricity = 0$ KWH Produced

$$Payback := \frac{TotalCost}{(ElectricBill + ExtraElectricity)}$$

$Payback = 9.012$ Years

The Payback with KWH costing .19 Cents = 13.52 Years

The Payback with KWH costing .238 Cents = 10.792 Years

The Payback with KWH costing .285 Cents = 9.012 Years

5.3. Biomass Energy Analysis

5.3.1 Is Biomass Energy Right For Your Building?

With the equations above it can be found how many total tons of wood pellets that are necessary to heat a home, how much it will cost for a year to purchase the required amount of pellets, and the number of years it will take to payback the cost of the boilers, the installation costs and the cost of the silo.

5.3.2 Raw Data Needed

The input parameters (raw data) needed to solve for the payback include the total gallons of fuel oil used by the building in a year, and the current price of heating oil.

5.3.3 Assumption made

In order to solve the equations below we needed to make some general assumptions. After speaking with an employee from BioHeat USA, we determined that two 180,000 BTU burners would need to be installed $5,000 each and an installation cost of $1,000, as well as the price of the silo which would be $20,000. Also the silo is optional, which dramatically reduces the payback. The only requirement if not using the silo is to manually shovel the wood pellets every other day into a 500 lb hopper.

Current Fuel Bill

$TotalGallons := 2460$ Total Gallons of Fuel Oil used in a year

$PriceUnit := 2.70$ Price of heating oil in CT

$FuelBill := TotalGallons \cdot PriceUnit = 6.642 \times 10^3$ Yearly fuel bill

Estimated Wood Pellet Total Bill

$UnitsPerTon := 120$ Amount of gallons of heating oil for one ton of wood pellets

$PriceTon := 200$ Price per one ton of wood pellets

$PelletTons := \frac{TotalGallons}{UnitsPerTon} = 20.5$ Total tons of pellets need to heat the town hall

$PelletBill := PelletTons \cdot PriceTon = 4.1 \times 10^3$ Yearly wood pellet bill

Savings

$SavingsYear := FuelBill - PelletBill = 2.542 \times 10^3$

Payback

<u>Option 1</u>

$BoilerPrice := 5000$ $Installation := 1000$ $SiloPrice := 20000$

Prices were made available from BioHeatUSA

Two 180,000 BTU burners will need to be installed

A 30 Ton Silo will cost $20,000
Note:Silo is not required and can significantly decrease the price

Payback

Option 1

$BoilerPrice := 5000$ $Installation := 1000$ $SiloPrice := 20000$

Prices were made available from BioHeatUSA

Two 180,000 BTU burners will need to be installed

A 30 Ton Silo will cost $20,000
Note:Silo is not required and can significantly decrease the price

$$Payback := \frac{[(BoilerPrice \cdot 2) + Installation + SiloPrice + PelletBill]}{SavingsYear} = 13.808$$

Option 2

500 lb hopper's are available for wood pellets also, which would eliminate the need for a silo

$$Payback2 := \frac{[(BoilerPrice \cdot 2) + Installation + PelletBill]}{SavingsYear} = 5.94$$

Current Fuel Bill

$TotalGallons := 2460$ Total Gallons of Fuel Oil used in a year

$PriceUnit := 3.00$ Price of heating oil in CT

$FuelBill := TotalGallons \cdot PriceUnit = 7.38 \times 10^3$ Yearly fuel bill

Estimated Wood Pellet Total Bill

$UnitsPerTon := 120$ Amount of gallons of heating oil for one ton of wood pellets

$PriceTon := 200$ Price per one ton of wood pellets

$PelletTons := \frac{TotalGallons}{UnitsPerTon} = 20.5$ Total tons of pellets need to heat the town hall

$PelletBill := PelletTons \cdot PriceTon = 4.1 \times 10^3$ Yearly wood pellet bill

Savings

$SavingsYear := FuelBill - PelletBill = 3.28 \times 10^3$

Payback

Option 1

$BoilerPrice := 5000$ $Installation := 1000$ $SiloPrice := 20000$

Prices were made available from BioHeatUSA

Two 180,000 BTU burners will need to be installed

A 30 Ton Silo will cost $20,000
Note:Silo is not required and can significantly decrease the price

$$Payback := \frac{[(BoilerPrice \cdot 2) + Installation + SiloPrice + PelletBill]}{SavingsYear} = 10.701$$

Option 2

500 lb hopper's are available for wood pellets also, which would eliminate the need for a silo

$$\text{Payback2} := \frac{[(\text{BoilerPrice} \cdot 2) + \text{Installation} + \text{PelletBill}]}{\text{SavingsYear}} = 4.604$$

Current Fuel Bill

$TotalGallons := 2460$ Total Gallons of Fuel Oil used in a year

$PriceUnit := 4.00$ Price of heating oil in CT

$FuelBill := TotalGallons \cdot PriceUnit = 9.84 \times 10^{3}$ Yearly fuel bill

Estimated Wood Pellet Total Bill

$UnitsPerTon := 120$ Amount of gallons of heating oil for one ton of wood pellets

$PriceTon := 200$ Price per one ton of wood pellets

$PelletTons := \frac{TotalGallons}{UnitsPerTon} = 20.5$ Total tons of pellets need to heat the town hall

$PelletBill := PelletTons \cdot PriceTon = 4.1 \times 10^{3}$ Yearly wood pellet bill

Savings

$SavingsYear := FuelBill - PelletBill = 5.74 \times 10^{3}$

Payback

Option 1

$BoilerPrice := 5000$ $Installation := 1000$ $SiloPrice := 20000$

Prices were made available from BioHeatUSA

Two 180,000 BTU burners will need to be installed

A 30 Ton Silo will cost $20,000
Note:Silo is not required and can significantly decrease the price

$$Payback := \frac{[(BoilerPrice \cdot 2) + Installation + SiloPrice + PelletBill]}{SavingsYear} = 6.115$$

Option 2

500 lb hopper's are available for wood pellets also, which would eliminate the need for a silo

$$\text{Payback2} := \frac{[(\text{BoilerPrice}\cdot 2) + \text{Installation} + \text{PelletBill}]}{\text{SavingsYear}} = 2.631$$

Option 1

Payback with price of oil at $2.70= 13.8 years
Payback with price of oil at $3.00= 10.7 years
Payback with price of oil at $4.00= 6.1 years

Option 2

Payback with price of oil at $2.70= 5.9 years
Payback with price of oil at $3.00= 4.6 years
Payback with price of oil at $4.00= 2.6 years

5.4. Geothermal Energy Analysis

5.4.1 Is Geothermal Energy right for your home or building?

Below is a calculation of how many years it would take to payback an installed geothermal system. The information on this city hall building that was researched was found to be that they used 2460 gallons of heating fuel per year. The building used two boilers that powered 182,000 btu/hour. To figure out the system cost we had to assume that for every square foot in the building would cost $16 of work inside the building and would cost $8500 per 1000 ft^2 of outside work (This assumption was supplied by the vendor, nexamp). Next we needed the square footage of the building which we had assumed to be 2500 ft^2. Finally, on average geothermal saves 50-70% spent on heating cooling per year. We assumed geothermal to save 60% of what is spent on heating oil per year. With this information we figured out the payback of the installation to be 15 years. That is not an ideal investment for right now but what must be considered is that we have not taking into account the help from the government, which gives tax incentives to green energies. This renewable energy also reduces the buildings carbon footprint.

5.4.2 Raw Data Needed

By using these equations the raw information needed are; Square-footage of the building, Amount of heating oil used per year, and current price of heating oil (in gallons). With this information inputted, the simple payback can be solved.

5.4.3 How precise is the payback?

The point of this software is to give a general number for an estimated cost of a geothermal system and how good the invest looks in the long run. There are other variables that will affect the payback that are not taken into account such as; government tax incentives, how much inside work really needs to be done or can the system be attached in with existing system, and heat loss through doors, windows, ect. With this said, these variables would most likely need a vender and consultant. The software is very simple to use and can give anyone a quick answer to see if geothermal is right for their home or building.

Geothermal Energy

Size of Heat Pump

1 gallon diesel and heating oil = 139,000 btu

Energy information administration. http://www.eia.doe.gov/kids/energyfacts/science/energycalculator.html

1 ton = 12,000 btu/hr

Geothermal Heat Pumps - by Bruce Harley www.builditsolar.com/projects/spaceheating/builder's%20guide%20to%20GeoThermal.pdf

$Gal := 2460$ Per year

$$Tons := \frac{(Gal \cdot 139000)}{5500 \cdot 12000}$$

Heating and cooling average per year = 5,500 hours (Mass average given by Nexamp)

$Tons = 5.181$ Heat pump size

Cost of System Nexamp gave original numbers

1 ton system costs = $1,300

Inside work cost (Nexamp)

Total cost of inside work = $16 per sq ft of building

Outside work Cost (Nexamp)

Total cost of outside work = $85000 per 1000 sq ft of building

$A := 2500$ (A is square footage of building)

$Inrate := 16$

$Outrate := 8500$

Total Cost of Installing System and Equipment

$SystemCost := Incost + Outcost$

$SystemCost = 6.125 \times 10^{4}$

PAYBACK (in years)

Nexamp says saves 50-70% on what you spend to heat with fuel oil.

Lets say 60%

Cost of fuel oil per gallon * amount of gallons per year = Amount spent per year(OrigSpent)

$FuelOilCost := 2.70$

$GalUsed := 2460$

$OrigSpent := FuelOilCost \cdot GalUsed$

$OrigSpent = 6.642 \times 10^{3}$

OrigSpent is the amount of money spent on Heating per year

$SavingsPerYear := OrigSpent \cdot .60$

$SavingsPerYear = 3.985 \times 10^{3}$ Dollars saved per year on fuel oil.

$$Payback := \frac{SystemCost}{SavingsPerYear}$$

$Payback = 15.369$ Years

PAYBACK (in years)

Nexamp says saves 50-70% on what you spend to heat with fuel oil.

Lets say 60%

Cost of fuel oil per gallon * amount of gallons per year = Amount spent per year(OrigSpent)

$FuelOilCost := 3.00$

$GalUsed := 2460$

$OrigSpent := FuelOilCost \cdot GalUsed$

$OrigSpent = 7.38 \times 10^{3}$

OrigSpent is the amount of money spent on Heating per year

$SavingsPerYear := OrigSpent \cdot .60$

$SavingsPerYear = 4.428 \times 10^{3}$ Dollars saved per year on fuel oil.

$$Payback := \frac{SystemCost}{SavingsPerYear}$$

$Payback = 13.832$ Years

PAYBACK (in years)

Nexamp says saves 50-70% on what you spend to heat with fuel oil.

Lets say 60%

Cost of fuel oil per gallon * amount of gallons per year = Amount spent per year(OrigSpent)

$FuelOilCost := 4.00$

$GalUsed := 2460$

$OrigSpent := FuelOilCost \cdot GalUsed$

$OrigSpent = 9.84 \times 10^{3}$ OrigSpent is the amount of money spent on Heating per year

$SavingsPerYear := OrigSpent \cdot .60$

$SavingsPerYear = 5.904 \times 10^{3}$ Dollars saved per year on fuel oil.

$$Payback := \frac{SystemCost}{SavingsPerYear}$$

$Payback = 10.374$ Years

Fuel Oil Rises to $2.70 a gallon the Payback = 15.3 Years

Fuel Oil Rises to $3.00 a gallon the Payback = 13.8 Years

Fuel Oil Rises to $4.00 a gallon the Payback = 10.4 Years

Chapter 6: Conclusions

Our project involved performing thorough research on four alternative energies: solar, wind, biomass, and geothermal energies. The technologies involved with each type of energy were investigated. The feasibility of each alternative energy was evaluated from a technical and financial approach.

For a case study, the implementation of these alternative energies was considered for the town hall in Pomfret Connecticut. Different payback periods depending on the rise in oil prices, or the rise in the price of a kwh were found. Based on the building location, size and consumption, the two most feasible alternatives would be biomass and geothermal technologies. For solar energy, Connecticut is not the most ideal location (due to low incident radiation), which results in a payback period of around 45 years, which is not feasible. Although wind energy has a payback period of around 13 years, the town hall is located on a fairly tight space with many tall trees which would be a problem if a wind turbine were to be built near the building; therefore wind energy may not be feasible. Biomass energy which has a payback period of around 13 years may be considered. The site has plenty of space for a silo to store wood pellets. Geothermal energy has a payback period of around 15 years, and plenty of space is available to install a heat pump system.

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