Renewable Energy Alternatives

A Major Qualifying Project

for Stantec Consulting Ltd.

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Abstract

The goal of this project was to develop a Renewable Energy Best Practices Manual for Stantec Consulting Ltd. The manual will be used by Stantec employees for assessing renewable energy alternatives at a specific location. The information researched for each option was current technology, best location, cost range, efficiency, and downsides/environmental impacts. The manual also includes a checklist and comparison table of each of the renewable energy alternatives, as well as fossil fuels.

Executive Summary

Renewable energies increasingly need to be used to preserve our Earth. Renewable energy technologies use resources that are naturally replenished, including wind, sunlight, water, geothermal heat, and biomasses, and do not emit pollutants including carbon dioxide. These renewable energies also do not release greenhouse gases which are a contributor of global warming. Currently there are many organizations, engineering firms, and consulting firms working with renewable alternatives to help reduce the number of pollutants released in the environment.

Stantec Consulting Ltd. offers professional consulting services in a variety of professional consulting services including "planning, engineering, architecture, interior design, landscape architecture, surveying, environmental sciences, project management, and project economics for infrastructure and facilities projects."[2] Since Stantec has a broad variety of services available, they are increasingly proposing renewable energy alternatives for their clients.

Stantec's increasing number of renewable energy projects has overloaded the company's experts in the field. Due to the rapid growth of renewable energy technologies, Stantec needs to use younger or less experienced engineers for these jobs. There is a steep learning curve however, due to the fact that there is no readily available "textbook" with a compilation of the information needed. Stantec decided that they need a resource to provide to these less experienced engineers to quickly bring them to speed on the current technologies available.

The main goal of this project was to create a Best Practices Manual (BPM) that will encompass all major and well known renewable energy alternatives. This BPM will be available for all Stantec employees to view via their company network. Stantec will use this manual as a reference document for renewable energy projects.

To compile a BPM for Stantec the team first selected the main topics by reviewing Stantec's existing electronic BPM. Notes and presentations provided by the team's advisor, Klaas Rodenburg, were also reviewed. Based on this information it was decided that Biomass, Geothermal, Hydro, Solar, and Wind Energy were going to be the main topics studied. Areas of research, including current technologies, best locations, efficiencies, costs, and environmental impacts, were studies in depth as a basis for the team's information.

The BPM contains detailed information on the five topics mentioned, as well as sub-topics for each of the renewable energy alternatives. The BPM also contained a comparison table and checklist of the data found. The comparison table lists all of the renewable energy technologies, as well as conventional fossil fuels. The table compares technologies, best locations, efficiencies, cost, downsides/environmental impacts, and general information for each of the topics. The checklist allows an engineer to get a better understanding of the renewable energy alternative and can use it to determine if it is viable or not.

The last aspect of the BPM was a set of conclusions devised by the team as to where each technology would be of best use. It was also noted that renewable energy technologies are not practical in every situation and in every location. It was determined that the best way to integrate renewable energy technologies into the world is through hybrid systems.

Table of Contents

List of Figures

List of Tables

List of Equations

Capstone Design Experience

The capstone design consisted of analyzing a site location and determining the best suited renewable energy option available. Using the chart and checklist located in the Renewable Energy Alternatives Best Practices Manual, it was determined that a micro-hydropower system would work best at that particular site. Then using the BPM and its various sources, a micro-hydropower system was analyzed and designed.

In accordance with the Accreditation Board of Engineering and Technology (ABET) General Criterion for capstone design, this Major Qualifying Project has incorporated six realistic constraints. They are as follows:

Economic

The BPM addresses both cost range and payback periods associated with installing a micro-hydropower system. Based on these figures it was determined that a system similar to the one that was designed is an extremely cost effective method of generating power. Despite the fact that a micro-hydropower system has a high initial cost, over time there will be a greater energy savings. The cost to generate power using this system is about half to one-third less than buying power from a local utility company. The payback period for the system is also short and after this time period there are only minimal maintenance costs.

Environmental

The effects that a project has on the environment are extremely important to consider before the project is implemented. The system was designed to divert the minimal amount of water from the stream into the canal and forebay. The river flow will only be altered for about 150 feet, where the water is then diverted back into the river and the conditions will be resumed to their original state. These impacts to the environment are minimal compared to the carbon emissions that would be created by using existing grid power supplied by fossil fuel power plants.

Sustainability

Sustainability is comprised of environmental, economic, and social aspects. The design of this system encompasses each of these different aspects and brings them all together. A micro-hydropower system is a sustainable design based on the fact that it is an off-grid power generator and can be the lone source to generate electricity for a home. Once the system is constructed and the paid off, the system is very low maintenance and can sustain on its own.

Constructability

The design of the micro-hydropower system was developed to be constructible. It was specifically designed using the Piscataquog River flow and head difference. Many micro-hydropower systems are designed in a very similar and rather simple matter, making these systems constructible in even the most remote locations. The accessible construction material, as well as the availability of turbines and generators makes the system simple and easy to construct.

Ethical

Similar to many projects ethical practices play a role in the design and construction of this micro-hydropower system. This system was designed with the best practices in mind, as well as the impact that it would have on the surrounding area. Ethical discussions about power generation today revolve around the construction of fossil fuel power plants that emit harmful green house gases. The micro-hydropower system emits no harmful greenhouse gases and is an ethical choice during a time of global warming.

Health and Safety

The health and safety of the people using this system was taken into account. For an off-grid source of power generation, micro-hydropower plants are among the safest. If a fossil fuel generator was used, dangerous fuels would have to be stored near the residents' home. A fossil fuel generator would also emit harmful pollutants very close to the residents' home. The micro-hydropower plants do not contain hazardous materials (if environmental friendly lubricants are used) and emits no harmful pollutants.

Abbreviations

AC	-	Alternating Current
Btu	-	British thermal unit
C	-	Celsius
DC	-	Direct Current
DOE	-	Department of Energy
EIA	-	Energy Information Administration
EJ	-	Exajoule
EPA	-	Environmental Protection Agency
F	-	Fahrenheit
ft.	-	Feet
ft.^{2s}	-	Feet squared
ft.^{3}	-	Feet Cubed
gal.	-	Gallon
gpm	-	Gallons per minute
GW	-	GigaWatt
GWh	-	Gigawatt-hour
kW	-	KiloWatt
kWh	-	KiloWatt-hour
lbs	-	Pounds
LEED	-	Leadership in Energy and Environmental Design
m	-	Meter
mps	-	Meters per second
NREL	-	National Renewable Energy Laboratory
Mph	-	Miles per hour
MW	-	MegaWatt
RPM	-	Revolutions per minute
TW	-	TeraWatt
TWh	-	TeraWatt-hour
W	-	Watt
Wp	-	Watt-peak

1 Introduction

Renewable energies increasingly need to be used to preserve our Earth. Renewable energy technologies use resources that are naturally replenished, including wind, sunlight, water, geothermal heat, and biomasses, and do not emit pollutants including carbon dioxide. These renewable energies also do not release greenhouse gases which are a contributor of global warming. Figure 1 displays the breakdown of the electricity generated in the U.S. in 2008.[1] Renewable energies only accounted for 9% of the electricity generated, with a majority being from hydroelectric power.

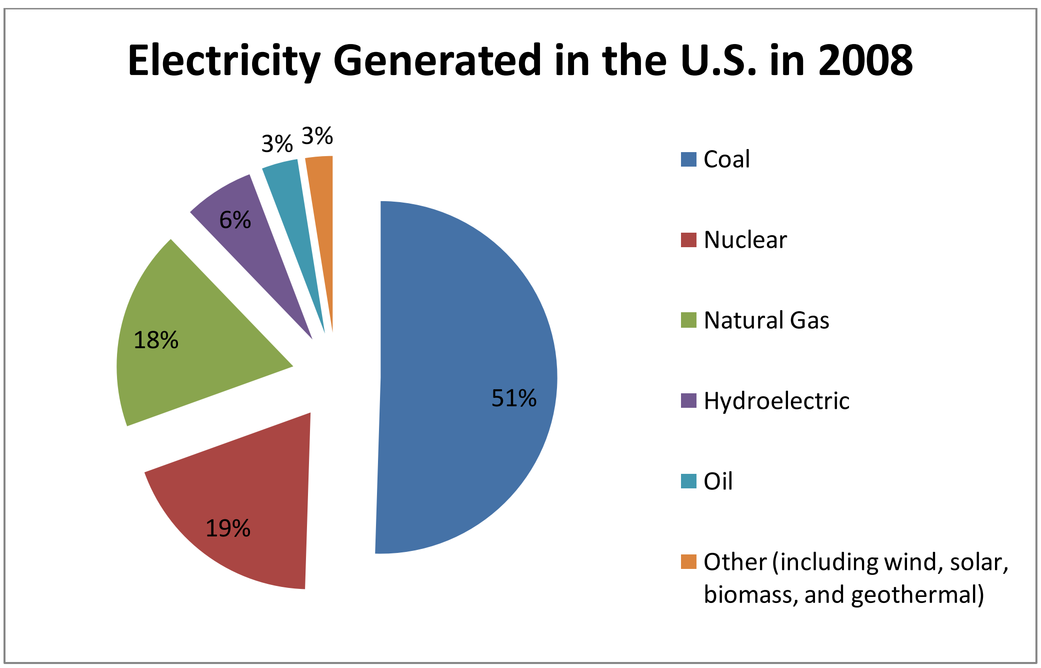

Figure 1: Electricity Generated in the U.S. in 2008

Stantec Consulting Inc. was founded in 1954 and offers professional consulting services, including "planning, engineering, architecture, interior design, landscape architecture, surveying, environmental sciences, project management, and project economics for infrastructure and facilities projects."[2] Stantec's clients are increasingly asking for renewable energy alternatives and with so many new technologies, there are not enough engineers with adequate experience evaluating site-specific options. When a company asks Stantec to design a renewable energy resource for them, an engineer has to research all alternatives and make the best decision possible with the information found. With no textbook and very few past examples it is difficult for engineers to make a well educated decision in a time-efficient manner.

Stantec has provided their clients with renewable energy alternatives, however they have realized that the process they currently use is not very efficient. Stantec recognizes that they need a solution to this problem and a standard procedure for its engineers to follow when proposing solutions to its clients. This process also needs to be available to the entire company so that Stantec can deliver a top notch and consistent products to its clients everywhere. This will aid Stantec in becoming a leader in renewable energy alternatives.

Stantec has decided that they need a renewable energy Best Practices Manual (BPM) that will be accessible to engineers in all of their offices. This BPM will be created through comprehensive research and analysis on commonly used renewable energy alternatives. It will compile all of the available information on renewable energy into an efficient document. The key part of this BPM will be a checklist that will allow the user to quickly sort through all options and pick those with the best potential. This is the most important part of the document because it will greatly increase the efficiency of Stantec's engineers. The BPM will be readily available for all Stantec employees to use on projects.

2 Background

2.1 Biomass Energy

Biomass energy or bioenergy utilizes energy stored in plants, as well as materials obtained from plants.

2.1.1 Biomass History

Biomass energy has been used to generate heat for thousands of years, mainly in the form of wood biomass systems. Not only did these systems heat people's homes, but they also were used for cooking purposes. Up until the 1800's, wood biomass systems were the main source of energy in both the U.S. and throughout the world. Over time there has been a shift in the means of generating energy, however many developing countries still rely on the use of wood biomass systems.[3]

Despite the fact that wood biomass has the potential to generate an adequate amount of power, only about 7% of the annual production of biomass is used by the world's population. Biomass energy encompasses a variety of technologies and can be generated from agricultural residue, wood wastes, trees and grass, and methane (from landfills, waste water treatment sites, and livestock).[4]

2.1.2 Wood

Wood is probably the most well-known biomass energy, as it is one of the oldest energy sources. Plants (including wood) are comprised mostly of a material called cellulose. Cellulose is produced from sugar during the process of photosynthesis and contains an abundance of stored chemical energy, which can be released as heat when the wood is burned.[5]

There are many sources of wood, perhaps the most common being forests. As long as these resources are not harvested too often and the ecosystem is not interrupted, the materials can easily be replaced by re-growth. Waste wood is also an option, which comes from wood manufacturing and processing wastes as well as debris from construction or destruction activities.[6]

2.1.3 Algae

Much like wood, algae relies on photosynthesis to harness solar energy as a means to create energy when it is combined with carbon dioxide and water. However, unlike many other plants, algae produce fatty lipid cells full of oil that can be used as a fuel.[7]

The term "algae" refers to microalgae, macroalgae, and emergents. Macroalgae are fast growing and grow in size of up to 60m in length. These algae can grow in both sea and saltwater and are most commonly referred to as "seaweed." Microalgae are microscopic photosynthetic organisms and can live in both salt water and freshwater. Emergents are plants that tend to grow in partially submerged marsh-like areas.

Currently most attention is given to microalgae with regard to biomass energy. Microalgae produce specific natural oils for biodiesel and are more efficient in their conversions of solar energy due to their simple structure. The cells also have easy access to water, carbon dioxide and other various nutrients due to the fact that the cells grow in aqueous suspension. Because of these factors microalgae are able produce approximately

30 times the amount of oil per unit area of land that terrestrial oilseed crops are capable of.[8]

It is approximated that algae could yield more than 2,000 gal. of fuel per acre per year of production. This is significantly more than other fuel sources. For instance, palm has the ability to produce around 650 gal. per acre per year, sugar cane 450 gal. per acre per year, corn 250 gal. per acre per year, and soy 50 gal. per acre per year (approximately 2.5% of the yearly yield of algae). The typical process of oil production using algae can be seen in Figure 2.

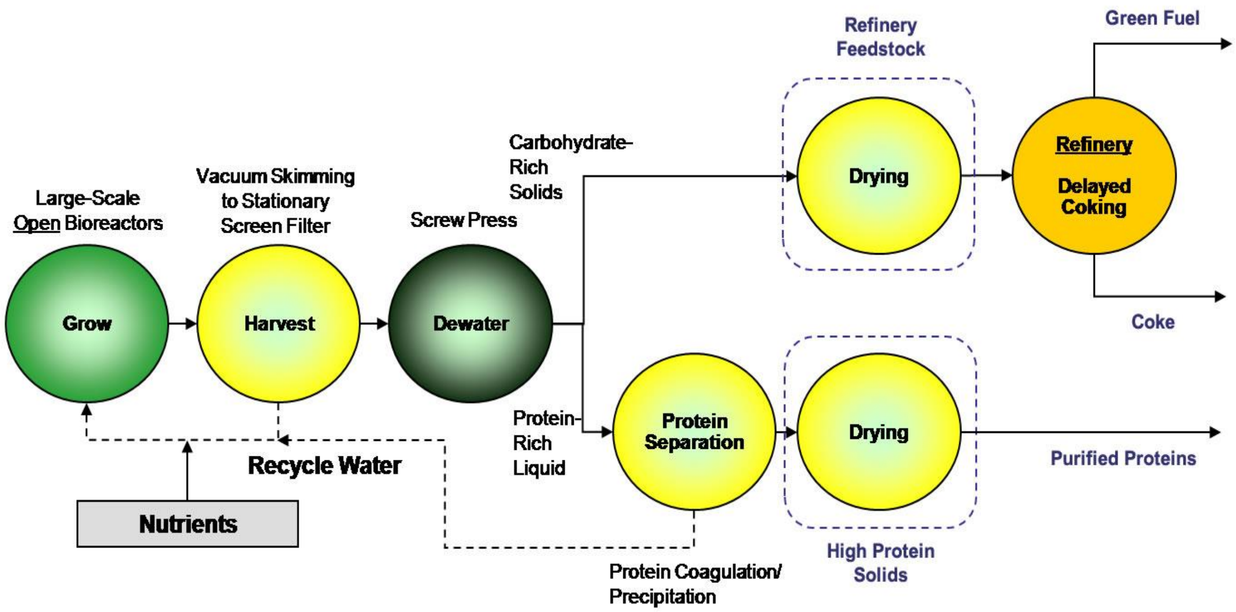

Figure 2: Typical Process of Oil Production with Algae[9]

2.1.4 "Grassahol"

"Grassahol" utilizes switch grass which is a hard and thick-stemmed plant that grows up to a height of about 3 m tall. It can grow in soils where most other crops cannot be grown and requires minimal water and fertilization.

The switch grass is harvested, chopped up into small pieces, and put in a fermenter. Enzymes work and break down cellulose from the plant into sugar. Yeast is then added which converts the sugar into alcohol. There is also another approach to converting switch grass into fuel. The plant is similarly chopped up, but is burned in what is called a "gasifier" at a high temperature. This process produces carbon dioxide, carbon monoxide, and hydrogen gases that are bubbled through a bioreactor. In this bioreactor, microorganisms then convert these gases into ethanol. This product, as an engine fuel, is about 85% as efficient as gasoline.[10]

2.1.5 Landfill Gas

Anaerobic decomposition takes place when waste is deposited into landfills, producing landfill gas. Landfill gas is composed of about about 50% methane and can be used for energy generation. Over the past 25 years technologies that focus on the extraction and use of landfill gas have been developed and there are around 950 landfill gas utilization plants worldwide today. A diagram of a modern landfill is demonstrated in Figure 3.

The extraction of this gas is not only beneficial because it can be used as an alternative to fossil fuels, but it is advantageous to the environment. Through extraction, methane emissions released into the environment are reduced. Since landfill gas can also be used in lieu of fossil fuels, this also reduces contribution to the greenhouse effect. [11]

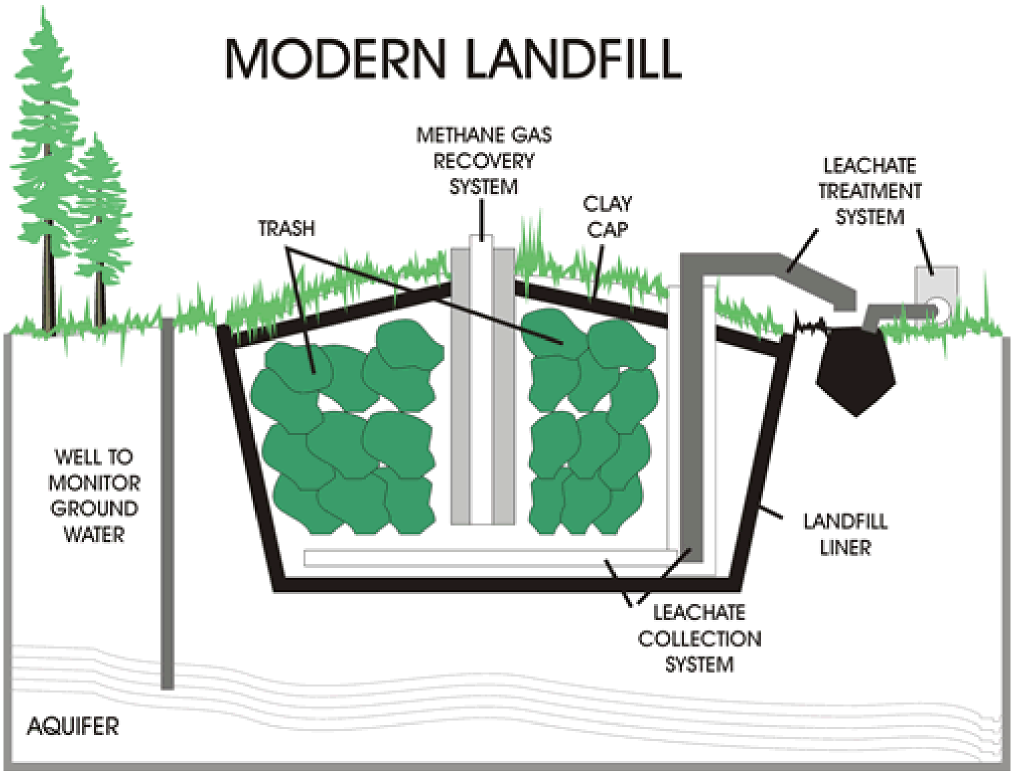

Figure 3: Modern Landfill Configuration [12]

Landfill gas recovery systems are installed during the active life of the landfill and completed at closure of the landfill. Vertical wells are drilled to the bottom of the waste, with spacing typically one well per each acre, and use header pipe to connect the wells. Horizontal collectors are implemented in active fill areas as well and use a blower and compressor vacuum to extract the landfill gas. The landfill gas that is extracted is then delivered to either a flare or a beneficial use project.[13]

2.1.6 Waste-to-Energy

Initially, waste-to-energy facilities produced vast amounts of emissions that were harmful to the environment. However over the past 15 years, these emissions have been greatly reduced through the installation of pollution control systems and scrubbers.

Landfilling municipal solid waste as a form of disposal can cause emissions of carbon dioxide as high as 1.3 Tons for every 1 Ton of waste landfilled.

Waste-to-energy is generally a better option for areas that reside on sandy soil, such as Long Island, New York and Florida. These soil conditions give way for easy contamination from landfills and could possibly transfer the contaminant to the nearby bodies of water. Many communities in areas such as these opt for waste-to-energy for that reason. Figure 4 demonstrates the heat and electricity that can be achieved using waste-to-energy technology with one Ton of waste.

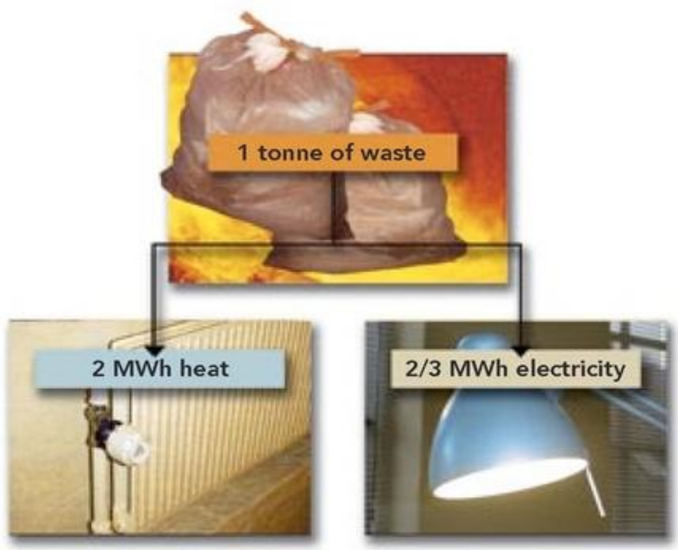

Figure 4: Yields of Waste-to-Energy Technology of 1 Ton of Waste[14]

The U.S. EPA enforces strict rules and regulations for waste-to-energy plants to adhere to in an effort to insure that harmful greenhouse gases and particles are not released into the environment. Waste-to-Energy plants are required to use devices that prevent pollution, such as scrubbers, fabric filters and electrostatic precipitators. Scrubbers clean the chemical emissions by way of spraying a liquid into the gas to neutralize the acids. Particles are removed from the emissions by the fabric filters and electrostatic precipitators.[15]

2.1.7 Biodiesel

Biodiesel is a biodegradable and non-toxic fuel that yields from vegetable oils, animal fats, cooking oil, or tall oil (a byproduct from pulp and paper processing). The process to produce biodiesel involves the oil reacting with some kind of alcohol. Methanol is generally the first choice, though ethanol can also be used. From this chemical reaction, gylcerine and biodiesel are produced. Biodiesel has a higher cetane rating than conventional diesel and also produces fewer life cycle greenhouse gas emissions when bruned.[16]

Petroleum diesel and biodiesel can also be mixed to form various biodiesel blends, which may be used in any diesel engine.[16] The most common blend of biodiesel is blended at 20% with petroleum diesel at 80% and is referred to as B-20.[17]

2.2 Geothermal Energy

Geothermal energy is simply earth-heat or heat that is generated from within the Earth. This heat can be contained as either steam or hot water and can then be used to generate electricity or heat buildings. Geothermal energy is most often obtained by drilling wells in the earth, comparable to the way oil wells are drilled.[18]

Despite the fact that geothermal energy is not the leading source of renewable energy in the U.S., in 2008 there was an estimated 2,958 MW of electricity being generated in 7 states alone. On top of this, in 2008 the U.S. was the world leader of geothermal energy, both in generation of electric power and online capacity. A majority of our geothermal energy comes from one of two sources, ground source geothermal (geothermal heat pumps or ground source heat pumps) or deep well geothermal, both of which have been around since the early 1900's.

2.2.1 Geothermal Energy History

North American's have been using geothermal energy for more than 10,000 years, starting with the Paleo-Indians. The Paleo-Indians settled at the hot springs, which were used for both cleansing and warmth. Although most settlements in both North America and Europe were centered around hot springs, it wasn't until the late 1800's that this hot water began to be piped into buildings and homes.[18]

The first ever geothermal plant was put into operation in the Western US in 1922, using steam from wells to generate 250 kW of electricity. This was only a small scale discovery and due to its lack of competitiveness to other power sources, it stopped being used. Nearly 26 years later, the first ground source heat pump was developed and put into use at a private residence and 12 years later that the U.S. put its first large scale geothermal power plant into operation. This plant was located at the Geysers and produced nearly 11 MW of power for over 30 years.[18]

Over time the technology has developed to what it is today. There is a better understanding of how the heat can be harnessed and various processes available to create electricity. Recent studies have shown that there are over 9,000 wells and springs (as well as geothermal resource areas and direct use sites) located in 10 western states of the U.S. identifying the remarkable potential of this renewable resource.[19]

2.2.2 Ground Source Geothermal

Ground source heat pumps are typically systems installed about 10 ft. below the Earth's surface and are generally used for more small scale applications (such as residential homes and commercial buildings). Despite the fact that the temperatures above ground change drastically throughout the year, the temperature below the surface will generally be around 50° and 60°F making it a very reliable and consistent source of energy. Ground source heat pumps can either transfer heat from the ground to heat a building or remove heat from a building to cool it.[20]

In 2004 a study showed that over 1,100,000 ground source heat pumps were installed throughout the world, with over half of them installed in the U.S. That same study also showed that there had been a 10% annual increase the number of ground source heat pumps being installed in 30 countries over a 10 year period. In the U.S. alone it has also been recorded that over 50,000 units are installed each year with the number constantly increasing.[21]

When looking to install a ground source heat pump there are two different types of ground loop systems to choose from. Either have a closed-loop system or an open-loop system. In order to determine which system is the most applicable for a particular site, factors such as climate, available land, local installation costs, and soil characteristics, are all taken into consideration.[22]

A closed-loop system is comprised of horizontal, vertical, and pond/lake systems. Although each of these systems can be applicable for both residential and commercial buildings, it varies as to which system would be the most efficient. A pond/lake system is generally the most cost effective, but is only suitable if there is a sizeable body of water near by. For this application coiled pipe is run from the building to the body of water at a depth of at least 8 ft.[22]

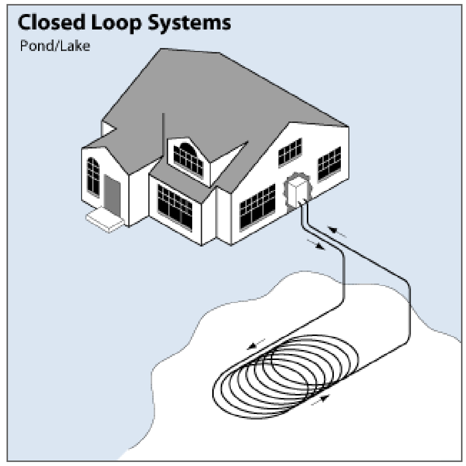

Figure 5: Closed Loop Pond/Lake System

A vertical system is typically used for large commercial buildings and schools because it decreases the required land area necessary for installation. Vertical loops also minimize the disturbance of landscaping and is used when the soil is to shallow for digging trenches (see Figure 6). A horizontal system is the most cost-effective system to use for residential homes when a pond/lake is not available for use. This system is the most efficient to install during new construction if the land is available and requires trenches that are at least 4 ft. deep to be built (see Figure 7).[22]

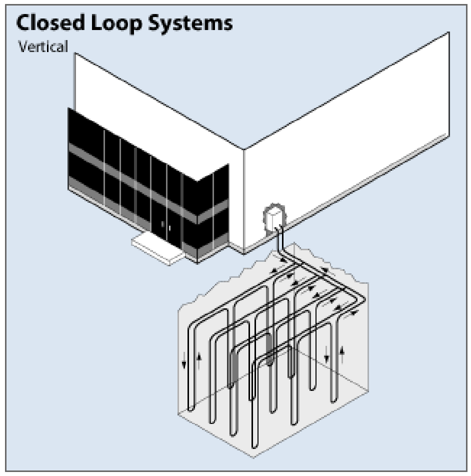

Figure 6: Closed Loop Vertical System

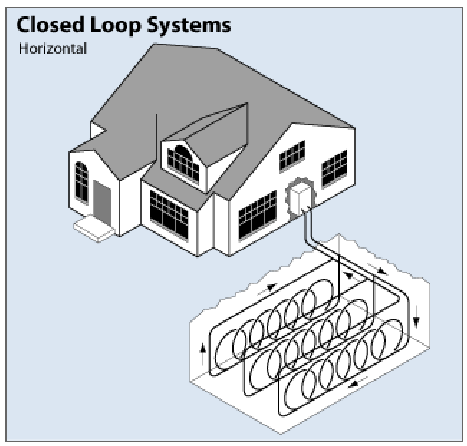

Figure 7: Closed Loop Horizontal System

An open-loop system uses either a well or surface body water as the fluid that circulated through the system. After the fluid is circulated through, the water is returned through a different pipe to where it came from. This option is really only feasible when there is a sufficient supply of fairly clean water. There are also local regulations and codes that have to be met due to the fact that water is being discharged back into the environment.[22]

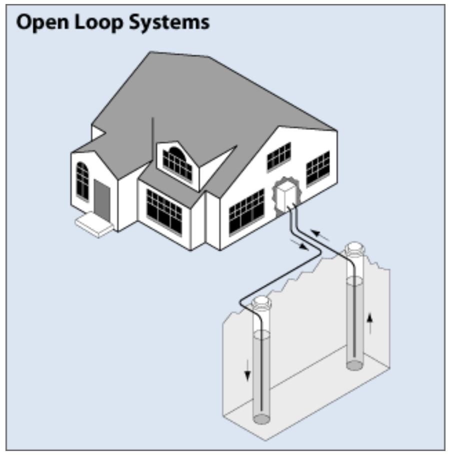

Figure 8: Open Loop System

2.2.3 Deep Well Geothermal

A deep well geothermal system requires a well (or series of wells) to be drilled miles into the earth. These wells will tap into underground reservoirs that contain steam and hot water. This heat will then be brought to the surface and be used for various applications (most common is to generate power). Deep wells typically tap into the hot water and rock miles below Earth's surface, however even deeper wells can be drilled to tap into really hot molten rock (also called magma).[20]

Deep well's are drilled in order to attain fluid with a hotter temperature. The deeper the well the hotter the temperature is going to be. One standard is that if the temperature within the first few meters of the Earths surface is the average temperature of the air, then the temperature about 2000m below the surface will be 60° C to 75° C and the temperature about 3000m below the surface will be 90° C to 105° C, and so on from there.[23]

Due to the high cost of the drilling and installation, deep well geothermal systems are typically used for large scale applications. In all geothermal systems there needs to be a heat source, a reservoir, and a fluid to transfer the heat. Once all of these components are acquired, the fluid can be pumped up to the surface and then be used to generate power.[23] There are three different types of reservoirs that can be drilled into. The first two are water-dominated reservoirs, which can either be high-temperature (beyond 5,000 ft. in the Earth) or low-temperature (usually less than 1,000 ft. in the Earth). The third type of reservoir is steam-dominated and is usually beyond 5,000 ft. in the Earth.[24]

In order to harness the power generated from underground reservoirs a power plant needs to be constructed. There are three different types of geothermal power plants. The first type is a flash steam plant which is used if there is a high-temperature, water-dominated reservoir. A flash steam plant will draw hot (typically above 360° F or 182° C) high-pressure water from deep in the Earth, into lower-pressure tanks. This will create "flashed" steam, which will be used to drive turbines.[18]

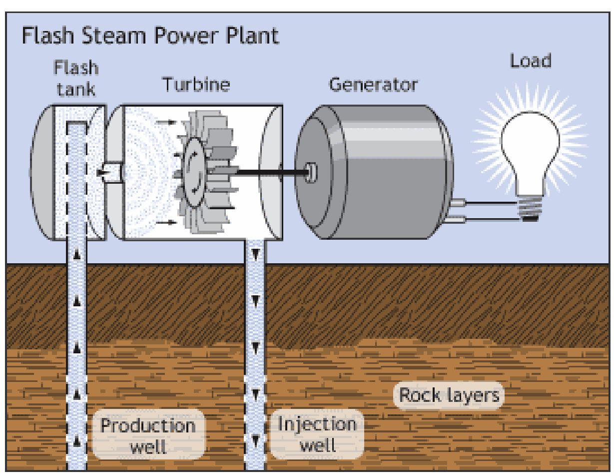

Figure 9: Flash Steam Power Plant

The second type of power plant is a dry steam power plant, which is typically used if there is a steam-dominated reservoir. This is the oldest type of geothermal power plant and perhaps the most simple. The steam from within the Earth is brought to the surface and sent directly to a turbine. The turbine powers a generator, which then produces electricity.[18]

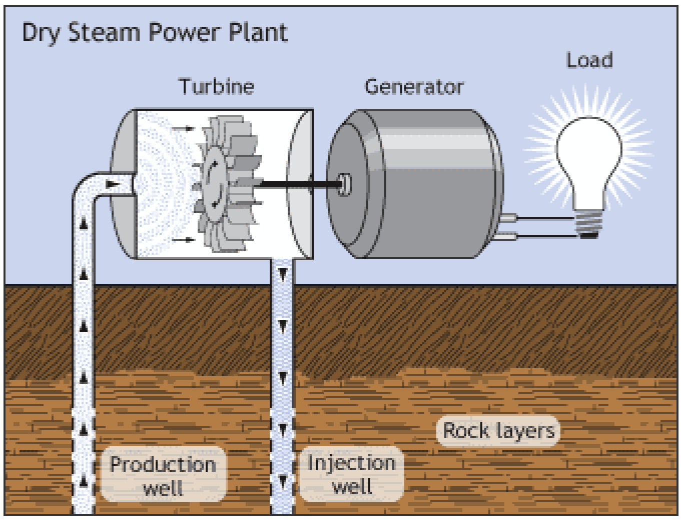

Figure 10: Dry Steam Power Plant

The last type of power plant is a binary-cycle power plant. Hot geothermal water and a secondary fluid (with a low boiling point) go through a heat exchanger. The heat from the hot geothermal water will cause the secondary fluid to vaporize. This vapor will then be passed through the turbine which is used to generate power. This system uses a moderate temperature water (below 400° F), which is the most common geothermal source.[18]

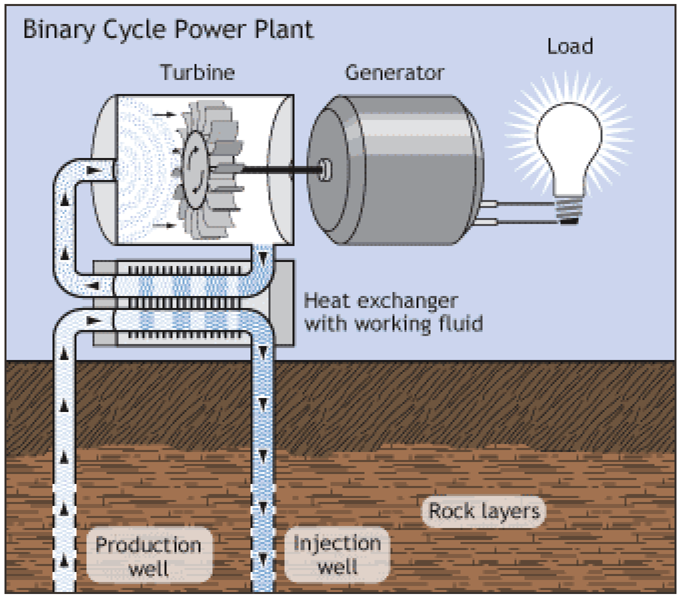

Figure 11: Binary-Cycle Power Plant

2.3 Hydropower

Today, hydroelectric power is the leading renewable energy source used to generate electric power. It has been cited that approximately 20% of the world's electricity production and 10% of the U.S. electricity production comes from hydroelectric power. Hydroelectric power, more commonly known as hydropower, is the process of generating electricity by utilizing the power of moving water.[25]

The most commonly known type of hydropower is conventional hydropower, where water is either diverted from a stream or from behind a dam and flows though a turbine which is connected to a generator. Once the water leaves the turbine it is then sent back into the stream or riverbed. Although conventional hydropower currently generates a majority of the hydroelectricity in the U.S., there are two other methods of generating hydropower. The first is through the use of waves and the second is through the use of tides.[25]

2.3.1 History of Hydropower

The use of water to generate power and perform work has been around for thousands of years. Over 2,000 years ago the Greek's used water wheels to grind wheat into flour, as well as saw wood and power textile mills. Over time the technology developed and eventually hydropower was generated using falling water. It wasn't until the 1770's that the turbine that is commonly used today was developed by a French military and hydraulic engineer.[26]

After this advancement the use of hydropower became more and more developed and in 1882 an electric generator was connected to a turbine creating the world's first hydropower plant in Appleton, Wisconsin. By 1907 the use of hydropower generated 15% of the U.S. electrical supply and by 1920 hydropower generated 25% of the U.S. electric supply. Between 1920 and 1940 the conventional capacity of hydropower nearly tripled, generating nearly 40% of the electric supply.[26]

From this point on the use of hydropower kept advancing as new technologies became widespread. Although the U.S. only generates about 10% of its electricity from hydropower the on-line capacity is much greater than it was back in the early 1900's. In 2003 nearly 100,000 MW of electricity was generated from hydropower and an estimated 30,000 MW of undeveloped capacity at approximately 5,677 different sites in the U.S.[26]

2.3.2 Conventional Hydropower

As previously mentioned conventional hydropower is where water is either diverted from a stream or from behind a dam and flows though a turbine which is connected to a generator.[26] Conventional hydropower is typically associated with the "power plant" aspect of hydropower and generates the majority of the 10% of hydroelectricity in the U.S.. The largest hydropower plants in the U.S. are located in the Pacific Northwest and generate about 75% of the required demand (see Figure 12 for leading hydropower producing states).[25]

Figure 12: Top Hydropower Producing States[27]

There are three main types of conventional power plants, each one suitable for specific situations. The first type of facility is a pump storage plant, which as the name implies, can store power. A generator is used to spin turbines backwards, which will pump water from a lower reservoir into an upper reservoir. The upper reservoir is used to store the power and controls when the water will be released. When the power is needed the water will be released back down into the lower reservoir, which will spin the turbine forward and power the generator to create electricity.[28]

The second type of facility is an impoundment facility and is the most common type of conventional hydropower. In this situation a dam is used to store water in a large reservoir. When the water is released from behind the dam, it will flow through a turbine and activate a generator which then produces electricity. In the U.S. alone there are nearly 80,000 dams, however only 2,400 produce electricity. Although not every dam is in a suitable location to create a hydropower plant, there is still a great potential for use.[28]

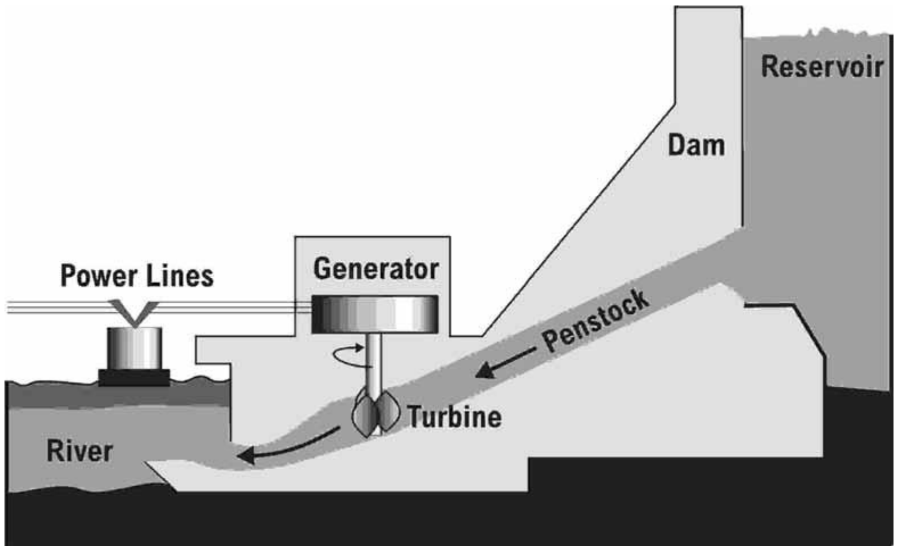

Figure 13: Typical Hydropower Plant[27]

The third and last type of facility is diversion or run-of-river facility. A portion of the water is diverted through a penstock (also known as a pipe) or canal and directed through a hydropower plant. The water that is diverted does not greatly decrease the flow rate of the river, nor is a dam required. Because of this there are decreased effects on the environment.[29]

The size of conventional hydropower plants can vary greatly. Based on the U. S. DOE standards there are large, small, and micro hydropower plants. The large scale hydropower plants generally have a capacity of more than 30 MW of power and serve many consumers. Small scale hydropower plants have a capacity anywhere between 100 kW and 30 MW and will typically supply a rural community in a developing country. Micro hydropower plants are the smallest and have a capacity of up to 100 kW of power.

These are often privately owned and operated and can be used for a home, farm, or ranch.[30]

Despite the fact that there are no definite figures for gross theoretical hydropower in the U.S., various studies have been done to determine potential theoretical hydropower. A study done in 1979 by the U.S. Army Corp of Engineers stated that there was a potential of 512 GW (which is comparable to 4485 TWh/year) of hydropower in the U.S. alone. The only drawback to this study was that not all of these sites were feasible to develop. Overall the technical feasibility is around 146,700 MW (which is comparable to 528,500 GWh/year) because of location and terrain conditions.[31]

2.3.3 Micro-Hydro Power

The use of micro-hydro power has become increasingly widespread over the past few decades, especially in developing countries. The use of these schemes are important in the economic development of remote areas that are looking to become more advanced. Micro-hydro power allows regions (like mountainous and rural areas) to have power that might not normally be able to. Typically these systems are very basic and use direct mechanical power or a turbine that is connected to a generator to produce electricity.[32]

The term micro-hydro is the term that is given to a hydropower system that generally produces 100 kW of power or less. The value 100 kW means that the system will have an instantaneous output of 100 standard units of electricity. In most situations micro-hydro power does not require the storage of water in order to generate power. Typically a run-of-river system will be used to simply to divert a small portion of the streams water towards the turbine. A low-head turbine will often be used for “micro” scale projects because there is small head (height of the water), but a sufficient flow of water.[32]

Micro-hydro systems are generally installed at off-grid sites that have a suitable water source. Homeowners that are located at such a site can either, buy a gas or diesel generator, purchase a renewable energy system, or extend a utility transmission line from a connection point. Micro-hydro power systems are favorable in such a situation because besides the initial cost, there are very few other costs associated with the system.[33]

Micro-hydro systems often have less of an environmental and social effect than large scale hydropower systems. There is less of an interference with the river flows since only a small portion of water is needed to make a low-head turbine spin and there is no need for the construction of a large dam. Both of these factors make micro-hydropower more "favorable" when the situation is appropriate to install a smaller system.[34]

2.3.4 Tidal Energy

The use of tides to produce power has been around for over 1,500 years making it one of the oldest ocean energy technologies used today. One of the earliest systems used was a tide mill which would be used to mill and grind grain as the tide when in and out. Although tide mills are not as commonly used today, there have been many technological advances made for the use of tides as a power producer.[35]

All coastal areas experience two low and two high tides in the period of one day. Despite the fact that not every coastal location is suitable to produce tidal energy, there are still over 40 sites throughout the world that could potentially harness the power of the tides. Presently no tidal plants have been installed in the U.S., but there are many promising areas in the Northeast and Northwest.[36]

Currently there are three major tidal technologies that are being used to harness tidal power. The first one is a tidal barrage or dam which uses a system of gates to force the water through a turbine which then activates a generator. The second is a tidal fence which is similar to a turnstile and will spin due to the tidal currents. And the third is tidal turbines which are very similar to wind turbines and usually set up in a similar fashion as wind farms. Similar to tidal fences, these turbines will spin due to tidal currents.[36]

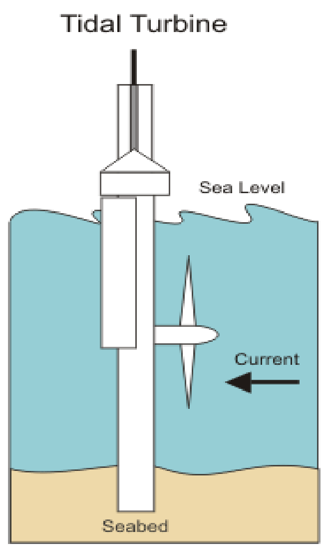

Figure 14: Tidal Turbine

Although not very many tidal power plants have been installed there are a few select sites throughout the world that have found success in using the tides to produce power. The largest and oldest plant is located on the Rance River in France and makes use of a barrage system. There are also plants located in the White Sea in Russia, as well as in Canada and Norway. A great promise for potential power is also located in Asia and as previously mentioned the U.S..[37]

2.3.5 Wave Energy

Wave power is generated by using either the energy on the surface of the wave or the pressure changes directly below the surface. With an estimated potential of 2 TW of electricity generation, wave power technology is proving to show a lot of promise. Despite the fact that wave power cannot be harnessed in all locations, there are many "wave rich" areas throughout the world, including many in North America.[38]

There are both off-shore and onshore systems which can be installed, each having their own advantages and disadvantages. Off-shore systems are typically located deep underneath the water, however there are more advanced technologies that have been developed that are floating devices.[38] The two most noted systems are the Salter Duck, which uses the bobbing motion of waves to power a pump and the Pelamis which is a semi-submerged system linked with hinges that pumps pressurized oil through hydraulic motors that drive a generator.[39]

Onshore systems are built along the shorelines and will use the energy of breaking waves to create power. There are three main technologies which are used onshore: an oscillating water column, a tapchan, and a pendulor device. An oscillating water column uses a device that is partially submerged and allows waves to enter the air column. After the waves enter the air column, it will rise and fall, which will change the pressure of the device. The wave then leaves the device and air will be pulled back trough the turbine generating power.[38]

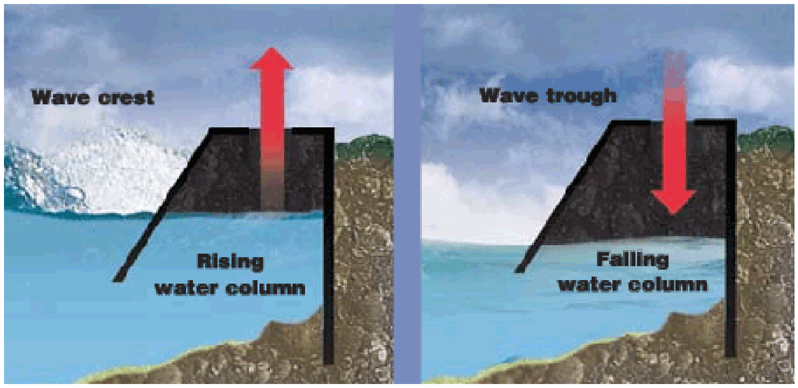

Figure 15: Oscillating Water Column

A Tapchan, which is also known as a tapered channel system, is comprised of a channel which directs waves into a reservoir constructed above sea level. The channel will narrow as it moves towards closer to the reservoir, which will cause the height of the wave to increase. The waves will hit the wall of the reservoir and spill over the top. From here the water is then fed through a turbine where power is then generated. A pendulor device is a much simpler design that is comprised of a rectangular box with one end open. A hinged flap is placed over the opening and as waves hit the flap it will swing back and forth which will power a hydraulic pump and generator.[38]

There are slight public concerns with onshore systems, as people feel these systems are not aesthetically pleasing. In order to avoid many of these concerns the off-shore systems are becoming more developed. Some of the challenges with this however, is that these systems must be able to withstand the force of a wave and over time the equipment might not last as long. Overall, the environmental impacts of these systems are trying to be kept at a minimum.[38]

2.4 Solar Power

According to the World Energy Council the annual solar radiation falling on the earth is more then 7,500 times the world's total annual primary energy consumption of 450 EJ. If all this solar energy was to be harnessed, it would be greater than all non-renewable energy sources (including fossil fuels and nuclear) combined.[40]

Solar energy is making use of the sun's rays to create other forms of energy and according to NASA this energy has been powering life on Earth for millions of years. This energy can be converted into both heat and electricity and can be used on either a residential or industrial scale. Currently there are various technologies used to harness solar power, however the two main ways to convert solar power into electricity is through concentrated solar power (CSP) plants and photovoltaic (PV) devices.[41]

2.4.1 History

Solar power dates back to ancient Greece and Rome. The Greeks and Romans used what we know as Passive solar to heat and light their homes. This was used in place of other methods of heating and lighting their houses year-round. Sun light wasn't used for direct power generation until 1861 when Auguste Mouchout invented a steam engine powered by the sun. The engine was not cost effective compared to other energies at the time. This invention was the beginning of solar power generation, and many other scientists continued to develop way to harness power from the sun throughout the 19th century.

During that time there were many designs of concentrated solar power which is a technique still used today. However there were no major breakthroughs in efficiency or cost reduction. In 1953 the first PV cell was developed from silicon. This technology was still too costly, almost six hundred times the price of PV cells today. Major research and money was not given to solar power until the Oil embargo of the 1970s. Countries realized their dependence on Oil and needed to develop new independent forms of energy. [42]

Slowly the price of solar cells was brought down by research and technology. It became cost effective to place PV on objects that were long distances from power lines, such as satellites and offshore oil rigs, in the 1950s and 1960s. During the 60s and 70s more applications for PV were devised. Most of these new applications had small power needs, such as ocean buoy, railroad warning signs, and some telecommunication towers. The 1980's saw the first roof installation of PV. However it was not until the 1990s were great breakthroughs in PV cells made it economical for the mass use of PV.[43]

CSP was only used in small applications for heating water and heating homes up until the 1980s. In the 1980's large solar collection power plants were constructed to show that such plants are capable of generating multiple MW of energy. These plants also had advanced power storage systems to prove that a steady stream of electricity could be providing from a large scale solar plant.[44]

2.4.2 Photovoltaic Power

PV are a form of solar power where sunlight is directly generated into electricity. PV cells are commonly made from semiconducting materials including Silicon, Copper, and Cadmium. These materials can be arrange in a variety of shapes including single crystal, poly crystal, ribbon, and amorphous. Different materials and different shapes are used to create high efficiencies for different applications.[45]

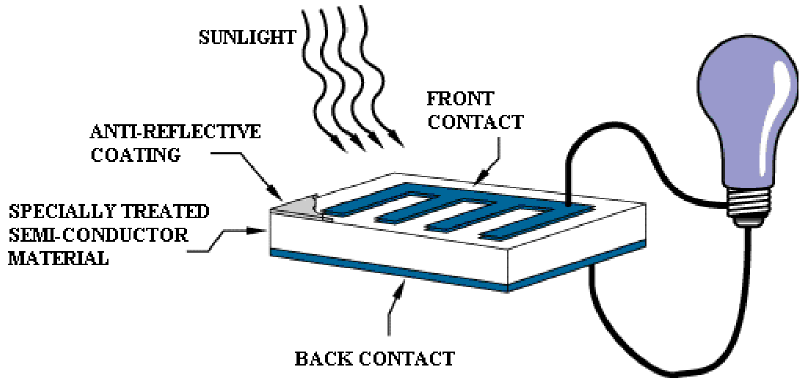

Figure 16: PV Cell[46]

When sun light hits a PV cell, electrons are given off. The PV cells are placed on a panel with wires running through the cells to form a solar module. When many cells give off electrons they move between different cells creating electricity. The wires in the panel then gather this electricity and carry it out of the panel. When modules are linked in an electrical series they are known as a solar array.

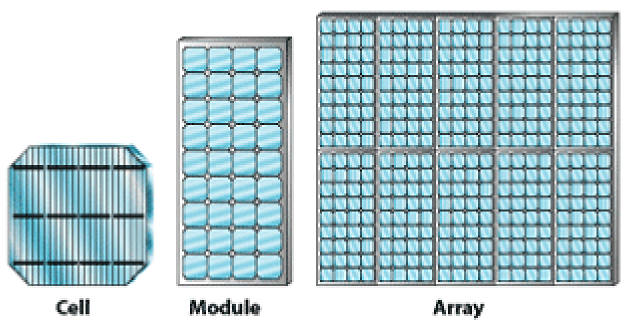

Figure 17: PV System[47]

Each Module is rated for its maximum power generations, Wp which is the maximum amount of W it can generate at any given time. When modules are connected in series to form an array the Wp is the sum of all of the modules Wp. Electricity generated from PV cells is in DC form. In order to be used in most electrical appliances or put back into the grid the electricity must be inverted toAC.[48] Batteries can be added into the system for energy storage to allow for energy during times of the day without sunlight.

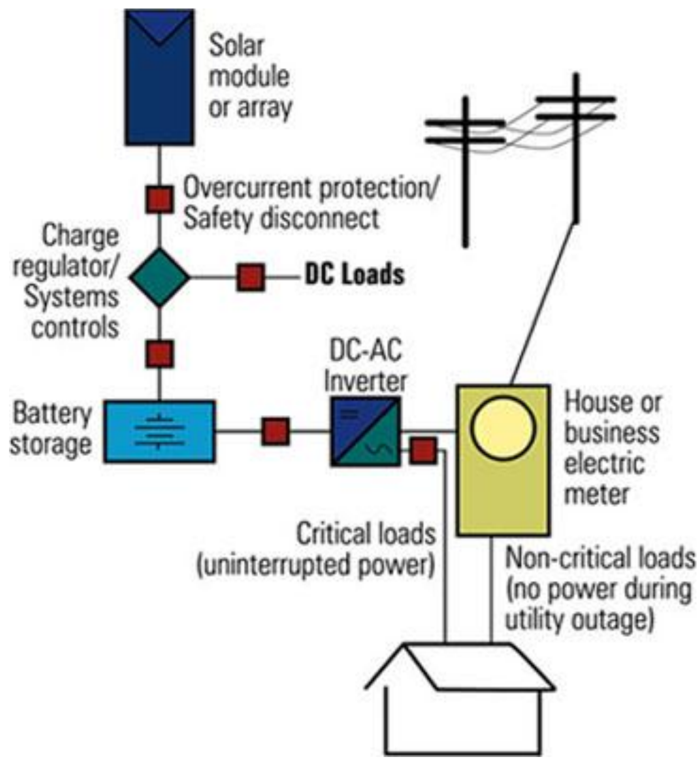

Figure 18: PV Household System[49]

There are many issues with integrating solar power into utility grids. Solar power is an intermittent source, because the sun does not shine constantly. This is different from a coal or nuclear plant which can run twenty four hours a day and because of this many utility companies will not allow large portions of the generated power to be solar. Solar power is too unpredictable and if used on a large scale it could cause power outages. Some utilities do allow smaller PV users, normally residential customers, to sell back unused generated electricity. The rate is often limited and varies between utility companies. Large PV plants need advanced energy storage capabilities to be accepted by a utility provider to generate large amounts of electricity for grid use.

Solar panels cone in a variety of sizes. Small home kits have solar panels as small as a single watt. A solar array is theoretically limitless because any amount of solar panels can be connected in series. The largest PV generating plant in the world is located in Spain and is rated at 60 MW and produces 85 GWh annually. The 10 largest PV plants in the world generate more than 30 MW of power, and the 50 largest PV plants generate more than 10 MW.[50]

Figure 19: Solar Power Plant in Spain[51]

Current and future research in PV is on improved efficiencies and reduced costs. The NREL is currently conducting research on PV materials, development of PV cells in material systems, modules, improved performance and reliability, and the commercialization of new PV technologies. [52] Another area of research that will benefit PV is energy storage. Improved energy storage systems will allow for more large scale integration of PV electricity into utility grids.[53]

2.4.3 Concentrated Solar Power

CSP or concentrating solar power systems uses the sunlight to create high temperatures (generally between 400 and 1000° C) that will be used to produce electricity or heat. This is done by using mirrors to reflect and concentrate the sun's rays into a small beam opposed to trying to harness the power over an extensive area.[40] In order to produce electricity in a CSP system, the sunlight is used to heat a fluid to a certain high temperature. Once this fluid is hot enough it will be used power an engine or spin a turbine, which then drives a generator. The generator then produces electricity for output.[54]

In addition to the fact that CSP systems are very efficient, they can also be integrated with other systems and can be equipped with storage units or can be used in conjunction with fossil fuel systems as a "hybrid" system. There are various CSP systems and technologies used today, however there are three "main" systems to look into. These systems are linear concentrator systems, dish systems, and central receiver or tower systems. [55]

A linear concentrator system is comprised of a large quantity of collectors in parallel rows that direct the sunlight onto a linear receiver tube. Typically linear CSP systems are broken down into two different types of technologies, parabolic troughs and linear fresnel reflector (LFR) systems. When using parabolic troughs the reflectors are situated with a receiver tube which contains a fluid. This fluid is then heated (either into water/steam or a heat transfer liquid) and transferred out of the trough field to a location where steam can be generated for power. A linear fresnel reflector system is very similar to a parabolic trough, however it uses flat or slightly curved mirrors that reflect the sunlight onto a receiver tube fixed above the mirrors. The fluid in the receiver tube is then heated and transferred out of the tube in a similar manner to the parabolic trough system.[54]

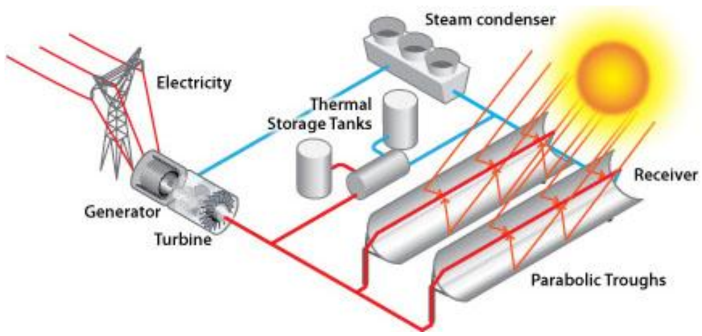

Figure 20: Parabolic Trough System

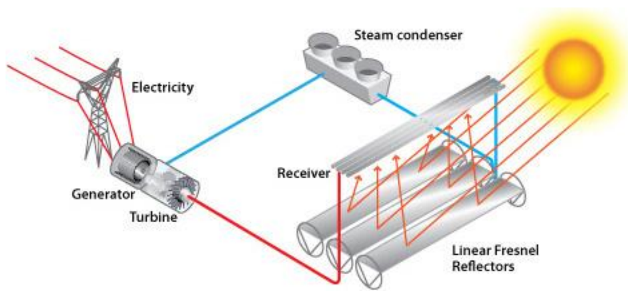

Figure 21: Linear Fresnel Reflector System

A dish system simply uses a dish, or solar concentrator, to collect the solar energy. The concentrated solar energy beam is then directed towards a thermal receiver which gathers the heat produced. Commonly, the dish is assembled to a structure that tracks the sun throughout the day to gather the greatest amount of solar energy possible.[54]

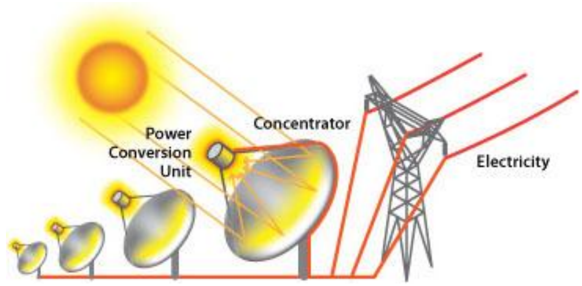

Figure 22: CSP Dish System

Lastly a central power or tower system uses heliostats, which are flat sun tracking mirrors, to direct the sunlight onto a receiver located at the top of a tower. The receiver contains a heat-transfer fluid which in turn generates steam. Any number of heat-transfer fluids can be used including water/steam, molten salts, or air. The steam that is generated is then used in a turbine generator to produce electricity.[54]

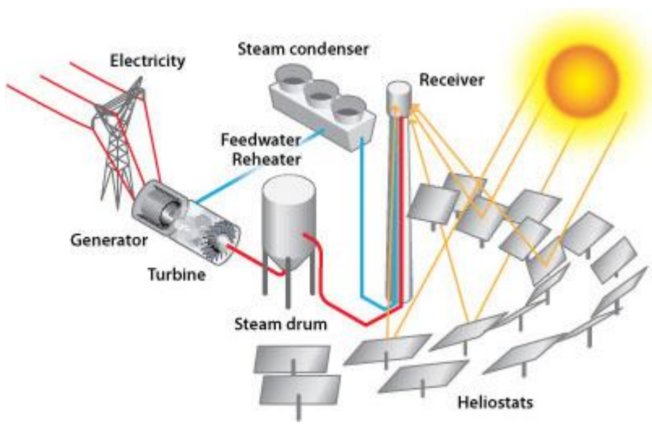

Figure 23: CSP Tower System

2.5 Wind Energy

Wind power is broken up into two main categories, onshore wind power and offshore wind power. The main difference between the onshore and offshore is the foundations. The foundation's size and shape vary between land and ocean applications. The most common foundations are gravity base, rock anchored, and deep foundation. The same turbines are used for both; however larger models are often used in the ocean.

2.5.1 Wind History

Wind Energy is a very general term. Energy can be harnessed from wind in many different forms. As early as 5000 B.C. the Egyptians used Sails on boats to propel them up and down the Nile. Around 200 B.C. windmills were being used in China, the Middle East, and Persia to pump water and in food processing. Wind was used all over the world for these purposes until the early 20th century. Denmark used a couple thousand of wind mills to drain water from the Rhine River around 1900.

The first wind mills constructed for the purpose of generating electricity were built in Scotland and Ohio in 1887. Over the next forty years more wind mills were constructed to produce electricity. The wide spread use of wind turbines wasn't until the 1930s. Companies began to mass produce wind mills which were used to generate electricity on farms in the great plains of the U.S. Wind turbines were used on farms that were out of reach of utilities to power lights and charge batteries.[56]

The idea of wide spread power generation from wind did not appear until the 1970s oil crisis. This was the first time that research was conducted to find ways to convert wind power into conventional electricity. Research was conducted on how to better produce electricity from wind and how to better connect it to utility grids.[57]

Today there is over 120 GW of global wind power installed. Europe accounts for roughly half, and North America accounts for one quarter of the globally installed wind power. Wind turbines as large as 5 MW are being installed across the world, with an average size around 1.5-3 MW. [58] Studies have shown that the global potential of wind energy is more than seven times the global demand in 2000.[59]

2.5.2 Wind Turbine Design

Wind turbines all work in a similar process. Wind power is generated by turbines that are powered by blades. The blades are connected to a rotor with a shaft that travels back into the nacelle, which houses the gear box. The gear box then increases the RPM to a level at which the generator operates. The blade and generator assembly are placed on top of a tower are generally 50m to 80m above ground. This height varies depending on manufacture and the optimization of available winds.[60]

Wind turbines have a range of wind speeds at which they can operate. They are known as the Cut in and Cut out speed. They vary by manufacture, but cut-in speeds average around 8mph and cut out speeds around 55 mph.[61] The cut-in speed is the lowest speed at which the generator is able to operate. The cut-out speed is the speed at which the stresses on the structure become too high. When this happens a brake will stop the blades from spinning. Some models also rotate 90 degrees to lessen the force.

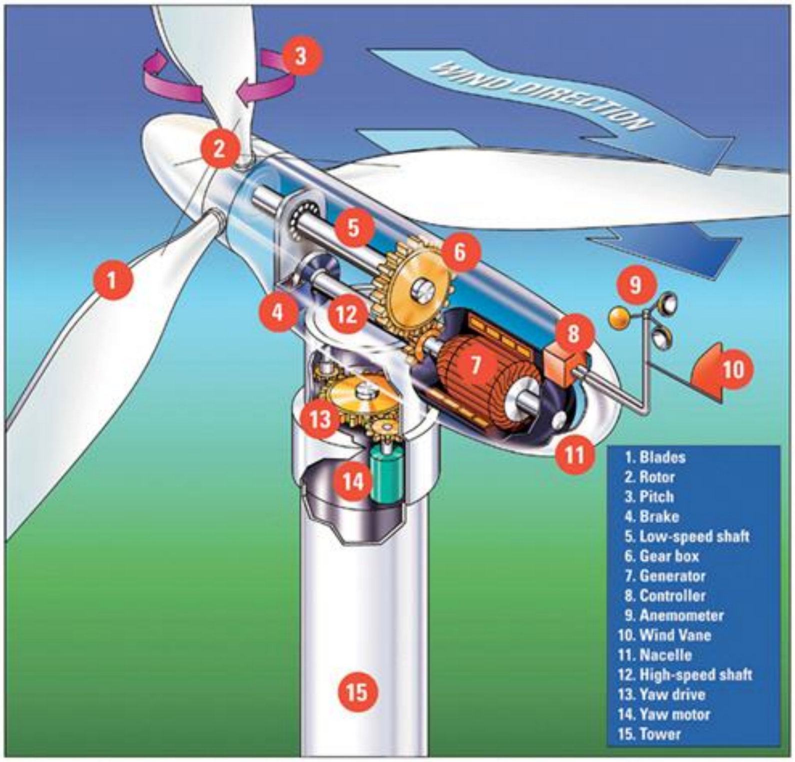

Figure 24: Wind Turbine[62]

The maximum theoretical efficiency of wind energy is governed by the Betz limit, which is 59 %. Due to characteristics of wind the Betz limit is the mathematical limit of the amount of energy that can be harnessed from wind. If 100% of the energy available were to be extracted from wind the turbine would have to stop the wind. If this were to happen the wind would blow around the turbine.[63] Power available from wind greatly increases with the increase of wind speed. The power available in wind is the cube of its wind speed. This means that if the wind speed doubles, the power available is multiplied by eight. Wind turbine efficiency is ultimately measured by its capacity factor. The capacity factor is used for all power generation and is the amount of power produced over a period of time divided by the power that would have been produced if the turbine operated at a maximum output of 100% during the same period. Because the wind does not constantly blow a capacity factor of 25-40% is normal. [64]

Current and proposed research on Wind Turbine focus on technologies that will be more cost effective at lower wind speeds. As many of the best wind resources in the world are being used technology must be designed to accommodate lower wind speeds. Other research topics include grid integration and environmental issues and making offshore wind power more cost effective.[65]

2.5.3 Onshore Wind Power

Onshore wind power consists of all wind turbines located on land. In recent years the size of turbines located on land has ranged between 1.5 MW and 3 MW. This has allowed for mass manufacturing, reducing price and increased quality.[6] Foundations for each site are designed specifically for that location depending on the size of the turbine and the characteristics of the soil. Most foundations are concrete with reinforced steel.

Two of the largest wind farms are located in the US. The Roscoe Wind farm in Texas went online in October 2009 rated at 781 MW, just bigger then the Horse Hollow Wind Farm in California with 736 MW.[66]

Figure 25: Wind Farm[67]

2.5.4 Offshore Wind Power

Offshore wind power consists of all wind turbines with foundations located in Water. Oceans, Seas, and lakes tend to be better locations for wind turbines due to stronger and more sustained winds. The price of offshore wind is higher due to longer distances from the utility grids and larger foundations needed. Currently all offshore wind turbines in the world reside in shallow water less than 30m deep.[68]

Figure 26: Offshore Wind Farm[69]

Offshore wind turbines have many advantages. Wind in the ocean is stronger and more stable, allowing for better efficiencies. These more efficient winds are also closer to many metropolitan areas that have the largest electric demand than the best onshore sites. With wind turbines being placed at sea, a majority of the negative thoughts about visual impacts of wind turbine will be lowered. Due to the fact that offshore winds are stronger and more consistent, larger more economical turbines can be installed. There are also fewer constraints on shipping and construction, allowing for lower costs.

When offshore turbines are design additional parameters are included. Foundations must be designed different to accommodate for higher towers as well as additional forces on the tower from waves. Towers must be designed to be stronger due to waves and extreme weather conditions. Also considerations due to erosion from sea water must be taken. Research on new designs for foundations is being conducted to try to lower the overall cost and allow wind turbines to be placed in deeper waters.[70]

3 Methodology

The goal of this project was to analyze the feasibility of future renewable and sustainable energy alternatives. The findings were compiled into a best practices manual (BPM) for Stantec Consulting Inc. employees to use as a reference for client consultations. The BPM was also condensed into a table and "checklist" in order to be able to quickly analyze which renewable energy option would be applicable and require an in-depth feasibility study. Below is a list of objectives that were completed in order to achieve the overall goal:

1) Research renewable energy alternatives
2) Determine the feasibility considerations of a particular renewable energy option
3) Compile findings into a BPM
4) Develop a checklist to help determine which renewable energy option is most applicable in a particular situation

The following sections describe the methods adopted to achieve each of these objectives. To see when each objective was completed, please reference the timeline in the appendix.

3.1 Research Renewable Energy Alternatives

In order to reach the final goal of creating a BPM, the first step was to conduct preliminary research on renewable energy alternatives. Based on past projects and what Stantec's clients are interested in, the renewable energy alternatives researched were

Biomass, Geothermal, Hydropower, Solar, and Wind power. Under each of these main categories, there are subcategories of which more in-depth research was performed. The subcategories are listed in Table 1.

Topic	Subcategories
Biomass	• Wood • Waste-to-Energy • Algae • Landfill Gas • Biodiesel
Geothermal	• Ground Source • Deep Well
Hydropower	• Micro-Hydro • Tidal • Wave
Solar	• Photovoltaic • Concentrated
Wind	• Onshore • Offshore

Table 1: Research Topics

Using this general outline each of these subcategories were researched based on specific information that would be useful to know during a client consultation or a feasibility study. Some of the specific information that was researched was overall cost of a system, payback period (not only for the equipment, but for the overall system), "ideal" locations for these systems to be installed, downsides and public concern, and best applications. The various technologies applicable to each system were also researched.

Most of the information that was gathered was found on the web. One major concern was the authenticity of the website and whether or not the information was biased or in fact correct. In order to ensure a site was authentic, mainly government websites or websites/organizations sponsored by government agencies were used for final research. Studies and documents done by Universities were also used as reliable sources. Websites that were sponsored by legitimate organizations (such as The National Hydropower Association or the International Energy Agency) with credible sources were often cited as well. Sites such as Wikipedia were not used, although their resources often lead to case studies and informative data.

The next form of research that was used was emailing government agencies for additional information on a particular topic. On a few websites it was noted that not all of the information was published or placed online. In these situations the agency or specific person mentioned was contacted to request additional information. This was a very favorable method of retrieving data due to the fact that the people contacted were very interested in the research that was being performed.

Another method of research used was speaking with Stantec employees about particular projects or knowledge they had on a particular topic. Either meetings or conference calls were set up and an interview was conducted. A description of the project at hand was given as background information and then specific questions were asked. A general outline of the questions asked is below. Although this was the basis for the interviews performed, questions were often catered specifically towards what the interviewee's main concentration in the field of engineering was.

1) What do you think Stantec needs to keep moving forward in the renewable energy sector?

2) What projects dealing with renewable energy have you worked on?

3) In your opinion, what renewable energy option shows the most promise for growth and development?

4) What are the steps you currently take when evaluating potential renewable energy alternatives?

5) Any opinions or input on a particular renewable energy source?

The final method of research was using the Worcester Polytechnic Institute's (WPI's) library and online literary resources. Through WPI's library website literary magazines, as well as previous MQP's and scientific journal articles were accessed.

3.2 Determine the Feasibility Consideration of a Particular Renewable Energy Option

Based on the type of "energy saving" a client wants to do will help determine the type of renewable energy alternatives available for them to use. Not every renewable energy option will be feasible to use in every situation. A location, land availability, and permit requirement are some factors to consider.

The most efficient way to determine the feasibility of a particular renewable energy option was to determine where it could be installed and where it couldn't be installed. This was done by simply researching ideal locations for the specific option. Not every renewable resource option can be installed in every location and this will help determine if the application is feasible quite quickly.

If the location for an option was very broad (for example you could install it almost anywhere) then the land availability was investigated. Certain renewable energy alternatives require a certain amount of space for construction and installation. This can be a limiting factor when determining if an option will be applicable in a specific situation. For many types of systems there are different technologies that can be used for the same purpose. In this situation, it is up to the engineer to determine if it is feasible to put one particular system in use over another and why it would be more appropriate.

3.3 Compile Findings into a Best Practices Manual (BPM)

One final product of this research is to create a BPM with all of the research. A best practice is a method, process, technique, incentive, or activity that is believed to be more effective during a particular outcome than any other technique, method, or process. The idea behind this is that with appropriate processes, checks, and testing, a desired outcome can be delivered with fewer problems and unforeseen complications.

A BPM is basically a collection of best practices that are inter-related (for this case all different types of renewable resource alternatives) compiled together into one document or manual. The BPM that was created will be used for further in-depth research when looking into a specific renewable resource option. For example if a client is particular interested in wind power and wind turbines, a Stantec employee can specifically look in that section of the manual to find out any extra information they need to know before speaking with the client.

Using all of the research gathered through the first two objectives, the BPM was organized in 5 sections, one for each of the renewable resource alternatives. These sections were then each organized into sub-sections. Each of the sections have the same sub-sections in order to make the manual consistent for easy comparison of technologies.

The sub-sections are types of technology, best location, cost range, efficiency, downsides/environmental impacts, and case studies.

3.4 Develop a Checklist to Help Determine which Renewable Energy Option is Most Applicable in a Particular Situation

Once all of the initial research for each renewable energy option was completed and organized in the BPM, a more condensed form of the data was created. Through speaking with more knowledgeable engineers, a checklist was determined to be the best format for organizing the most important information that is needed when determining which renewable resource option would work best in a particular situation. Although this checklist is not designed to only give you one option, it does help narrow down the number of advanced feasibility studies that must be done.

The main idea behind the checklist is that any one of Stantec consultants that are not familiar with renewable energy alternatives could use it and find it helpful. Although the checklist is not the ideal product for a more advanced engineer, it is a great stepping stone for entry level engineers. Many senior engineers already know most of the information that the checklist includes (especially if renewable energy alternative is their specific expertise), however it is knowledge that not everyone else would know.

The checklist is organized by renewable energy alternatives and their individual technologies. For example Biomass has 5 sub-technologies (algae, landfill gas, wood, waste-to-energy, and biodiesel) and Wind Power has 2 sub-technologies (onshore and offshore). The checklist is compiled with information that would be "useful" to know when choosing which system to design. For example cost, ideal location and efficiency are all topics that would be helpful to know prior to choosing a system. The idea of the checklist is to simply aid a consulting engineer to choose which renewable energy resource would be applicable or not.

In many situations more than one renewable resource option can be applicable. From here the BPM can be used as a reference to see if there is any additional information the client may need. A more in-depth feasibility study can also be done for each applicable option. The checklist is to be used to screen for renewable energy alternatives instead of conducting feasibility studies for each option only to find out that it will not work.

Another supplemental item to go along with the checklist is a condensed table of information. This table is a comparison of all of the different technologies for each renewable resource option. The table includes information that is both in the checklist, as well as in the manual. As opposed to looking through the entire manual to find one specific piece of information, the table can be used as a quick reference. See the table below for design format. This is not the complete chart with every category, but it is similar to the one that was created.

	Onshore Wind	Offshore Wind	Deep Well Geothermal	GSHP Closed Loop Horiz.	GSHP Closed Loop Vert.
Cost					
Ideal Location					
Land Requirement					

Table 2: Comparison Table Design

Both the checklist and the comparison table are located in the back of the BPM for easy accessibility. These tools are to be used in conjunction with the BPM, which has the more detailed information. After using the checklist and comparison chart and a renewable resource option is chosen, then a further in-depth feasibility study will take place.

4 Results and Findings

4.1 Research Renewable Energy Alternatives

There were two stages of research that was performed. The first stage of research was the background research to understand the different technology of each system and in which situations it was applicable (see Section 2: Background). The second stage of research was the more in-depth detailed research. This research focused more on the cost, payback periods, cost of power, efficiency, ideal locations, downsides, and environmental impacts of each renewable energy option. Research was also done by meeting with Stantec employees about renewable energy alternatives with which they had experience.

4.1.1 In-Depth Research

A majority of the in-depth research that was performed is encompassed in the BPM (see Appendix A). There is some information however that is not included in the BPM. Currently the U.S. is very fossil fuel dependent, which has many negative impacts on the environment. In 2008, there was a total energy consumption of 99.305 quadrillion Btu and 83.436 quadrillion Btu from fossil fuels. See Figure 27 for the percentage of energy consumption by sector.[71]

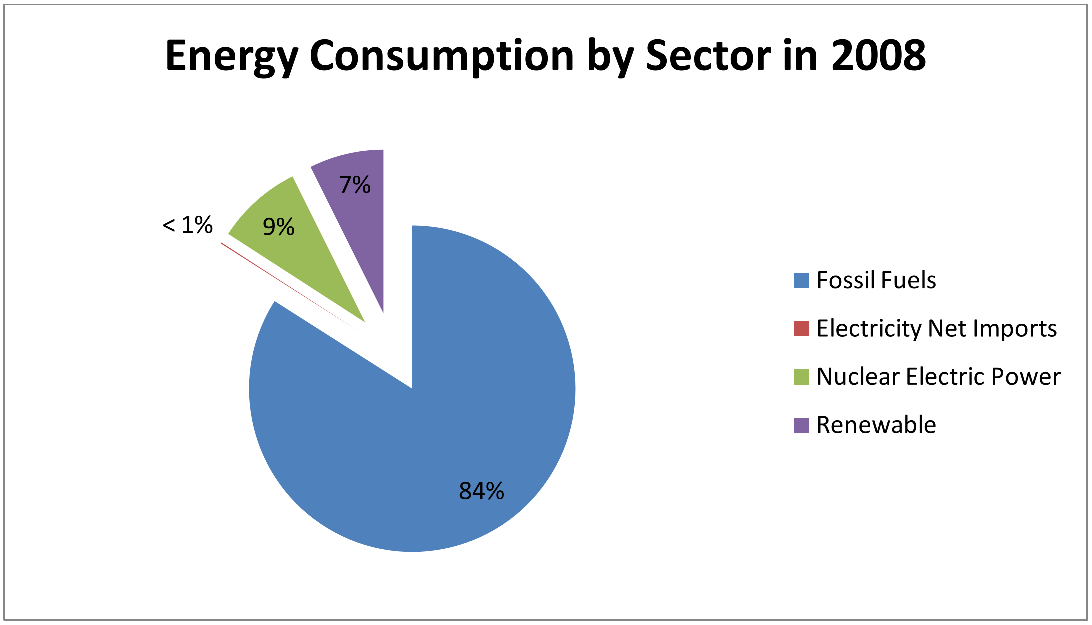

Figure 27: Energy Consumption by Sector in 2008

Over the last 5 years there has been a steady increase in the net electric capacity for renewable energy, but this is still significantly less than fossil fuels. The US still relies on the use of fossil fuels to generate power despite the fact that there is new technology to generate "clean" power. Figure 28 represents the US Energy Consumption by Energy Sector between 2004 and 2008. As shown the use of renewable energy to generate power has slightly increased, but it is still minimal when compared with the amount of power that is generated by fossil fuels.[71]

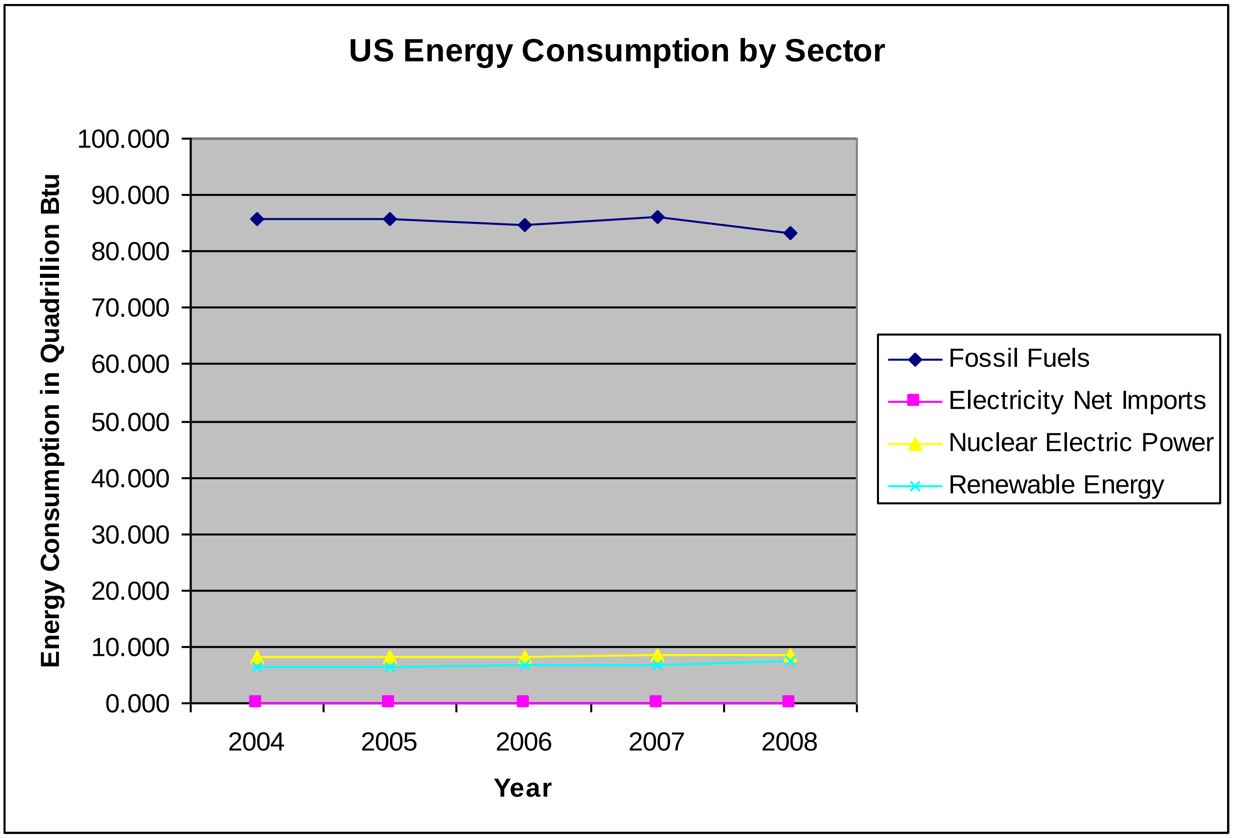

Figure 28: US Energy Consumption by Sector between 2004 and 2008

4.1.2 Meetings

There were three particular Stantec employees that were collaborated with. Klaas Rodenburg is Stantec's Sustainable Design Coordinator and the overall project advisor. Klaas aided the team in establishing necessary connections with other Stantec employees, as well as guiding the manual design based on Stantec's needs.

A presentation and informal interview was had with Tom Phelps and James Borden. Tom Phelps is from the Raleigh, North Carolina office and has over 27 years of experience in engineering design and management. He has managed many projects dealing with energy design and distribution and has dealt with various District Energy projects.

Prior to meeting with Tom Phelps a list of interview questions were sent to him. His written responses are as follows:

1) What do you think Stantec needs to keep moving forward in the renewable energy sector?

   A concise, rational, systematic checklist for prioritizing both renewable technology options and financial impact could be a great “market differentiator” for Stantec. It’s a way of clearly demonstrating that “we know our stuff”. …..in short, a diagnostic tool/process. Too frequently, renewable energy alternatives are selected for study (or even for project inclusion) based on ‘cool factor’ or other non-rational basis. While this works for clients who want to be leading edge, this approach does not work for the bulk of our clients, who generally require a sound financial basis for inclusion of these technologies. LEED qualification is based on a ‘points system’, which is primarily non-financial. If the choices put forward don’t make financial sense, most clients aren’t interested.

2) What projects dealing with renewable energy have you worked on? And if so, do you have a summary of the project/where could we find a summary?

   I’ve done a number of biomass (wood) boiler plant conversion studies, and am currently working with a solar thermal system start-up company that incorporates evaluation, design, installation, and financing as bundled services. I have no written descriptions for these.

3) Do you know of any good online resources or reliable agencies that have data/figures about renewable energy resources?

Far too many to list here. Also, my recommendations would depend greatly on the objective you're trying to achieve. For statistics on the U.S., start with the EIA. For a directory with links to many Alternative Energy web pages, start with http://www.energyplanet.info/Alternative_Energy/

4) In your opinion, what renewable resource option shows the most promise for growth and development?

   In North America, wood energy is (and has been for a very long time) the 2nd most prevalent renewable energy source, behind hydro. It is applied successfully only on an industrial scale, and usually in conjunction with forest products industry installations. Other biomass is economic under special circumstances, especially where it is available cheaply, usually as a crop by-product. Active solar thermal is financially viable and likely to become more prevalent at residential and institutional scale. Geothermal heat pumps can be economic at both residential and district energy system scale. Solar PV is clearly non-economic without substantial renewable energy 'premium' or tax credits. In most circumstances, wind energy also has limited financial feasibility. In both cases, their main weakness is poor availability and low load factor. For wind and solar PV, these obstacles cannot be overcome without a factor of 3 or more capital cost reduction, or 3x electricity cost increase, or quantum technological leap in energy storage technology.

5) Any opinions or input on a particular renewable energy source?

   District Energy (DE), especially in conjunction with Combined Heat and Power (CHP), has significant market penetration now, and is poised to become much larger. DE/CHP can be fueled with renewable fuels, but usually isn't. However, it usually results in CO_2 emissions reductions of half, compared to conventional energy sources. Also, chilled water thermal storage has significant financial benefits, but little beneficial environmental impact.

6) What are the steps you currently take when evaluating potential renewable energy alternatives?

   1st: What are the client's priorities and key issues for the project? If, for example, capital cost is fixed (as it usually is) many high capital cost / low operating cost options are immediately ruled out. 2nd: Examine the local availability and prices of each conventional fuel, and (especially) electricity. This exercise quickly rules out some options. 3rd Do a first-order estimate of the peak and average thermal and electric loads the client's installation is likely to require. 4th : examine any available tax credits or renewable energy credits. (These used to be of minor impact, but no longer.)

7) Are there constraints (e.g. site-specific, general related to geography or topography, etc.) that are common that we should take into account in preparing our BPM?

   Too many to list

8) What specific items would you find most useful in a BPM?

   See number 1 above.

During the meeting with Tom Phelps and James Borden additional probing questions were asked based on the information that Tom Phelps already provided. James Borden also provided feedback on some of the questions that were sent to Tom Phelps.

The overall result of the meeting with Tom Phelps and James Borden was that senior engineers already know a lot of the information a BPM would provide, however entry level engineers do not have the experience to know how to analyze a particular renewable energy option.

Tom Phelps and James Borden also gave the team suggestions as to what information to look for and how to design the manual. Many of Stantec's clients will come in and be interested in one particular renewable energy option, without looking at the "bigger" picture. The point behind the manual is for a consultant to just be able to quickly look up information for a renewable energy option and determine if it is even a feasible option. Tom Phelps and James Borden also suggested that the manual be used as a way to quickly assimilate the "criteria" that is known by senior engineers and that it is part of a high level screening process. The overall experience with them was extremely helpful and gave the project further guidance.

4.2 Feasibility of Renewable Energy Alternatives

In order to determine if a renewable resource alternative is applicable in a specific situation a feasibility study needs to be performed. Outlined below are the results the team found when researching the feasibility of each renewable energy option. In 2008, the total net electricity generation from renewable energy alternatives was 371,688,391,000 kWh, with conventional hydropower generating 248,085,084,000 kWh. Figure 29 represents the net electricity generation for renewable energy alternative.[71]

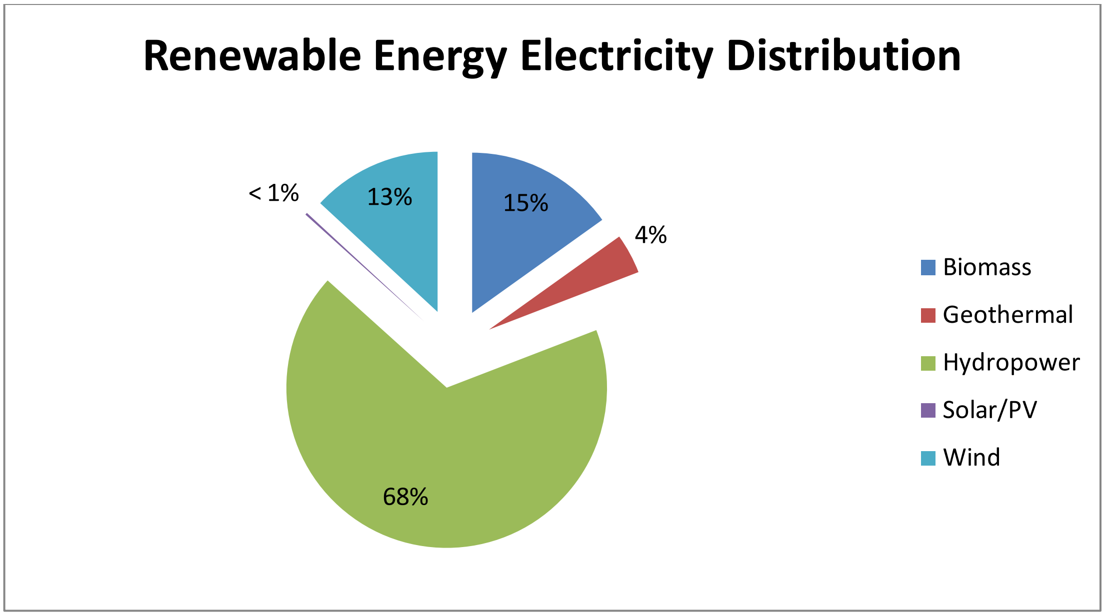

Figure 29: Renewable Energy Electricity Generation in 2008

4.2.1 Biomass

Biomass energy or bioenergy is one of the most recent renewable energy alternatives. Due to this fact, the technology is constantly changing and being improved upon. In 2008, biomass energy generated a total of 55,875,118,000 kWh. The break down for this power sector is represented in Figure 30. Municipal solid waste biogenic represents power from paper, paper board, wood, food, leather, textiles, and yard trimmings. Other biomass represents agriculture byproducts/crops, sludge waste, and other biomass solids, liquids, and gases.[72]

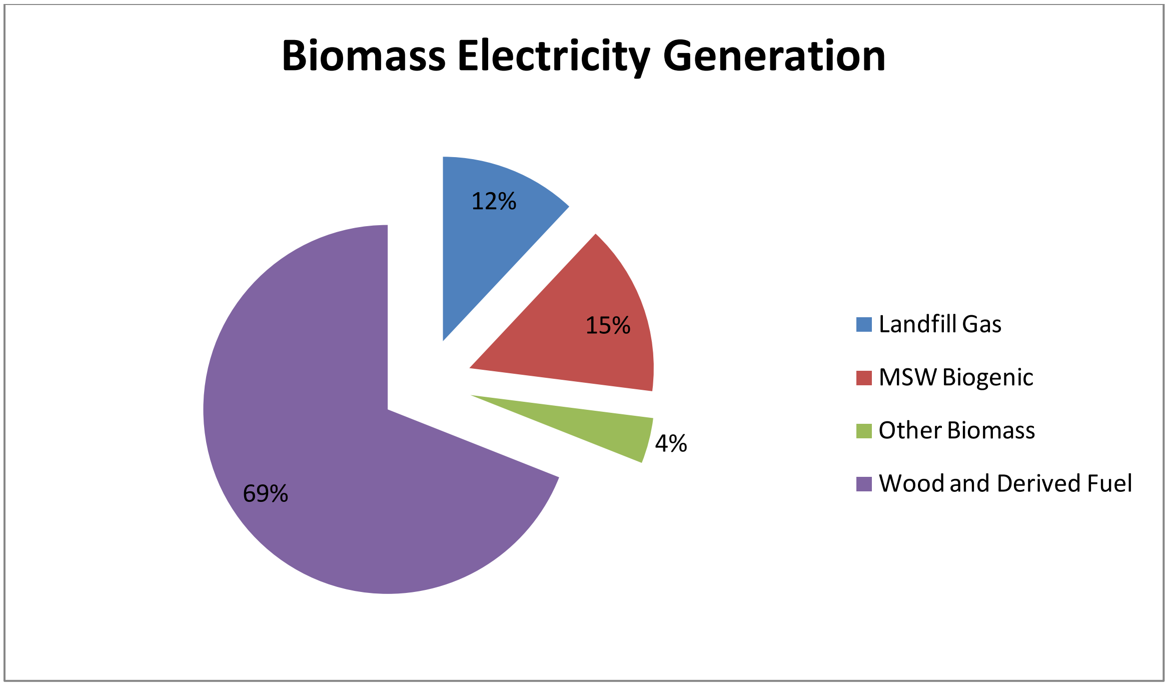

Figure 30: Breakdown of Biomass Electricity Generation in US

Currently wood and derived fuel (such as biodiesel) makes up the greatest amount of biomass electricity generation. Below are the subtopics that make up biomass energy and when their applications and most applicable.

4.2.1.1 Wood

A wood biomass system can be used on any scale, however the most common installations are for residential, commercial, and industrial applications. One of the limiting factors is whether or not there is an adequate wood source near the "chosen" site. Unless the site is within a 50 mile radius of a wood source, installing a wood biomass system is not an economically feasible option. The cost to transport the wood will increase the overall cost of the technology, as well generate emissions.[73]

It is very common for small wood biomass systems to be installed for residential applications to generate heat. Lumber mills will also use the wood scraps and wood chips to heat boilers to generate steam and fire kilns and to generate heat for direct use. Small scale wood systems will be between 65% and 75% efficient, making them good options for generating heat. Wood fueled power plants however are not as efficient and will only achieve a maximum efficiency of about 24%.[73]

4.2.1.2 Algae

Algae systems are typically large scale operations due to the amount of land required to install a system. The type of algae being grown will be the basis for what the ideal environmental conditions need to be, as well as whether the water it is being grown in needs to be fresh water or salt water. The two main types of systems that can be installed are closed bioreactors and open ponds. Closed bioreactors are often favored over open ponds because a closed system can be regulated unlike an open system that is subject to environmental changes.[7]

Ideally an algae “farm” is installed in a hot or tropical climate so the algae can be grown year round. The three main requirements for any algae system is a lot of land, warm temperatures, and adequate sunlight. Although an open pond algae farm can be installed in areas where the weather is not always warm, it is not an economically feasible option due to the fact that algae cannot be grown all year long. Closed bioreactors typically are not influenced due to the surrounding environment, however depending on the technology used to build the bioreactor outdoor conditions could affect the indoor conditions.[74]

Algae is grown to extract the oils that are found inside the plant, from which fuel can be generated. Due to the fact that the oils are the most important of the plant, the extraction technologies used to remove the oils are key to making an algae system feasible. The extraction technology used will vary based on the manufacturer of the equipment. One specific company, OriginOil, specializes in algae extraction and will have systems as efficient as 94% to 97%. Systems like this are ideal to use because there will be very little waste and more return.[75]

4.2.1.3 Landfill Gas

Landfill gas makes up about 12% of the electricity generated by biomass systems, producing 6,590,366,000 kWh of power.[71] Landfill gas systems are ideal to use in large landfills because they are harnessing harmful gases that would otherwise be released into the environment. Methane is one of the main components that make up landfill gas and also happens to be a harmful greenhouse gas, with a potency 21 times greater the carbon dioxide. By capturing these gases the negative impacts on the environment are being lessened and power is generated for consumption.[76]

The U.S. EPA created a profile for “candidate” landfills, which are ideal landfills for generating power. These landfills should have at least one million tons of waste and either still be in service or be closed for five years or less. For landfills still in service, horizontal extraction systems are ideal to use because none of the equipment is out in the open or in the way. The U.S. EPA’s Landfill Methane Outreach Program (LMOP) program estimates that there are 560 adequate landfills that can generate over 1,300 MW of power, which is the equivalent to 250 billion ft^3. per year of gas being captured.[77]

Landfill gas is not always the most efficient option due to the fact that it has less than 50% of the heating capacity of natural gas. Despite the fact that there is a reduced efficiency, landfill gas systems are extremely feasible in the appropriate situations. The fact that these systems not only prevent harmful toxins from being released into the environment, but also generate power make them multi-functional and an ideal system to use in landfills.[76]

Table 3 represents the waste energy consumption (in trillion Btu) by type of waste and energy use sector in 2007. As shown, landfill gas accounted for the largest generator, generating a total of 173 trillion Btu in 2007.[78]

Type	Sector				
	Commercial	Industrial	Electric Power		Total (Trillion Btu)
			Electric Utilities	Independent Power Producers	
Total	31	162	16	221	430
Landfill Gas	3	93	9	69	173
MSW Biogenic	21	6	5	134	165
Other Biomass	7	63	3	19	92

Table 3: Waste Energy Consumption by Type of Waste and Energy Sector in 2007

4.2.1.4 Waste-to-Energy

Waste-to-energy systems are ideal to install anywhere near an existing landfill (to reduce transportation costs) and not only eliminate landfill waste, but also generate power. These systems are typically installed on a larger scale and make use of waste that takes up space in one of the many landfills located in the US. Over 55% of the waste generate in the U.S. will end up in a land fill and about 14% of the waste generated will be burned in a waste-to-energy plant. Waste-to-energy plants are also cogenerators and will either create electricity for the grid or generate heat for buildings.[79]

Waste-to-energy plants are feasible to install due to the fact that they generate power from waste that would otherwise just emit methane and other harmful gases in landfills. The waste that is burned is not completely eliminated. Typically every 2,000 lbs of waste burned generates about 300 lbs to 600 lbs of ash. The fact that 4,000 lbs of waste is reduced by nearly 90% makes these systems extremely advantageous to install.[79]

4.2.1.5 Biodiesel

Biodiesel is a renewable energy option that is ready for wide spread use. Biodiesel can be used in any existing diesel engine. A few small and inexpensive parts in an engine need to be replaced and biodiesel will run just as well as petroleum diesel. Biodiesel has the advantage of reducing greenhouse gases emissions up to 75% and increasing lubrication in the engine, possibly extending its life span. Biodiesel can congeal and freeze up engines in cold weather however, with proper mitigation techniques, this can be avoided.[80]

Figure 31 shows the increase in biodiesel production between 2002 and 2006. As indicated there was a huge increase between 2005 and 2006 nearly tripling the production in one year alone. Due to this increase there was also an increase in the number of biodiesel distribution centers.[81]

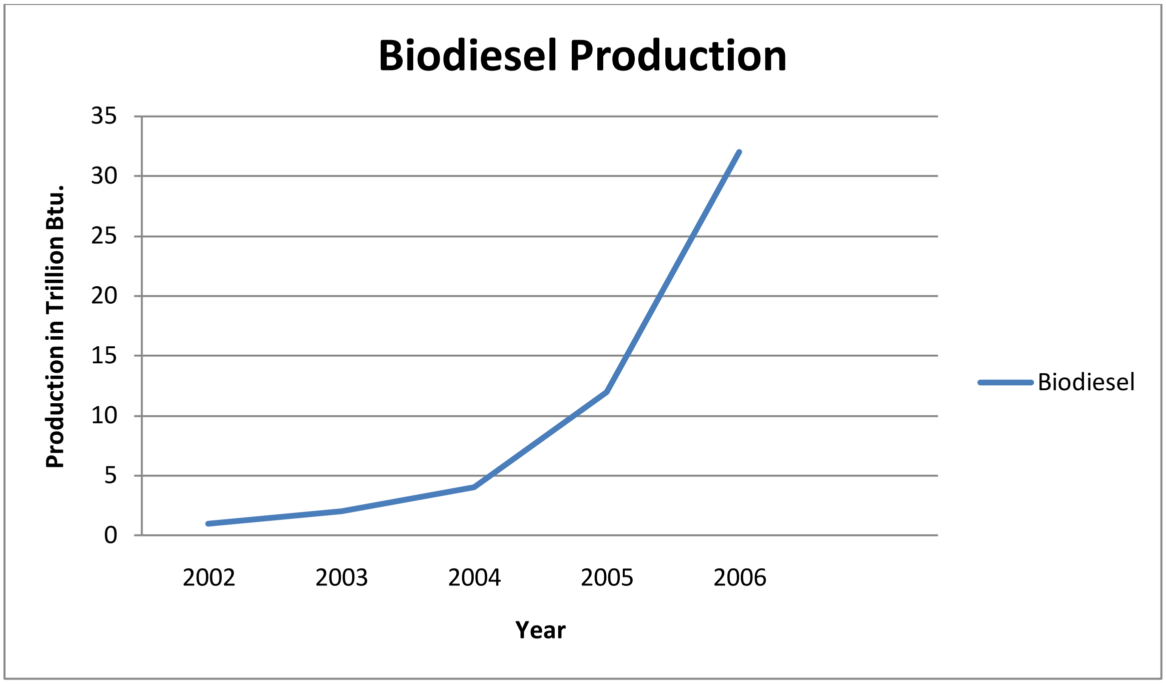

Figure 31: Biodiesel Production

4.2.2 Geothermal

Geothermal power only makes up about 4% of US renewable energy generation, with a net electricity generation 14,859,238,000 kWh in 2008. The two types of geothermal power researched were ground source heat pumps and deep well geothermal.[71]

4.2.2.1 Ground Source Heat Pumps

Ground source heat pumps are most applicable to use on a residential or commercial scale. These systems can be installed in most locations throughout the U.S. due to the fact that the ground temperature 10 ft. below the surface is somewhat consistent throughout the year.[20] These are an economically feasible option to install for most applications due to the fact that there is an annual energy savings anywhere between 30% and 60%.[22]

For small scale applications these systems also have a higher efficiency than air-source heat pumps and will decrease the cost in heating/cooling a building. A ground source heat pump will be most promising to use in buildings where temperatures are maintained between 68°F and 78°F for at least 40 hours a week. This means that these systems can be installed in both a residential home and an office building. There are 4 main types of systems that can be installed. Each system will be feasible under certain circumstances and generate the most power based on the environmental conditions.[22] Figure 32 represents the increase in the energy consumed by ground source heat pumps from 1990 to 2008.[71]

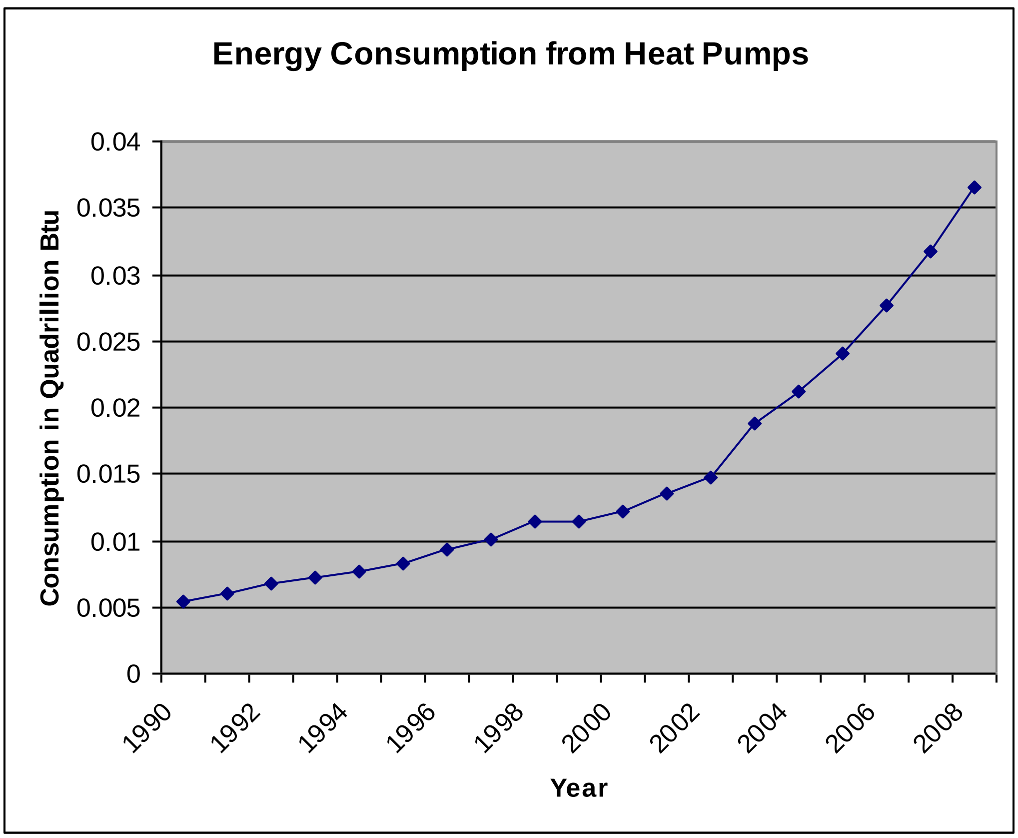

Figure 32: Energy Consumption from Ground Source Heat Pumps

4.2.2.1.1 Pond/Lake Systems

A pond/lake system is the most cost effective option to install, however not applicable in all situations. These systems require a sizeable body of water located near the chosen site. The body of water is ideally at least 8 ft. deep and requires about 100 feet to 300 ft. of piping per ton of heating/cooling.[22]

4.2.2.1.2 Horizontal Closed-Loop System

If a pond/lake system is not applicable, then a horizontal system is the next most cost effective option. Horizontal systems are ideally installed in locations where there is a lot of land available and there is at least 4 ft. of soil to excavate. These systems are also best to install in situations where there is new construction due to the fact that trenches have to be dug to install the system. For a horizontal system there needs to be about 2,500 ft.^{2} of land available for every needed ton of installed capacity.[22]

4.2.2.1.3 Vertical Closed-Loop System

Vertical systems are ideally used for large commercial building and schools because it decreases the required land area necessary for installation. These systems are also best to install if there if the soil is difficult to dig into or if it is really rocky. In order for these systems to be installed about 250 ft.^{2} of land is required for every ton of capacity of heating/cooling. Generally depths of 100 ft. to 300 ft. per ton of heating/cooling need to be reached as well.[22]

4.2.2.1.4 Open Loop System

Open loop systems require either a well or surface water to be used as the fluid that circulates through the system. These systems are only feasible to use when there is a sufficient supply of clean water to minimize any corrosion problems. The water for the system also needs to be "warm" water, which is water that is typically warmer than 5°C. The feasibility of this type of system will also vary based on whether or not is it "legal" to discharge water back into the environment.[22]

4.2.2.2 Deep Well

Deep well geothermal systems are only feasible to install if there is an underground reservoir located near the chosen site. A deep well is drilled to attain temperatures greater than those near the surface. In general a deep well will be over 5,000 ft. deep and attain fluid over 90° C. There are three different types of reservoirs that can be drilled into to generate power. There are high-temperature water-dominate reservoirs (beyond 5,000 ft. in the Earth) or low-temperature water-dominate reservoirs (usually less than 1,000 ft. in the Earth). There are also steam-dominated reservoirs which are usually deeper than 5,000 ft.[23]

Deep well geothermal systems are only feasible for large scale applications due to the high cost of the investment. Not only do deep wells need to be drilled, but power plants need to be installed near the wells in order to harness the power. The ideal areas to drill deep wells are near hot springs, geysers, volcanoes, and fumaroles (holes where volcanic gases are released) because these features occur near reservoirs. In general, these features are found in the Western U.S., Alaska, and Hawaii. Despite the fact that large scale geothermal plants are typically not very efficient, the amount of gases released from the power plant are negligible compared to those that traditional power plants emit.[20]

4.2.3 Hydropower

Approximately 68% of the renewable energy generated in the U.S. is from hydropower power plants. Although this energy is typically generated by conventional power plants, micro-hydropower, tidal power, and wave power all contribute to the energy generated as well.[71]

4.2.3.1 Micro-Hydropower

Micro-hydropower systems are those that generate 100 kW of power or less. These are usually small scale applications and generate power for a farm, small community, or large residential home. A micro-hydropower system is ideally located in a mountainous or hilly region that receives a lot of year round rainfall.[32]

Despite the fact that one of these systems are feasible near any stream/river or falling water source, the most power will be generated in areas where there is always a consistent flow of water. The time of year will sometimes have an effect on the amount of water that is flowing and in these situations consistent power won't be generated. Ideally there should be a minimum stream flow of 10 gpm or a drop in head of 10 ft. in order to generate an adequate amount of power.[82]

Typically micro-hydropower systems are reasonably priced and very efficient, making them a feasible option to install in rural communities and developing countries. These systems also have minimal to no emissions making it an "environmentally friendly" way of generating power. The only impact that these systems will have is on the surrounding environment and stream flow and even then, the impacts are limited.[83]

4.2.3.2 Tidal Power

Unlike other renewable energy resources, the use of tides to generate power is extremely predictable making it a favorable system to install. Tidal power systems require either a coastal or offshore location in order to be installed. These systems can also be installed on a substantial river, similar to the Rance Power Plant in France. Tidal power can be generated either from the change of tides or from tidal currents.[37]

In order to harness the power of the tides and for the system to be feasible, there needs to be a tidal difference of 12 ft. or more. Due to this requirement, not every coastal or offshore location is feasible for the use of tidal power generation. Some of the ideal locations to generate tidal power are off the coast of Washington, British Columbia, and Alaska. There are also suitable locations off the coast of Maine and England as well.[84]

If the conditions are right, tidal power plants are an economically feasible option to install and will have efficiencies as high as 80%. There are also minimal environmental impacts associated with the installation of tidal power systems making them an even more viable option to install. One of the main factors that is associated with tidal power plants is that the turbines that are installed may harm the aquatic wildlife, however there are methods to reduce this effect. Tidal barrage/dams will have the greatest impact of the local environment especially if a dam needs to be built. In situations like this, a tidal power plant may not be the most feasible option.[40]

4.2.3.3 Wave Power

Wave power is a relatively “new” form of renewable energy technology, however there is an estimated 2 TW of potential electricity generation from this form of power. It is feasible to install either onshore or offshore wave power systems, however the most promise is shown for offshore systems. Offshore systems are more feasible to develop due to the fact that there is minimal public concerns that can effect the construction of these systems.[38]

The ideal locations to install wave power systems are on the Western coastlines of continents between the latitudes of 40° and 60° above and below the equator. Some feasible locations to install these systems are off the Northwest coast of the U.S., as well as England and Scotland due to the winds from the Atlantic Ocean. Although the middle of the Pacific Ocean shows great potential for wave power, it is not a feasible location because it would be difficult to distribute the power back to the U.S. after it is generated.[85]

In ideal conditions, wave power systems can have efficiencies as high as 80% and 90% depending on the type of technology that is used. The environmental impacts created by wave power systems are extremely limited. There are zero emissions produced during the electricity generation process and technically the power source is unlimited. The only disadvantage to this type of system is that it must be able to withstand the constant force of the waves, therefore these systems need to substantially built to stand up to the steady force.[85]

4.2.4 Solar

4.2.4.1 Photovoltaic (PV)

With the current cost of PV modules the best applications are stand alone and small scale power needs in areas that have a very high annual solar insolation. In areas that do not have high solar insolation, PV becomes cost effective when you compare it to the cost of traditional electricity and the cost of installing additional power lines. If excess power can be sold back to a utility company it also increase its feasibility, however rates vary from company to company. Studies have shown that very large scale PV power plants in the world's deserts would be economically feasible, but extremely large initial capital costs and the uncertainty due project complications scare away investors.[86]

Areas such as the Southwestern U.S. have enough annual solar insolation that it becomes feasible for residential applications to supplement or cover daily electricity needs. PV becomes more cost effective when utility companies allow you to sell excess electricity and when state and national incentives are available. All of this depends on the region of installation. PV emits no greenhouse gases during operation, however small amounts are emitted from equipment during construction and manufacturing.[86]

Figure 33 represents the increase in the use of PV panels. Over the last 10 years the shipments of PV solar panels have increased by nearly 1,400%.[87]

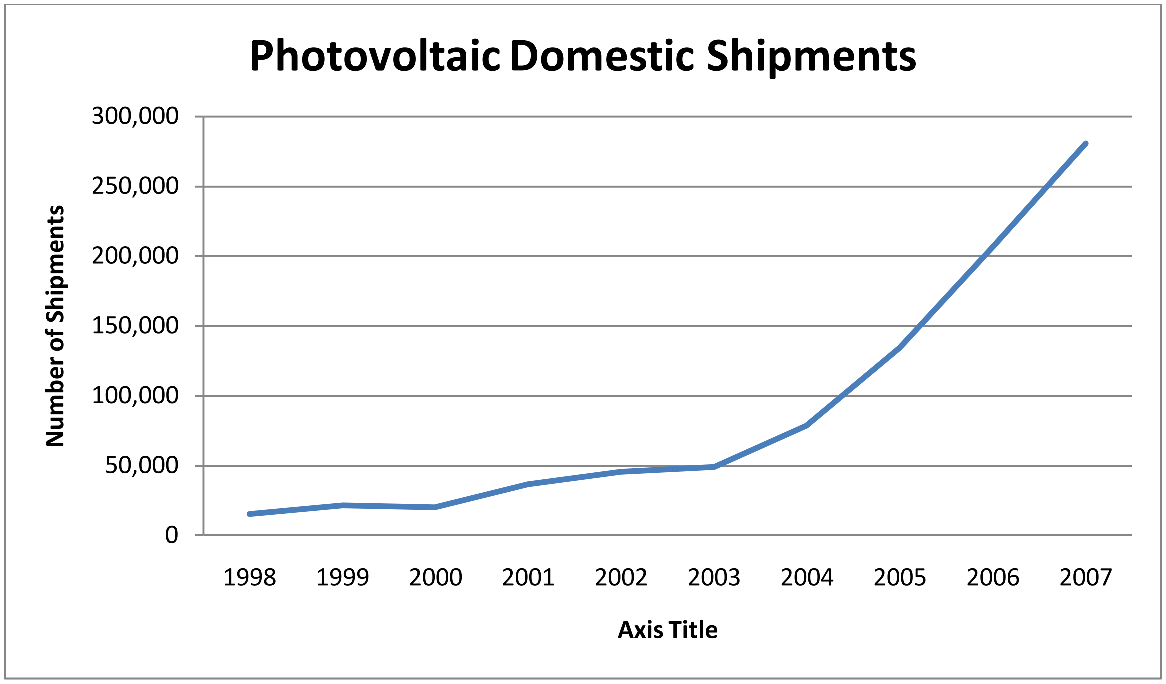

Figure 33: Annual Photovoltaic Domestic Shipments between 1998 - 2007

4.2.4.2 Concentrated Solar Power (CSP)

CSP is a feasible renewable energy option to be used in large scale in areas with very high solar insolation. CSP has not been tried on a small scale since high manufacturing costs and amount of area needed render it infeasible. Large scale CSP plants are economically feasible to install because of reduced construction cost. Also there are so few CSP systems that there is not a competitive market for CSP collectors, and many plants that have been built to date are all somewhat unique.[54]

The best sites for CSP plants are areas with the highest annual solar insolation. Deserts generally have very high annual solar insolation and have very little to no value. CSP plants can be sited on otherwise useless land for very low costs. This increases its feasibility and also saves other land from being used for power production. CSP emits no greenhouse gases during operation, however small amounts are emitted from equipment during construction and manufacturing.[54]

4.2.5 Wind

4.2.5.1 Offshore

Offshore wind power is still in the development stage and is not considered ready for widespread use. Current foundation technology limits offshore wind turbines to waters less than 30m deep. Larger capacity wind turbines are used offshore in an attempt to make them more cost effective, however the cost of construction and installation of additional transmission lines is expensive. These additional costs make offshore wind energy almost twice as expensive as onshore. Higher capacity factors due to stronger more consistent offshore winds could offset this price, but the best winds can not be utilized due to water depth restrictions.[88]

Another obstacle to overcome is the area of public concern. One major concern is environmental impacts. Environmental impact studies have been conducted on offshore wind farms in northern Europe but there have not been many extensive and long term impact studies. Many of the areas with waters less than 30m deep are local fishing grounds and if damaged could have large effects on local economies. Also people are concerned with ruining the visual aesthetics of local beaches. Wind turbines do not emit greenhouse gases during operation, but small amounts are emitted by equipment during construction and manufacturing.[88]

4.2.5.2 Onshore

Onshore wind turbines are feasible at the residential and commercial scale. Residential wind turbines become cost effective at sites where there is a very strong wind resource. Since residential wind turbines have a lower height than industrial wind turbines they often are not as efficient because the strong high winds are not available. Large scale wind farms require large tracts of land with strong sustained winds. The Midwest northern Texas has the best wide spread wind resources in the country. Ridge lines in hilly and mountainous areas often have strong wind resources, however the ridge must be accessible to construction equipment to allow for a wind farm to be built.[38]

While large scale wind farms are spread out over a greater area of land, the actual land used is very minimal. Large wind farms can be integrated into crop fields with little to no impact. Bird deaths have been a environmental concern of wind farms however a extremely small amount of birds are killed by wind turbines and migratory birds learn to simply fly around them. Wind turbines do not emit greenhouse gases during operation, but small amounts are emitted by equipment during construction and manufacturing.[89]

4.3 Best Practices Manual

The final product of the team's research is the BPM. The BPM compiles all of the data that was collected into one document. This document can be found in Appendix A and is the document that is to be used by Stantec employees.

4.4 Checklist

In order to guide a consulting engineer in screening renewable resource alternative, a checklist was designed. The checklist is to be used as a series of guidelines and gives a general overview of the different factors that the systems require. There are cost and efficiency data in order to guide a consultant in case there is a cost restriction or budget for a system that is looking to be designed. The checklist is as follows:

Biomass

Wood

- ___ Wood can be converted to energy through combustion, gasification, cogeneration, and cofiring
- ___ Applicable within a 50 mile radius of wood source
- ___ Residential, commercial, and industrial applications are most common
- ___ Costs about $50,000 to $75,000 per .3 MW of heat input for an installed heat/boiler system between .3 MW and 1.5 MW
- ___ Wood combustion plants generate power for between $0.06 to over $0.11 per kWh
- ___ Wood combustion systems typically have an efficiency between 65% to 75% and CHP systems have efficiencies between 60% to 80% for large scale applications and between 65% to 75% for small scale
- ___ Wood cannot be harvested too rapidly because it will deplete the local ecosystem
- ___ CO_2 emitted is 90% less than fossil fuel power plants

Algae

- ___ Algae produces fatty lipid cells full of oil - this oil can be used as fuel
- ___ Can be harvested in open ponds or closed bioreactors
    - ___ Closed bioreactors can have the temperature and water levels regulated
    - ___ Open ponds are shallow channels which are more difficult to regulate
- ___ An almost “unlimited” supply of water is required
- ___ Large plots of land with adequate sunlight are needed
- ___ The best location to install and algae farm is in a hot or tropical environment
- ___ Estimated construction costs for algae pond can be around $80,000 per hectare

___ Depending on the oil extraction technology, approximately 95% of the oil will be extracted

Landfill Gas

___ Vertical wells or horizontal systems can be installed

  ___ Horizontal systems are used for active landfill areas

___ Candidate landfills should have at least 1 million tons of waste or more

___ Landfill must either still be in use or be closed for 5 years or less

___ Landfill cannot have a ban on organic material

___ For a 10m deep landfill collection systems cost ranges between $20,000 and $40,000 per hectare and suction systems cost $10,000 to $45,000 per hectare

___ Average cost of power is $0.04 per kWh

___ About 40% to 50% of the gas that is released is recovered and collection efficiencies are between 60% to 80%

___ Landfill gas will only have about 50% the heating capacity of natural gas

Waste-to-Energy

___ Municipal solid waste/garbage is needed in mass quantities

___ Garbage is burned to heat a boiler and generate steam – This steam powers a turbine generator which generates electricity

___ 2,000 lbs of garbage will reduce to 300 to 600 lbs of ash

___ The waste used in these systems will come from either land fills or direct collection

___ Small scale plants cost between $110,000 and $140,000 per daily ton of capacity

___ For every ton of waste about 500 to 600 kWh of electricity is made

___ Systems are about 80% efficient

___ Pollution control systems or scrubbers will need to be installed so no harmful byproducts (metals/iron) are released into the air

Biodiesel

___ Biodiesel is created from oils including vegetable oil, waste cooking oil, animal fats, or byproducts of pulp and paper processing by the process of transesterification

___ Can be used in any diesel engine after an inexpensive retrofitting.

___ Biodiesel available to the general public at regular pumps ranges in cost from the same as petroleum diesel to $1 more per gallon depending on the area.

___ The horsepower, torque and engine outputs are equally if not slightly lower than with petroleum diesel

___ CO_2 emitted is 78% less than petroleum diesel

Geothermal

Ground Source Heat Pumps

General for All Systems

___ Systems cost around $2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installatoin

___ No underground utilities or sprinkler systems are in the area of the "chosen" location

___ Most promising application is in buildings that are maintained between 68°F and 78°F for at least 40 hours a week

___ Common for residential, commercial, and school applications

___ Ground temperature 10 ft. below the surface typically remain around 50°F to 60°F year round

___ Systems can be used to either heat or cool a building

___ The geological, spatial, and hydrological factors all play a role in the type of system installed

___ Annual energy savings between 30% and 60%

___ Investment paybacks are anywhere from 2 to 10 years

Closed-Loop Pond/Lake

___ Adequate body of water required to install 100 ft. to 300 ft. of piping (3/4" to 1 ½" in diameter) per ton of heating/cooling

___ Water 8 ft. deep or more is favored

___ State/federal regulations allow using water from pond/lake

Closed-Loop Vertical

___ Adequate for very rocky or difficult to dig soil

___ Depths between 100 ft. and 300 ft. (using ¾" to 1 ½" diameter piping) per ton of heating/cooling need to be reached

___ Adequate space for boreholes to be 15 ft. to 20 ft. apart

___ About 250 ft.^{2} of land is needed for every ton of capacity
___ Typically favored to lessen the disruption of landscaping
___ Commonly used for large commercial buildings and schools

Closed-Loop Horizontal

___ Soil depths of at least 4 ft. are needed in order to dig trenches
___ Enough area for trenches to be 4 ft. to 6 ft. apart and 6” to 24” wide
___ Adequate land to install 400 ft. to 600 ft. of pipe (3/4” to 1 ½” in diameter) for every ton of heating/cooling capacity (if a slinky system is installed this figure can be reduced by 1/3 to 2/3)
___ About 2,500 ft.^{2} of space is needed for every ton of capacity
___ More cost effective to install as opposed to a closed-loop vertical system

Open Loop

___ Well/surface water is available for use
___ Sufficient supply of clean water (soft water is best to minimize any possible corrosion problems)
___ Local/federal regulations allows water discharge back into the environment
___ Water is warm (over 5°C)

Deep Well Geothermal

___ Underground water/steam reservoir is located near site
___ Once a reservoir is located and wells drilled there are three different types of power plants that can be installed to harness the power
    ___ Flash Steam Plants are used for a high-temperature, water-dominated reservoir
    ___ Dry Steam Power Plants are used if there is a steam dominated reservoir
    ___ Binary-cycle power plants are used if there is moderate temperature water (below 400° F) which is most common
___ Geothermal reservoirs are commonly found in the western U.S., Alaska, and Hawaii
___ The cost of well drilling will make up 42% to 95% of the total system cost
___ A competitive plant will cost around $3,400 (or more) per kW installed
___ New geothermal projects can cost from $0.06 to $0.008 per kWh of energy produced

___ Local/federal regulations allow drilling miles into the Earth

Hydropower

Micro-Hydropower

___ 100 kW or less of power will be produced
___ Stream, river, or falling water source needs to be located within a mile of the site
___ Ideal locations are mountainous regions that receive a lot of year round rainfall
___ Adequate stream flow of 10 gpm or a drop of at least 2 ft. (10 ft. is favorable) in order to generate power
___ An impulse turbine is adequate for high, medium, and low head pressure, while a reaction turbine is only adequate for medium and low head pressure
___ Permits and water rights managed to be obtained
___ Costs $1,000 per kW of output plus installation fees
___ Looking at the typical life cycle cost of the system the cost will generally range from $0.03 to $0.25 per kWh
___ The payback period is generally between 5 and 10 years
___ Typically efficiency's can range from 50% to 80% and sometimes can be as high as 90%

Tidal

___ Coastal/offshore location – Off the coast of Washington, British Columbia, and Alaska are ideal – Maine, England, and Asia also show potential
___ Tidal power is very predictable making it a very reliable source of power
___ The three potential technologies that can be used are: Tidal Barrages/dams, tidal fences (which stretch across a channel or between small islands), and tidal turbines (which are similar to wind turbines and spin due to currents)
___ Tidal turbines work best if the current is about 5 mps and in water that is 65 ft. to 99ft. deep
___ Tidal difference of at least 15 ft. or fast currents
___ Tidal power costs about $0.10 per kWh

___ Efficiency can be as high as 80%, however if there is low-head storage then the efficiency will be below 30%

___ Permits and water rights are obtainable for the given site

___ Turbines can cause damage to fish and construction of dams will affect the natural ecosystem

Wave

___ Coastal (onshore)/offshore location

___ Offshore systems can be located underwater or on the surface (uses the bobbing of the waves to generate power (Salter Duck))

___ Onshore systems use the breaking of waves to create power (an oscillating water column, tapchan, or pendulor device can be installed)

___ Location with adequate wave supply – Ideally on the western coastline of continents between the latitudes of 40° and 60° above and below the equator

___ The Northwest coast of North America, England, and Scotland show great potential

___ Power costs about $0.50 per kWh of power

___ Efficiencies for the Salter Duck can be as high as 90% and an Oscillating Water Column will be around 80%

___ Onshore systems create a lot of noise and are considered unattractive

___ Systems must be built to withstand a lot of force for long periods of time

___ Permits and water rights are obtainable for the given site

Solar Power

Concentrated Solar Power

___ CSP power plants need a large area of land, up to hundreds or thousands of acres.

___ Cost of CSP plants range from $2M to $5M per MW

___ Cost of electricity from CSP plants is around $0.12/kWh, but is expected to drop in the near future due to increased research, manufacturing, and development.

___ The best locations for CSP plants are often deserts which otherwise have very limited use

___ Current CSP technologies can convert 20-40% of the sunlight into power
___ When thermal storage units are incorporated into a CSP plant it can increase its capacity factor and continue to produce energy in the dark
___ CSP plants emit no greenhouse gases during operation

Photovoltaics

___ PV arrays can be used anywhere the sun shines, however they will be most cost effective in areas such as the U.S. Southwest which receives high levels of solar insolation
___ PV modules cost $3.37 per Watt in 2007
___ PV becomes cost effective in area's without high solar insolation where the cost of installing transmission lines would increase the price of grid power
___ Commercially available PV can convert 5-20% of the sunlight into power
___ PV emits no greenhouse gases during operation

Wind Power

Offshore Wind

___ Current technology only allows offshore turbines in water up to 30m deep
___ Minimum wind speeds of 8 mph are required for a turbine to generate electricity
___ The coast of the Northeastern U.S. and the Cost of the Pacific Northwest from Oregon to Alaska are good locations to site offshore wind farms
___ Farms cost around $2.4M per MW of capacity and the cost of electricity is $.095/kWh
___ Wind turbine capacity factors are around 30% however strong and more consistent offshore winds could increase that number.
___ Farms can be properly sited to avoid fishing grounds and shipping lanes
___ There is often public concern for the marine environment and visual aesthetics

Onshore Wind

___ The best location for wind turbines in the U.S. is the Midwest and northern Texas as well as ridgelines in hilly and mountainous areas that are accessible by construction equipment.

___ Minimum wind speeds of 8 mph are required for a turbine to generate electricity

___ Farms cost around $1M per MW of capacity and electricity costs $.04/kWh

___ Wind turbine capacity factors are around 30% however stronger and more consistent winds can increase that number.

___ Wind farms cover large areas of land however the footprint of foundations is a small percentage. The land can be used for other things and is often integrated into farmland

___ At a distance of 350m the sound of a wind turbine is similar to the background noise in a house

Along with the checklist is the comparison table of the different renewable energy alternative and their various systems. This is to be used if a client is looking between two different options and wants to be able to look up information quickly opposed to going through the entire manual.

	Wood Biomass	Algae Biomass	Biodiesel Biomass	Waste-to-Energy Biomass	Landfill Gas Biomass
Technology	- Combustion - Gasification - Cogeneration - Cofiring	- Open Ponds - Closed Bioreactors	- B100 (pure biodiesel) - Mixed with petroleum biodiesel. B20 (20% biodiesel, B5, and B2 are most common)	- Garbage is burned to heat a boiler and generate steam – This steam powers a turbine generator, which generates electricity	- Vertical Wells - Horizontal system (for active landfills)
Location	- Anywhere within a 50 mile radius of a source of wood	- Ideally installed in a hot or tropical environment, especially for open pond systems	- Can be used in any diesel car after small and inexpensive upgrades. Cold weather (below freezing) can cause biodiesel to congeal, however techniques are used to avoid this.	- Close to an existing landfill so transportation costs can be reduced	- At least 1 million tons of waste - Landfill must still be in operation or closed within the last 5 years
Cost	- $50,000 to $75,000 per .3 MW of heat input for installed heater/boiler system between .3 MW and 1.5 MW - Generate power for between $0.06 and over $0.11 per kWh	- The average cost of 100 acre farm is about $1 million with a payback ranging from 5 to 15 years - Construction fees for a pond can be around $80,000 per hectare	- In July 2009 the U.S. national average for biodiesel was $3.08 (B100)	- Small scale plants cost between $110,000 and $140,000 per daily ton of capacity	- For a 10 meter deep land fill collection system, the cost is between $20,000 and $40,000 per hectare and the suction systems cost $10,000 to $45,000 per hectare - Average cost of power is about $0.04 per kWh
Efficiency	- Combustion between 65% and 75% - CHP between 60% and 80% for large scale or 65% and 75% for small scale	- Varies based on the extraction technology, but can be as high as 95%	- B100 produces 8.65% less heat when combusted than petroleum diesel	- Typical efficiencies are about 80%	- About 40% to 50% of the gas that is released is recovered - Collection efficiencies are between 60% to 80%
Downsides	- Wood can't be harvested too rapidly because it will deplete local ecosystem	- A large amount of land and endless supply of water is required	- 2-4% increase in NO_x. If engine is not retrofitted for biodiesel it can clog fuel lines and filters	- Metals/iron are released during the burning process, but they can be trapped by scrubbers	- Landfill gas will only have about 50% the heating capacity of natural gas
General Info.	- CO_2 emitted is 90% less than fossil fuel plants	- Algae produce fatty lipid cells which are full of oils – these oils are used as fuel	- CO_2 emitted is 78% less than petroleum diesel	- 2,000 lbs of garbage will reduce to 300 to 600 lbs of ash	

	Closed Loop Pond/Lake GSHP	Closed Loop Vertical GSHP	Closed Loop Horizontal GSHP	Open Loop GSHP
Technology	- 100 ft. to 300 ft. of piping (3/4" to 1 ½" in diameter) per ton of heating/cooling	- Depths between 100 ft. and 300 ft. (using ¾" to 1 ½" diameter piping) per ton of heating/cooling	- 400 ft. to 600 ft. of pipe (3/4" to 1 ½" in diameter) for every ton of heating/cooling capacity - If a slinky system is installed this figure can be reduced by 1/3 to 2/3	-Well/surface water is available for use - Typically water warmer than 5°C is required
Location	- Near a pond/lake, favorably that is 8 ft. deep or more	- Adequate for very rocky or difficult to dig soil - About 250 $ft.^2$ of land is needed for every ton of capacity - Boreholes need to be 15 ft. to 20 ft. apart	- Soil depths of at least 4 ft. in order to dig trenches - Enough area for trenches to be 4 f.t to 6 f.t apart and 6" to 24" wide - About 2,500 square feet of space is needed for every ton of capacity	- Ideal locations are near a surface body of water or in an area with a high ground water table
Cost	- Systems cost around \$2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years	- Systems cost around \$2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years	- Systems cost around \$2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years	- Systems cost around \$2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years
Efficiency	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights
Downsides		- Not as cost effective as horizontal or pond/lake system		- Local/federal regulations must allow for water discharge back into the environment which is not always possible
General Info.	- State/federal regulations must allow for taking water from body of water	- Typically favored to lessen the disruption of landscaping - Commonly used for large commercial buildings and schools	- More cost effective to install as opposed to a closed-loop vertical system	- Sufficient supply of clean water (soft water is best to minimize any possible corrosion problems)

	Deep Well Geothermal	Micro-Hydropower	Tidal Hydropower	Wave Hydropower
Technology	- Deep wells drilled miles into the earth to tap reservoir - Flash steam, dry steam, or binary-cycle power plants are installed to harness power	- 100 kW or less of power will be produced - An impulse turbine is adequate for high, medium, and low head pressure, while a reaction turbine is only adequate for medium and low head pressure	- Tidal Barrages/dams - Tidal fences (which stretch across a channel or between small islands) - Tidal turbines (which are similar to wind turbines and spin due to currents)	-Onshore systems use the breaking of waves to create power (an oscillating water column, tapchan, or pendulor) - Offshore systems can be located underwater or on the surface (uses the bobbing of the waves to generate power (Salter Duck))
Location	- Near an underground water/steam reservoir - Commonly found in western US, Alaska, and Hawaii	- Stream, river, or falling water source needs to be located within a mile of the site - Ideal locations are mountainous regions that receive a lot of year round rainfall	-Coastal/offshore location - Ideally off the coast of Washington, British Columbia, and Alaska - Maine, England, and Asia also show potential	- Coastal (onshore)/offshore location - Location with adequate wave supply – Ideally on the western coastline of continents between the latitudes of 40° and 60° above and below the equator
Cost	- The cost of well drilling will make up 42% to 95% of the total system cost - A competitive plant will cost around $3,400 (per kW installed - New geothermal projects can cost from $0.06 to $0.008 per kWh of energy produced	- Costs $1,000 per kW of output plus installation fees - Based on typical life cycle cost of the system the cost will generally range from $0.03 to $0.25 per kWh - The payback period is generally between 5 and 10 years	- Tidal power costs about $0.10 per kWh	- Power costs about $0.50 per kWh of power
Efficiency		- Typically efficiencies can range from 50% to 80% and sometimes can be as high as 90%	- Efficiency can be as high as 80%, but if there is low-head storage the efficiency will be below 30%	- Efficiencies for the Salter Duck can be as high as 90% and an Oscillating Water Column around 80%
Downsides	- Drilling wells will weaken the surrounding area, which may cause earthquakes	- Will affect the general make up of the stream due to the fact that water will be diverted to power the turbine	- Turbines can cause damage to fish and construction of dams will affect the natural ecosystem	- Onshore systems create a lot of noise and are considered unattractive -Systems must be built to withstand a lot of force for long periods of time
General Info.	- Local/federal regulations must allow drilling miles into the Earth	- Adequate stream flow of 10 gpm or a drop of at least 2 ft. (10 ft. is favorable) in order to generate power	- Tidal power is very predictable and very reliable - Tidal turbines work best if the current is 5 mps and is 65 ft. to 99ft. deep	- Permits and water rights managed to be obtained

	CSP Solar Power	PV Solar Power	Offshore Wind Power	Onshore Wind Power
Technology	- Parabolic Trough - Linear Fresnel Reflector - CSP Dish - CSP Tower	- Single crystal - Poly Crystal - Ribbon - Amorphous	- Wind turbines are sited off the coast in waters up to 30m deep.	- Wind turbines capture wind and produce electricity
Location	- In the sunbelts of the world which are generally between the latitudes of 40°North and 40° South. The American Southwest has a very large potential for CSP	- PV can be used anywhere the sun shines - Most effective in stand alone applications where the cost of installing additional power lines would become very costly.	- The U.S. Northeast and Pacific Northwest from Oregon to Alaska are suitable.	- In the U.S. the most extensive wind resources are located in the Midwest. - Any accessible hilltop or ridge line will have the highest winds of a given area (an 8mph minimum speed is best)
Cost	- Power cost around \$0.12 per kWh of power - Capital cost of plants vary between \$2 million and \$5 million per MW of capacity	- Power costs between \$0.06 and \$0.17 per kWh of power -the average price for modules in 2007 was \$3.37 per peak watts	-Power costs \$0.09 per kWh. - Capital cost range between \$1 million and \$2 million per MW of capacity	-Power costs \$0.04 per kWh. - Capital cost is around \$1 million per MW of capacity
Efficiency	- varies between technologies but is generally between 20-40%. Energy storage systems can increase the efficiency.	- Commercially available PV efficiencies range between 5%-20%. - Labs have produced cells that can transform 40% of sun light hitting the cell	- Capacity factors range between 25-40% however offshore wind is generally high due to stronger, more consistent, and less turbulent winds offshore.	- Capacity factors range between 25-40% however are generally in the lower range onshore.
Downsides	- Large CSP plants take up large areas of land, however are often located in deserts. - Concentrated beams of sunlight can kill birds and insects	- Toxic and hazardous chemicals are used during manufacturing, however damage can be avoided by following safe manufacturing procedures	- Visual aesthetics of shorelines are of concern - 0.001% of bird deaths are accounted from wind turbines - Marine ecosystems can be harmed, but initial research shows it to be very low.	- Turbine noise can also be an issue however is similar to the background noise in a house at a short distance away. - 0.001% of bird deaths are accounted from wind turbines
General Info.	- Many downsides can be mitigated - The use of deserts increases the value of previously degraded and unusable land.	- Still expensive compared to other energies however can become cost effective in areas where grid power is not readily available.	- 78% of U.S. electricity demand comes from the 28 states with shorelines.	- Proposed wind turbines must pass local zoning laws

	Coal	Natural Gas	Oil
Technology	- Typically coal is burned in a boiler to heat water and produce steam which powers a turbine and generator and produces electricity	- Steam generation units - Centralized Gas Turbines (hot gases are used to turn a turbine) - Combined Cycle Units (both a gas turbine as well as a steam unit)	- Crude oil is refined into petroleum products which can be used to power engines - The three basic steps of a refinery are separation, conversion, and treatment
Location	- A coal power plant can be installed almost everywhere - The cost to transport the coal will factor into the cost of the entire system	- Natural gas is used throughout the US, but the states that consume the most are Texas, California, Louisiana, New York, Illinois, and Flordia	- Oil is mainly produced in the US, Iran, China, Russia, and Saudi Arabia - Oil refineries can be located almost anywhere however it can occupy as much land as several hundred football fields
Cost	- An average plant costs $ 4 M per MW of power - The price of electricity can be as low as $0.048 to $0.055 per kWh	- Costs $200 per ton of annual liquification capacity - The price of electricity can be as low as $0.039 to $0.044 per kWh	- Large facilities cost between $4 and $6 Billion - The cost of electricity can vary, but it can be as high as $0.18 per kWh
Efficiency	- Most coal power plants are only about 30% efficient - Newer technologies may increase the efficiency to 50% or 60%, but this may vary greatly	- The efficiency of a steam generation unit is about 33% to 35% - Centralized gas turbines are less efficient then steam generation units - Combined cycle units can have efficiencies up to 50% or 60%	- Oil refineries typically have extremely high efficiencies - These efficiencies range from 80% to 90% and sometimes even higher
Downsides	Various emissions are released - 0.82 lb CO2 released per kWh .004 lbs NO_x per kWh .006 lbs SO_x per kWh	- Cleanest burning of the fossil fuels, but CO_2 still produced - Exploring and drilling for natural gas has a large impact on the land and marine habitats nearby – There are technologies to reduce the "footprint though)	- Burning emits: CO_2, NO_x, SO_x, VOCs, PM, and Lead - Each of these pollutants will have negative impacts on the environment and human health - Drilling for oil may disturb land and ocean habitats, however technologies can be employed to help reduce this
General Info.	- Approximately 50% of the electricity in the US comes from coal plants and 40% of the World's electricity comes from coal plants - The cheapest fossil fuel to burn for generating electricity but also the dirtiest	- Low levels of nitrogen oxides are emitted and virtually no particulate matter (both are harmful greenhouse gases) - The combustion of natural gas emits almost 30% less carbon dioxide than oil, and just under 45 % less carbon dioxide than coal - Cogeneration is possible	- Refining crude oil will produce more products than what was put in. There is a gain of about 5% from processing - Processing crude oil produces Diesel, heating oil, jet fuel, residual fuel, gas, and liquefied petroleum gases

5 Conclusion

Upon completing the final research for each renewable resource option it was determined that not all of these systems are feasible for generating large quantities of power. Theoretically all of the World's power could come from renewable energy sources, however this is not a realistic goal which can be completed in the next 20 years. In order to convert the World's energy source from traditional to renewable power a huge financial investment would have to be made. With today's present economy, no one is really willing to invest the billions of dollars necessary to begin to make this transition.

Despite the fact that every little advancement that is made is only helping the environment, in order for any real change to happen huge advancements need to be made. There are various tax incentives and other government incentives available to help spur the renewable resource sector, but it isn't incentive enough for private investors. The cost of renewable power is still more than the cost of traditional power, making it less appealing. Although there are many benefits to installing any one of these renewable resource systems, no investor is willing to invest a large sum of money to help make a difference.

This is where a hybrid-system can come into use. Similar to hybrid cars, a renewable resource hybrid system will integrate traditional and renewable power sources to generate one output of power. Hybrid systems can also combine multiple renewable energy systems, such as a solar and wind power plant. Although this is not as "environmentally friendly" as a pure renewable resource system, it is a step in the right direction and cost effective as well.

Appendix A: Renewable Energy Alternatives BPM

Renewable Energy Alternatives Best Practices Manual

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Stantec

Table of Contents

List of Figures

List of Tables

1 Introduction

Climate change occurs naturally and has many times throughout the history of the Earth. However over the past two hundred years climate change has occurred due to industrialization and the actions of people. Currently there is a very favorable climate for human life, but with the increased rate of climate change we could be heading towards a negative environment for people to live in. It is accepted that this may naturally happen over a long period of time and we could adapt. However with the abuse of fossil fuels and natural resources increasing the rate of climate change, we may not be able to adapt fast enough and not have the resources to do so.

Renewable energies increasingly need to be used so that we can preserve our Earth. Renewable energies use resources that are naturally replenished, including wind, sunlight, water, geothermal heat, and biomasses. These renewable energies also do not release greenhouse gases which contribute to global warming. In 2008, the electricity generated in the United States consisted of 50.5% Coal, 19% nuclear, 18.3% natural gas, 6.4% hydroelectric, 3.3% oil, and 2.5% was all other wind, solar, biomass, and geothermal energies.[1]

Renewable energies only accounted for 9%, which a majority being generated by hydroelectric power. Renewable energies are also attractive to clients because of public opinions. Society as a whole is pushing for renewable energies, but it is not always the most economical choice for a company. Some companies are promoting the fact that they used renewable energies in an attempt to attract new customers.

1 2030 Timeline

In May 2009 the US Energy Information Administration (EIA) published their annual International Energy Outlook. This document not only includes projected energy forecasts, but also analyzes the current energy consumption. Some of the major highlights of this document are World Marketed Energy Consumption data, World Energy Use by Fuel Type, World Delivered Energy Use by Sector, and World Carbon Dioxide Emissions.[2]

Currently, there is expected to be a world marketed energy consumption increase from 472 quadrillion Btu. in 2006 to 778 quadrillion Btu. in 2030. Meaning that there will be a 44% increase in energy consumption in less than 25 years. Although the increase in energy consumption is nothing new, the major demand for power will be put on traditional energy sources opposed to renewable energy sources.[2]

A majority of the energy demand increase is expected to come from countries not part of the Organization of Economic Cooperation and Development (non-OECD countries are typically described as having low-income economies such as Brazil, South Africa, Indonesia, and India). The OECD energy consumption increase is expected to be around 15%, while the non-OECD energy consumption increase is expected to be around 73%.[2]

Due to this major consumption increase, more fuel will need to be produced. Figure 1 represents the projected World energy use by type of fuel. As you can see there is an increase in all fuel types, however the use of renewable and nuclear do not even compare to the use of natural gas, coal, and liquids.[2]

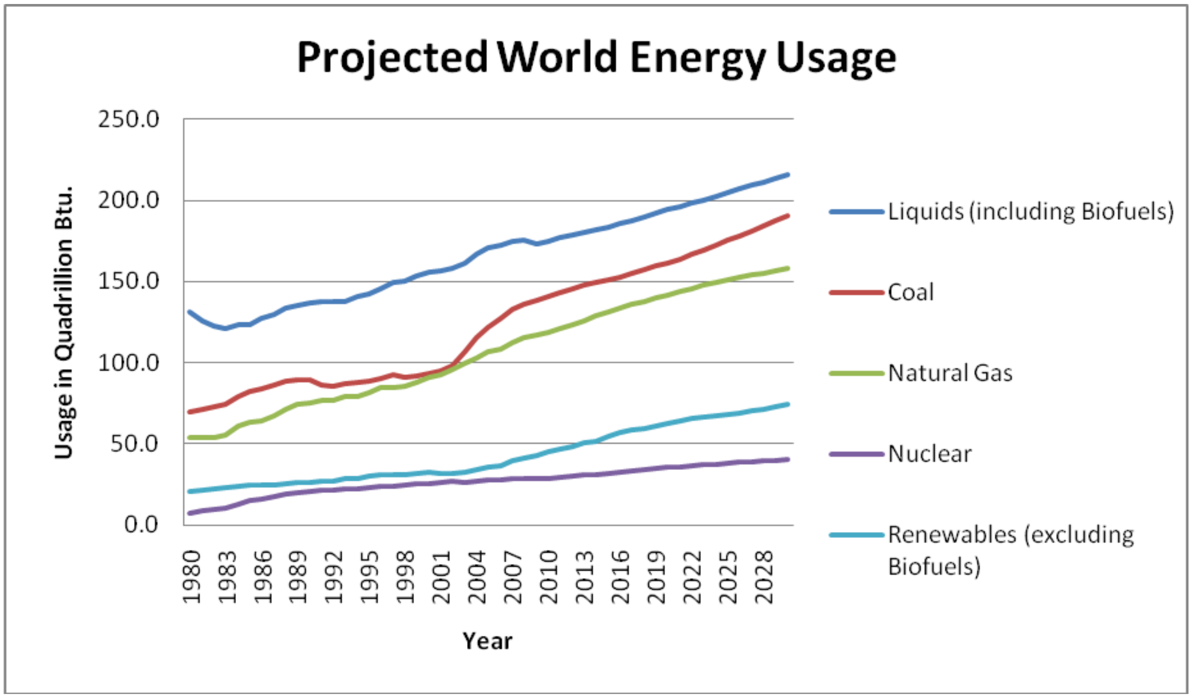

Figure 1: Projected World Energy Usage

Since the 1980's liquids (such as petroleum) have been the main energy source, mainly because of their use in transportation. In 2006 it was estimated that the World consumed 85 million barrels per day and in 2030 this number is expected to increase to 107 million barrels per day. [2]

Despite the fact that the World mainly uses liquids, the major electricity generator is coal. In 2010 it is expected that 8,668 trillion kWh's of electricity is going to be generated by coal and renewables will only generate about 4,072 trillion kWh's. By 2030 it is projected that coal is going to generate 13,579 trillion kWh's and that renewables will generate 6,769 trillion kWh's. Despite the fact that there is an increase in both of these numbers, renewables still fall short of traditional electricity generators. See Figure 2 for the electricity generation breakdown by various fuel sectors. [2]

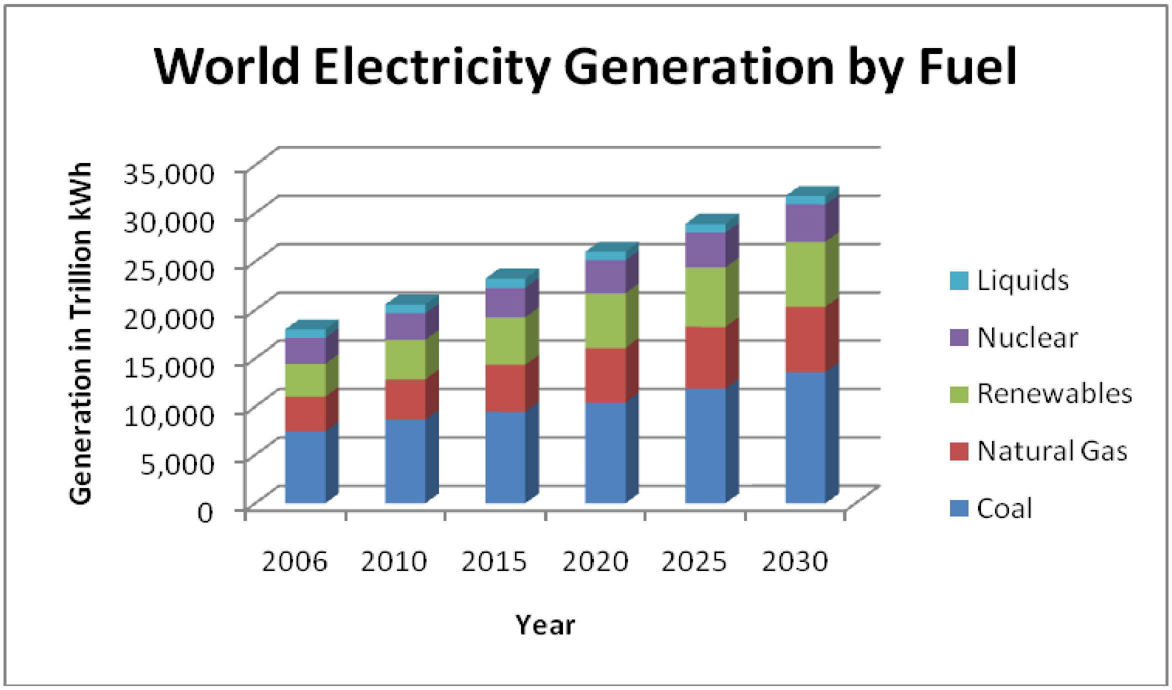

Figure 2: World Electricity Generation by Fuel

Although it is important to see where a majority of the power comes from, it is also important to look at the cost of the power. Figure 3 represents the levelized cost of power for both 2012 and 2030. The levelized cost of power is the average cost of power over the lifetime of the power plant. This means that all capital expenses, operating and maintenance costs, and fuel costs of the power plant are taken into account. The levelized cost graph includes the more traditional power generators such as advanced coal, conventional gas/oil, advanced gas/oil, and combustion turbines, as well as renewables such as solar thermal and PV, onshore and offshore wind, geothermal, biomass, and hydroelectric. [2]

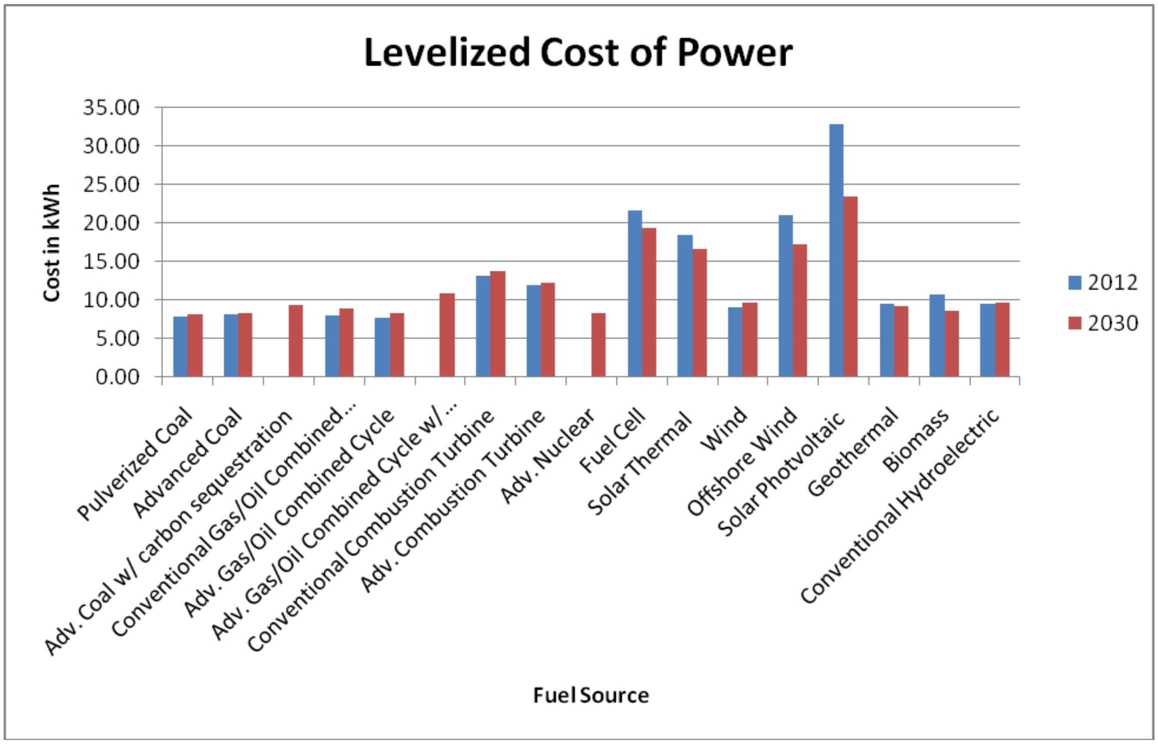

Figure 3: Levelized Cost of Power by Sector

Figure 3 show that even by 2030 most of the traditional power generators still produce cheaper power than renewables. The most promising renewables are biomass, geothermal, and conventional hydroelectric power costing only about one cent more than conventional gas/oil, advanced gas/oil, and advanced coal systems by 2030. Due to the major increase in energy usage and the competitive levelized costs of renewables, alternative energy shows a great promise for future use. [2]

2 Fossil Fuels

Fossil fuels are nonrenewable energy resources and cannot be replaced once the supply has been depleted. Fossil fuels specifically were created from the remnants of plants and beings from millions of years ago. Included in the fossil fuels family are coal, natural gas, and oil.

2.1 Coal

Coal is formed from the remnants of plants and animals. As other layers are formed on top of the original remnants, the energy from the decomposition of these once-living life forms will become trapped. With enough heat and pressure coal will be formed. Coal is mainly composed of carbon and hydrocarbons and in the United States, coal is the most plentiful of the fossil fuels.[3]

2.1.1 Cost of Plant

The cost of construction for a coal-fired power plants is on the rise, due to generally higher construction prices. The price of a 300 MW power plant is priced at approximately $1.1 billion. This levels out to about $4 million per MW.[4]

2.1.2 Cost of Electricity

A study done by the Massachusetts Institute of Technology found the average cost of coal to be $1- $2 per MMBtu.[5] It has been found however, that the cheapest cost of electricity generated by coal is $0.048 to $0.055 per kWh.[6]

2.1.3 Greenhouse Gas Emissions/Environmental Impacts

According to the Impact of Pollution Prevention Iowa Waste Reduction Center, about 0.82 lb of CO2 released per kWh generated in the worst case. It is approximated that .004 lbs of nitrogen oxides (NOx), 0.006 lbs sulfur oxides (SOx), and 1.05 lbs of methane are produced per kWh.[7]

2.2 Natural Gas

Natural gas is formed similar to the way coal is. Over millions of years, the remains of animals and plants are covered and given ample heat and pressure, natural gas. However, unlike coal, natural gas is made primarily of methane.

2.2.1 Cost of plant

According to the Gas Technology Institute, the cost of a liquefied natural gas plant with the ability to process 390 Bcf per year will vary in price range from $1.5 to $2 billion. Additionally the Gas Technology Institute has found plant capital costs to be around $200 per ton of annual liquefaction capacity.[8]

2.2.2 Cost of electricity

Research done by the Massachusetts Institute of Technology has found the average cost of natural gas to be $6 to $12 per MMBtu.[5] However it has been found that the cheapest cost of electricity generated by natural gas is between $0.039 and $0.044 per kWh.[6]

2.2.3 Greenhouse gas emissions/Environmental Impacts

Out of all the fossil fuels natural gas is the cleanest, releasing the lowest quantity of harmful gases when combusted. Carbon dioxide is still produced, but the emission of other greenhouse gases such as SO_x and NO_x are significantly lower than that of coal or oil plants.

2.3 Oil

Oil, just like natural gas and coal, is formed over a period of millions of years from dead plants and animals. After being covered with layer after layer of sediments and with the application of heat and pressure from the earth, crude oil will be formed.

2.3.1 Cost of plant

According to research done by the Cato Institute in Washington, DC, the cost of construction for large oil refinery falls in the range of $4 billion and $6 billion.[9] The cost to refine crude oil is somewhere in the range of $0.30 and $0.60 per gallon.[10]

2.3.2 Cost of electricity

A study done by the Massachusetts Institute of Technology found the average cost of oil to be in the range of $6 - $12 per MMBtu.[5] Over time the cost of electricity generated by oil has increased from $0.06 per kWh, to nearly three times that value. In 2008 it was recorded that the cost was almost $0.18 per kWh for electricity generated by oil.[11]

2.3.3 Greenhouse gas emissions

When burned as a fuel, oil emits various gases. Included in these gases are carbon dioxide, sulfur dioxide, carbon monoxide, nitrogen oxides, volatile organic compounds, particulate matter, and lead. These gases are harmful not only to the environment (as greenhouse gases or contributors), but are also harmful to people as they can both cause and make existing health problems worse, such as respiratory illnesses and heart disease.[12]

3 Biomass

Biomass energy (or bioenergy) utilizes energy stored in plants, as well as plant material and organic material from animals. The energy that is obtained can then be converted into chemicals, fuels, materials, and power. The three main types of biomass energy are biofuels, bioproducts, and biopower. These main types have sub-categories, which make up the biomass technologies that are used today.[13]

In addition to this there are many different sources for biomass energy. These sources include municipal solid waste, agricultural and forestry residues, industrial waste, and aquatic and terrestrial crops. Although biomass is not widely used today, there is a lot of power generating potential available.[13]

3.1 Wood

Plants are comprised mostly of a material called cellulose, wood included. This cellulose is produced from sugar during the process of photosynthesis. The cellulose that is produced contains an abundance of stored chemical energy, which can be released as heat. When wood is burned this heat is released, which can either be used directly to heat a home or to generate alternative types of power.

3.1.1 Description of Technology

There are various technologies that can be used to convert wood to energy. The main types are combustion, gasification, cogeneration and cofiring. Each technology has its advantages and disadvantages and are applicable in certain situations.

3.1.1.1 Combustion

Wood combustion is often used by forest product companies (such as lumber yards) to generate power. In the process of combustion, wood (in a variety of forms) is shipped and maintained at an energy plant holding site. Belt conveyors will then be used to transfer the wood to a combustor. In the combustor the wood is burned and the heat is transferred to a steam or hot water boiler.[14]

Steam turbines are then used to convert the steam into electric power. Any steam that is left over can then be used in other plant processes. Hot water boilers are used to generate heat for other buildings and it is distributed through pips that run between buildings.[14]

3.1.1.2 Gasification

In the gasification process, wood is heated in an environment without oxygen until carbon monoxide and hydrogen are released. After these gases are released one of two things can happen. The first thing that can be done is that the gases can be mixed with pure oxygen or air, in which case full combustion will occur and heat will be produced. The alternative is that the gases can be cooled and purified to be used as fuel for gas turbines and engines.[14]

3.1.1.3 Cogeneration

Cogeneration, also known as combined heat and power (CHP), is the production of both heat and electricity from a single fuel. Either a wood gasification unit, steam turbine, or internal combustion unit can be used as a cogeneration unit. Although there are some challenges with designing CHP units, they can create more electricity and heat from less fuel than separate heat and power (SHP) system. [14]

3.1.1.4 Cofiring

Cofiring is the process of using biomass products to generate electricity in a coal plant. Although biomass products cannot be the only fuel source in a coal boiler, it is a good alternative to help create cleaner energy. Cofiring is a rather new technology (it has only been implemented since the early 1990's), however it shows great potential in large scale coal power plants.[14]

3.1.2 Best Location

Wood biomass technologies can be used nearly anywhere, however it is not always an economical choice. For most situations it is best if the final destination of use is within a 50 mile (80.5 km) radius of the source of wood (see Figure 4 for forest coverage located in North America). Transportation is very expensive and if the wood has to travel a long distance to get to its final destination, it is not an efficient option.[14]

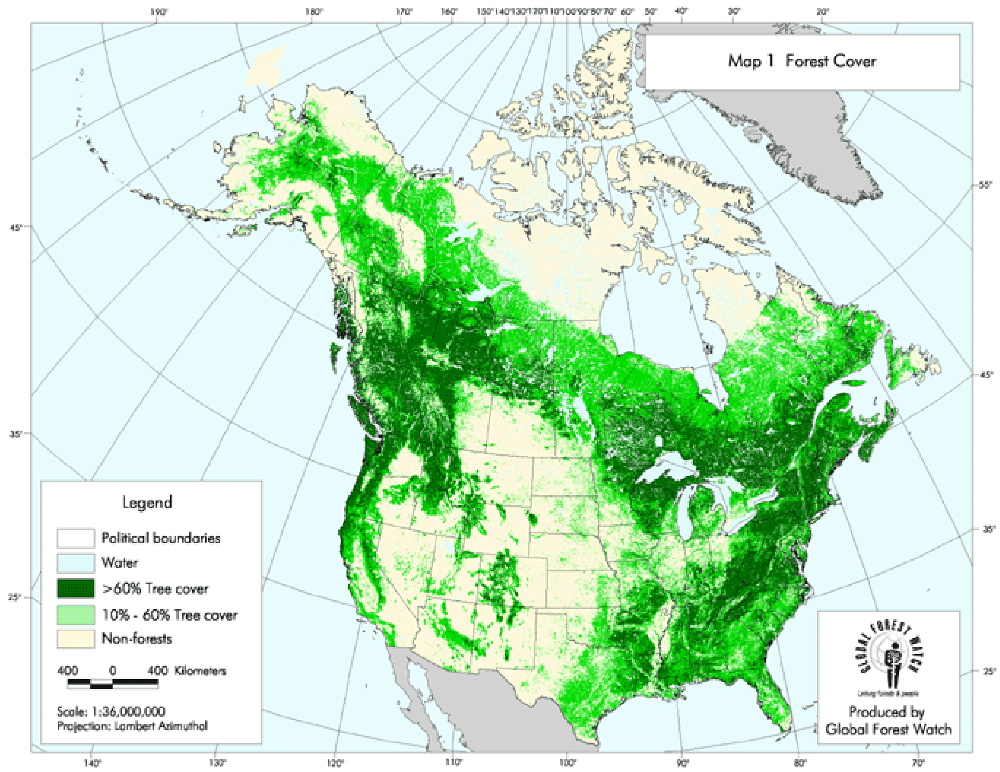

Figure 4: North America Forest Coverage[15]

Biomass power can be used for a variety of applications, however residential, commercial and industrial applications are the most common. As long as the location using the wood is located in or near a wooded region, wood biomass is an applicable renewable resource option.[14]

3.1.3 Cost Range

The cost of wood biomass varies greatly depending on the type of technology that is being used. For most large scale systems, the initial cost will be about 50% higher than a standard fossil fuel system. Although this is not applicable for every situation, it is a general rule of thumb to go by. Some of the important cost factors to look into are cost per kWh of power, typical cost of the system, and payback period

Currently an installed 0.3 MW to 1.5 MW fuel burner or boiler system will cost about $150,000 to $225,000 per MW of heat input. Wood combustion power plants will typically generate electricity between $0.06 to over $0.11 per kWh. The cost of cofiring systems will vary slightly. If "woody residue" is used in a coal firing plant, it will cost about $0.02 per kWh of power and the average cost for an investment is around $180 to $200 per kW of capacity.[14]

Some other comparisons can be seen in Figure 5. This represents the size and cost of electrical, thermal, and combined heat and power (CHP) facilities. In general CHP facilities have a higher capital cost and use more fuel, but it is a "clean" way to generate power making it an attractive source of energy.

	Size (MW)	Fuel use (green ton/yr)	Capital cost (million $)	O&M[a] (million $)	Efficiency (%)
Electrical					
Utility plant	10–75	100,000–800,000	20–150	2–15	18–24
Industrial plant	2–25	10,000–150,000	4–50	0.5–5	20–25
School campus	N/A	N/A	N/A	N/A	N/A
Commercial/institutional	N/A	N/A	N/A	N/A	N/A
Thermal					
Utility plant	14.6–29.3	20,000–40,000	10–20	2–4	50–70
Industrial plant	1.5–22.0	5,000–60,000	1.5–10	1–3	50–70
School campus	1.5–17.6	2,000–20,000	1.5–8	0.15–3	55–75
Commercial/institutional	0.3–5.9	200–20,000	0.25–4	0.02–2	55–75
Combined Heat and Power (CHP)					
Utility plant	25 (73)[b]	275,000	50	5–10	60–80
Industrial plant	0.2–7 (2.9–4.4)	10,000–100,000	5–25	0.5–3	60–80
School campus	0.5–1 (2.9–4.4)	5,000–10,000	5–7.5	0.5–2	65–75
Commercial/institutional	0.5–1 (2.9–7.3)	5,000	5	0.5–2	65–75

[a]Operating and maintenance.
[b]Sizes for the CHP facilities are a combination of electrical and thermal; the first figure is electrical and the figure in parentheses is thermal. 1MW = 3.413 million Btu/h.

Figure 5: Comparison of Electrical, Thermal and CHP Facilities [14]

3.1.4 Efficiency

The efficiency of a wood biomass system varies based on the type of technology. Similar to many other systems, one technology will be more efficient and cost effective than another. A standard wood combustion system will achieve an efficiency of between 65% to 75%, however electricity generated from wood-fueled power plants will only be about 18% to 24% efficient. With such a low efficiency, the only way for a wood-fueled power plant to be a good source of power is if the wood is bought for an extremely low cost.[14]

Combined heat and power (CHP) facilities will have higher efficiencies. The standard efficiency for a utility or industrial plant is between 60% and 80%. For a smaller application such as a school campus or a commercial usage the efficiency will change slightly. For these applications the standard efficiency will be between 65% and 75%.[14]

3.1.5 Downsides/Environmental Impacts

Although there are many positive aspects of using wood biomass systems, there are also some negative aspects. In a strictly aesthetic sense, harvesting wood depletes wooded areas and makes them less visually appealing. There are also certain regions that will not allow the use of wood-burning stoves or fireplaces on days that are deemed "high-pollution days."

There are also potential environmental impacts of using wood. If too much wood is harvested too rapidly or in a way that damages parts of the ecosystem, it can be problematic. Carbon monoxide and particulate matter are also released from burning wood, but this can be reduced by using clean burning technologies with wood burning stoves/fireplaces.[16] On average the amount of carbon dioxide emitted during the burning process is 90% less than when burning fossil fuel.[14]

3.1.6 Case Studies

In Warren, Pennsylvania a hospital utilizes a wood residue-powered boiler system to create heat and hot water. The hospital houses about 400 employees and 200 patients. Of the hospital's 3 boilers, one was reconfigured in 1990 to burn wood. The facility uses around 71 tons of wood residue each day during peak winter months and uses approximately 35 tons per day in the summer. The annual average use of wood is 7,520 tons. The operational costs of the system is about $145,000 per year, which is about $400,000 less than what would be spent on a system that combusts gas as opposed to wood.[17]

Since the facility is about 80 miles away from its source of wood, it is capable of burning gas if necessary. Warren Hospital has a contract with its wood supplier that states if the supply of wood is running low and burning gas is required, then the supplier must provide monetary compensation for the cost of gas burned. [18]

The system is up and running between 70% and 80% of the time and usually when it is not running it is scheduled for maintenance. The on-site storage can hold about one week's worth of wood or about 59,000 ft^3. Though the system saves money as opposed to gas, there is still a $280 cost per month, to landfill the ash that is created in the process. This equals $3,360 per year to properly dispose of the ash, which is still significantly less than the $400,000 saved per year by using wood as opposed to gas.[19]

3.2 Algae

3.2.1 Description of Technology

Like many plants, algae relies on photosynthesis to harness solar energy as a means to create energy. But unlike many other plants, algae produce fatty lipid cells which are full of oil. This oil can then be used as a source of fuel. [20] On the other hand, microalgae produce natural oils which are necessary to create biofuels.

Currently there are two different land-based systems used to grow algae, open ponds and closed bioreactors. Open ponds are made up of shallow channels which are filled with freshwater or seawater (the type of water used depends on the algae being grown). In order to keep the pond aerated and the algae suspended the water will be continuously circulated.[18]

Closed bioreactors are enclosed systems which are made of either glass or clear plastic. Unlike open ponds, closed bioreactor systems do not have to worry about water evaporating from the system. These systems however are hard to control. Temperature control and water storage and two main issues associated with using closed bioreactors.[18]

Unlike regular algae, microalgae have a simple structure that makes the organisms more efficient in their conversions of solar energy. The cells can access water, carbon dioxide, and other various nutrients, due to the fact that the cells grow in aqueous suspension. Microalgae are extremely efficient and are able to produce about 30 times the amount of oil per unit area of land that terrestrial oilseed crops can.[21]

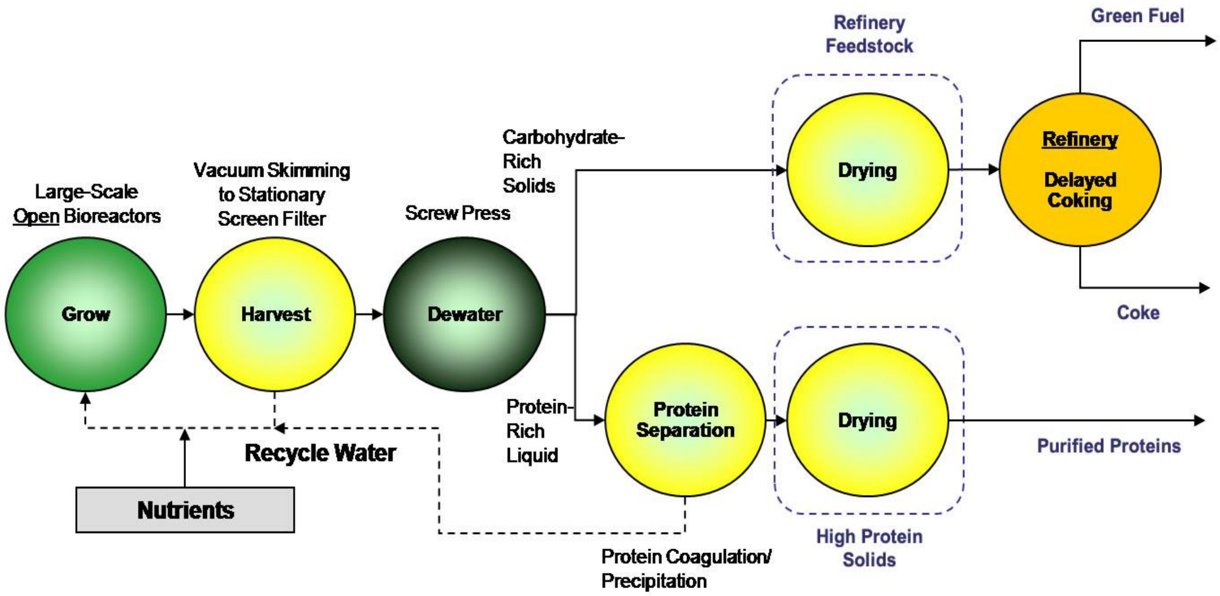

Figure 6: General Algae System Process 22

3.2.2 Best Location

Algae systems can be installed in most locations throughout North America. The main requirements for these systems are land availability, temperature, and sunlight. These systems require a lot of land to install (some systems can take up hundreds of acres of land), along with a good freshwater supply due to evaporation that may occur.[18]

Closed bioreactors can be used in most locations throughout the year due to the fact that the temperature and sunlight can be regulated internally. No “outside” factors are really involved in these systems, making them applicable in a wide variety of locations. The efficiency of open pond systems depends mainly on the location. Unless an open pond is installed in a hot climate it cannot be utilized throughout the year. These ponds can only operate in the warmer months, making it more efficient for these to be located in warmer climates.[23]

3.2.3 Cost Range

Producing algae requires ample open land for the production ponds. The land must also receive adequate sunlight. The average cost of a 100 acre farm (with installation) is around $1 million with a payback period for the investment ranging from five to fifteen years. Although this is not the exact cost for every farm, it is a good estimation of most large scale applications.[24] On top of the cost of the land, there are also construction fees for the system. Michael Briggs, a physics professor from the University of New Hampshire, estimates that the construction costs for algae pond can be around $80,000 per hectare.[25]

The cost of actually producing microalgae varies greatly as well. The type of system that is used to grow the algae will have an effect in the cost of the algae that is produced. For example an open pond system (raceway system) will produce 2.2 lbs (1 kg) of microalgae for about $3.80. On the other hand a closed bioreactor system (photobioreactor) will produce 2.2 lbs (1 kg) of microalgae for about $2.95. Both of these values are based off the fact that 220,462 lbs (100,000 kg) of microalgae will be grown. If this figure is increased to growing 22 million lbs (10 million kg) of microalgae the cost of production will be reduced to $0.47 per 2.2 lbs (1 kg) for photobioreactors and $0.60 per 2.2 lbs (1 kg) for raceways.[26]

3.2.4 Efficiency

The efficiency of a biomass algae system will changed based on the type of extraction system that is used to remove the oil from the algae. Most systems are extremely efficient in growing algae, as long as the growing environment is monitored and regulated. OriginOil, which specializes in algae extraction, recently finalized its Single Step Extraction system for extracting algae oils. The new efficiency of the oil extraction system is 94% to 97% making it one of the best in the industry.[27]

Besides the extraction efficiency, it is important to look into the sunlight to biomass efficiency. This figure is the photosynthetic efficiency and represents the amount of sunlight that is actually used in the process of photosynthesis. Theoretically about 45% of the solar energy that reaches a plant can be used for photosynthesis. This figure however is under ideal conditions. In reality the efficiency is only about 3% to 6% due to the fact that not all of the sunlight will be absorbed and optimum solar radiation levels will not always be reached.[28]

3.2.5 Downsides/Environmental Impacts

Algae production requires a large amount of land that receives adequate sunlight, which can be a limiting factor in some cases. Additionally, water storage and proper temperature control can be very costly. A lot of water is required for an open pond system to be used and this has an impact on the surrounding environment.[18]

3.3 Landfill Gas

When waste is deposited into landfills anaerobic decomposition occurs. During this decomposition stage landfill gas is produced. Landfill gas is made up of methane, carbon dioxide, hydrogen sulfide, and non-methane volatile organic compounds (VOC's). Approximately half of the landfill gas is made up of methane, which can be used for energy generating purposes. Landfills will collect the methane that is generated and then treat it and sell it as a fuel source. This treated methane can then be burned, similar to regular fuel, to generate either electricity or steam to power a turbine.[29]

Over the past 25 years plants that focus strictly on the extraction and use of landfill gas have been created. As of December 2008 there were a total of 480 operational landfill gas projects in the United States. The extraction of this gas is not only beneficial because it can be used as an alternative to fossil fuels, but it is advantageous to the environment. Through the extraction process, methane emissions into the environment are reduced.[30]

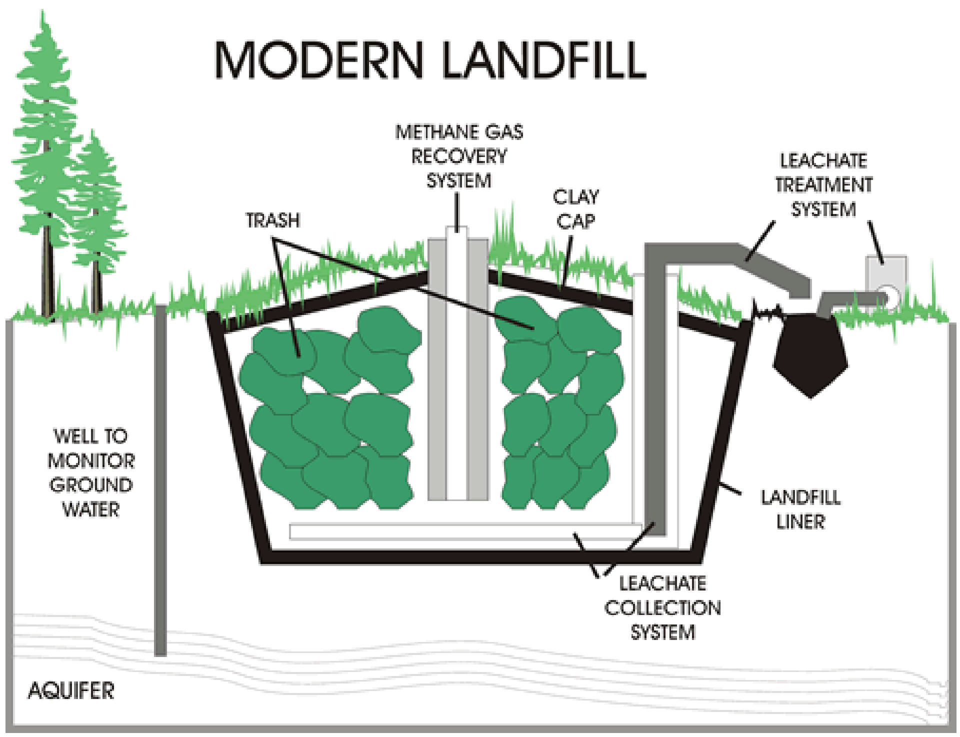

Figure 7: Modern Landfill

3.3.1 Description of Technology

Landfill gas recovery systems are currently used to capture the gases that would otherwise be emitted into the environment. There are two different types of systems that can be used. Vertical well systems are a series of wells spaced approximately one well acre apart are drilled to the bottom of the waste and connected with a pipe. Horizontal collectors on the other hand are buried below the landfill and are often used if the area is an active fill area. For both systems either a blower or vacuum is used to extract the gases from the landfill. The extracted gases are then sent into a central collector and then cleaned and compressed. From here the gas is either delivered to another site for usage or sent through a generator to create electricity (see Figure 8 for system process).[31]

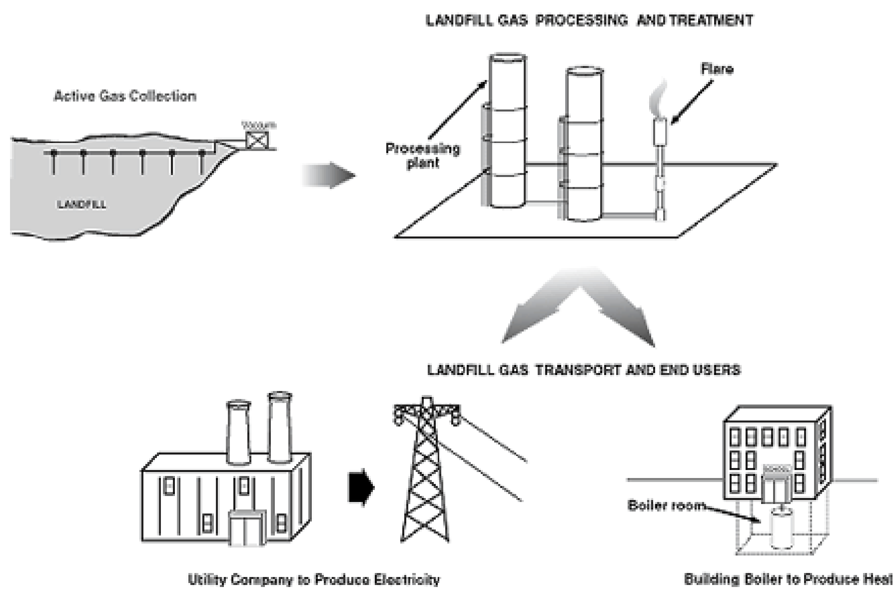

Figure 8: Landfill Gas Process[32]

3.3.2 Best Location

The types of gases generated by a landfill will vary based on a variety of things. The type of garbage buried, the size (depth and height) of the landfill, the age of the landfill, and the chemical environment of the landfill are all important characteristic. All of these characteristics will change based on the location of the landfill. Despite the fact that landfills are located all throughout the United States, not all of them are suitable for landfill gas extraction.[33]

According to the United States EPA a "candidate" landfill needs to have certain characteristics in order to make the extraction technology worthwhile. These landfills generally need to have at least one million tons of waste and are either still be in service or has been closed for five years or less (see Figure 9 below for "candidate" landfills). Other landfills can be used, however this is more of a case by case basis and do not always follow the general standards.[28]

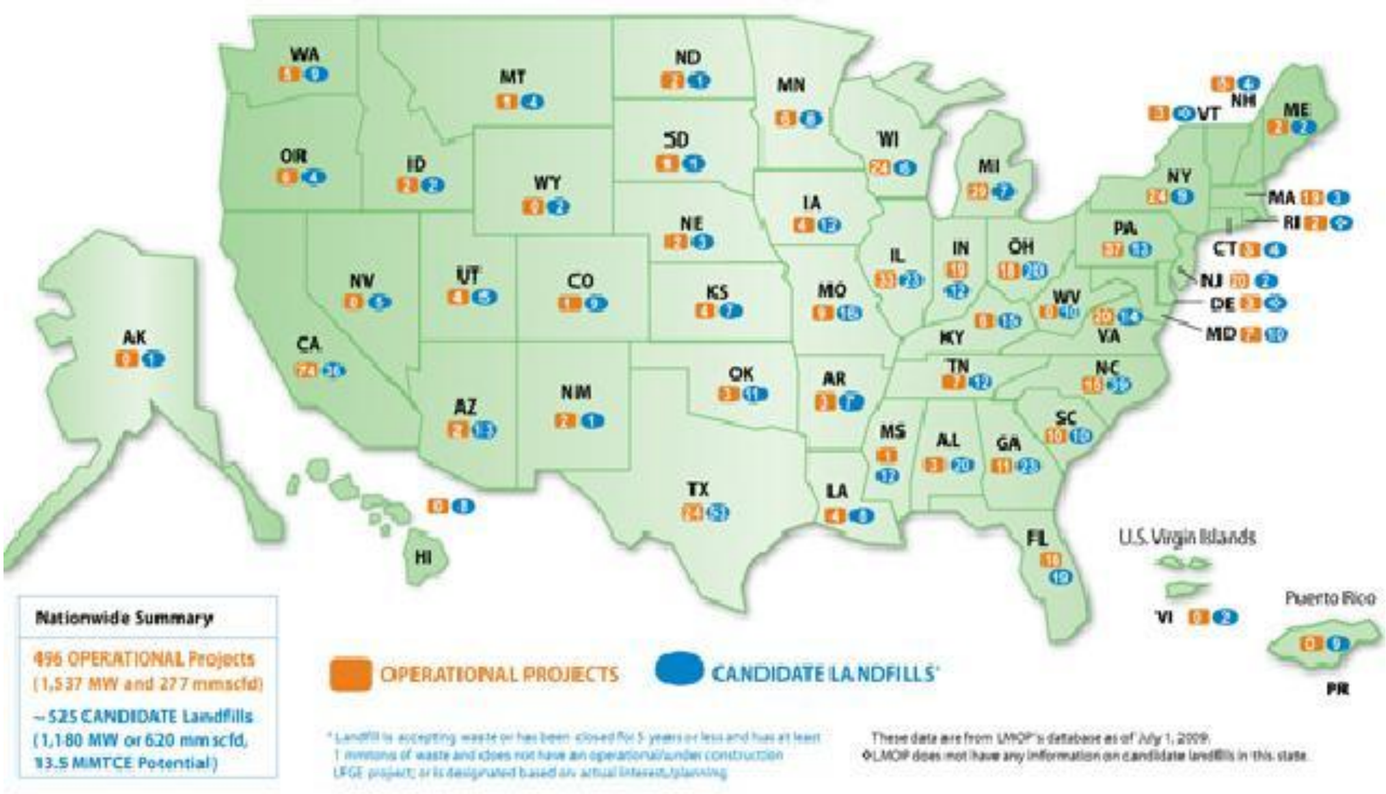

Figure 9: Landfill Gas Energy Projects and Candidate Landfills

The United States EPA has a Landfill Methane Outreach Program (LMOP) that estimates that 560 landfills exist and a total of over 1,300 MW of power or 250 billion cubic feet (7.1 cubic meter) per year of gas can be generated from landfills. With over 400 projects in development in the United States and over 1,100 worldwide, there is a huge potential for landfill gas energy.[34]

3.3.3 Cost Range

Despite the fact that there are two different types of landfill gas technologies, the investment cost for each of them are about the same. In terms of an average 10 meter deep landfill, the cost of a collection system can range anywhere from $20,000 to $40,000 per hectare. In addition to this a suction system (which consists of monitoring equipment, control systems, and vacuum pumps) costs between $10,000 US and $45,000 per hectare.[35]

There are also extra costs added if the landfill gas is going to be used directly to generate electricity. Gas engines will generally cost between $850 and $1,200 per kW in low and middle income countries. The total cost ranges for an extraction system is summarized in Table 1.[33]

Component	Cost in $/ kW
Collection System	200-400
Suction System	200-300
Utilization System	850-1200
Planning and Design	250-350
Total	1550-2250

Table 1: Price Range of Landfill Gas Extraction System

The total cost for selling landfill gas energy will change based on whether or not it is being used during peak hours. The price for electric power will range from $0.01 per kWh (off peak) to $0.08 per kWh (peak). The average cost however is $0.04 per kWh making landfill gas energy a competitive source of power. The costs for electricity can be as low as $0.004 per kWh in the United States if the project is subsidized.[36]

3.3.4 Efficiency

Similar to many other systems, the efficiency of a landfill gas system can vary greatly depending on the type of technology being used, as well as the specific landfill. The United States EPA conducted a study in 2002 that strictly studied the efficiencies of landfill gas collection systems. Based on the figures that were reported, collection efficiencies can range from 60% to 85%. Some efficiencies were even as high as 90%, however the average value was about 75%. [37]

It is also important to look at how much landfill gas is lost to the environment before it is collected. Even though most landfill gas systems located within the landfill, some of the gas will escape before the system can "vacuum" it up. Studies have shown that about 40% to 50% of the gas is actually recovered, with some landfills acquiring about 60% of the gas.[33]

3.3.5 Downsides/Environmental Impacts

Landfill gas is not always the most efficient option, as it has less than 50% of the heating capacity of natural gas. However technology is still being researched and improved upon, with only a limited number of landfill gas-to-energy plants around the world today.[38]

Besides the reduced efficiency, there aren't very many other downsides. Landfill gas systems are no different than regular landfill's and have many of the same impacts.

Public concern show that they are unattractive and often smell, however not much can be done to change these factors.[31]

The environmental impacts associated with landfill gas extraction systems are mainly positive. As previously mentioned methane makes up about 50% of landfill gas. Not only is methane a greenhouse gas, but it is also extremely harmful and is about 21 times more potent than carbon dioxide. By extracting landfill gas, methane is also being extracted, which helps reduce the toxins being released into the environment.[39]

3.3.6 Case Studies

Landfill gas collection has been successful utilized in the Zámbiza landfill in Ecuador. The landfill was in operation for about 23 years, ending in 2002. During this time, over 5 million tons of waste was deposited at the landfill. Upon its closing it was deemed that this site possessed ideal traits for gas capture. [40]

The methane in the ground was captured and flared with about 10 hectares of the site defined as an area for capture. The site has the capability to maintain a 2,500 kW installed power gas utilization plant. The Zámbiza gas utilization plant would then be able to produce about 14,000 MWh of electricity per year, on average, ending in the year 2016.[40]

The project has potential for positive environmental impacts. It is estimated that carbon dioxide emissions will have been reduced by 777,000 tons. In addition to the environmental changes brought about by this project, people living in the vicinity of the site will also be exposed to less harmful emissions, are they are now captured as opposed to being released freely into the environment.[40]

3.4 Waste-to-Energy

Municipal solid waste (MSW), is more commonly known as garbage and is generated by people throughout the world. This waste is often made up of food scraps, paper, wood, plastics, and so on and gets transported to landfills located throughout the United States. Opposed to just leaving this waste in landfills and taking up space, it can be burned at waste-to-energy plants or in incinerators.[41]

Waste-to-energy plants will use the heat that is generated by burning waste and will generate steam to either create electricity or heat buildings (known as cogeneration). Incinerators on the other hand simply just burn the trash, but don't use any of the heat that is generated. In the United States alone over 55% of the trash that is generated ends up in landfills. Waste-to-energy plants can use some of this trash, to generate even more heat and power.[39]

3.4.1 Description of Technology

Waste-to-energy plants are very similar to coal fired power plants, the main difference being the energy source used. Waste is deposited into a combustion chamber, which is used to heat a boiler. The boiler will give off steam and this steam will be used to power a turbine of a generator. This generator will then produce electricity and be distributed by utility companies. The basic workings of a waste-to-energy plant can be seen in Figure 10.[42]

Although waste-to-energy plants seemingly eliminate garbage, they also produce ash as a byproduct of the burning. Typically 2,000 pounds (907 kg) of garbage will be reduced to about 300 to 600 pounds (136 to 272 kg) of ash. Despite this fact, waste-to-energy plants are still very beneficial. Not only do they generate electricity, but they also reduce the amount of waste in landfills.[40]

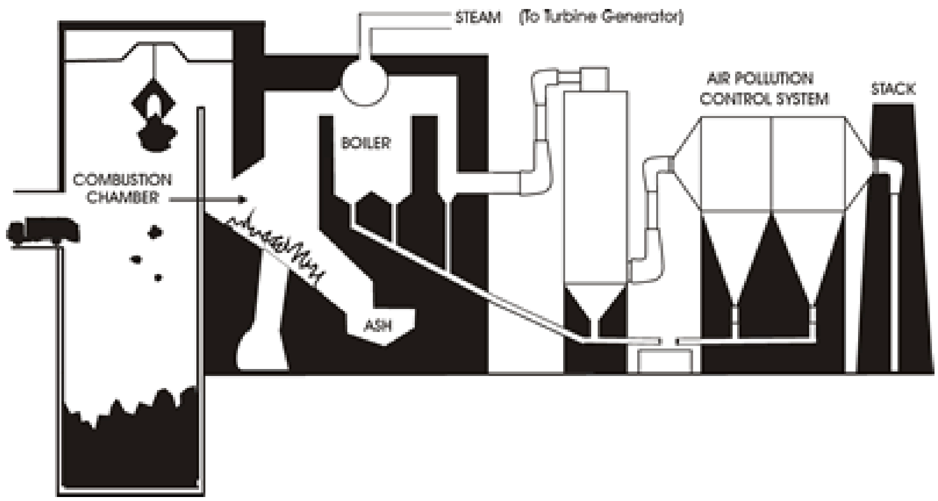

Figure 10: Waste-to-Energy Diagram

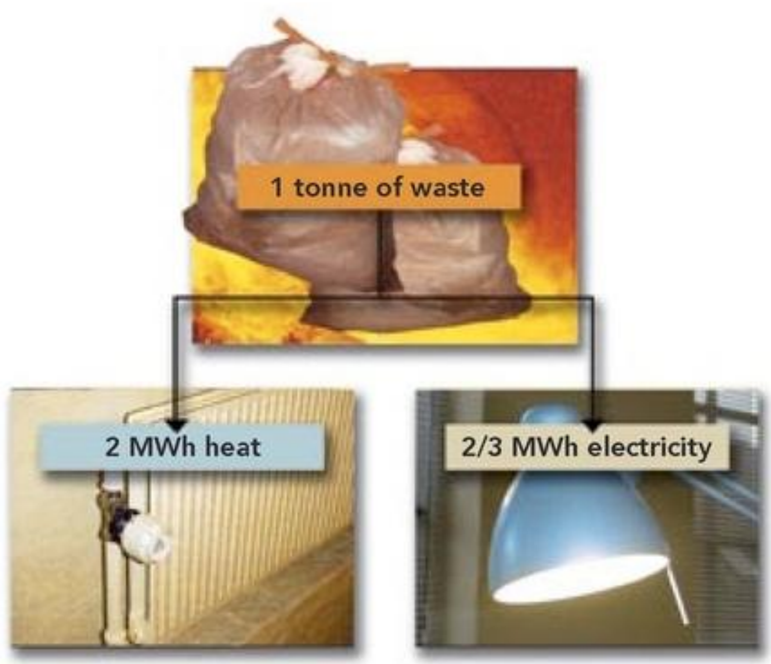

Figure 11: Energy Yields of Waste-to-Energy System[43]

3.4.2 Best Location

Currently there are over 600 waste-to-energy plants in 35 countries throughout the world. Waste-to-energy is becoming an increasingly popular practice in countries that have limited space, particularly in Asia and Europe. Currently the United States only burns about 14% of their waste in waste-to-energy plants, where as Denmark and Switzerland burn about half of their wastes in waste-to-energy plant. The top 5 countries with highest percentage of waste-to-energy utilization can be seen in the graph below.[39]

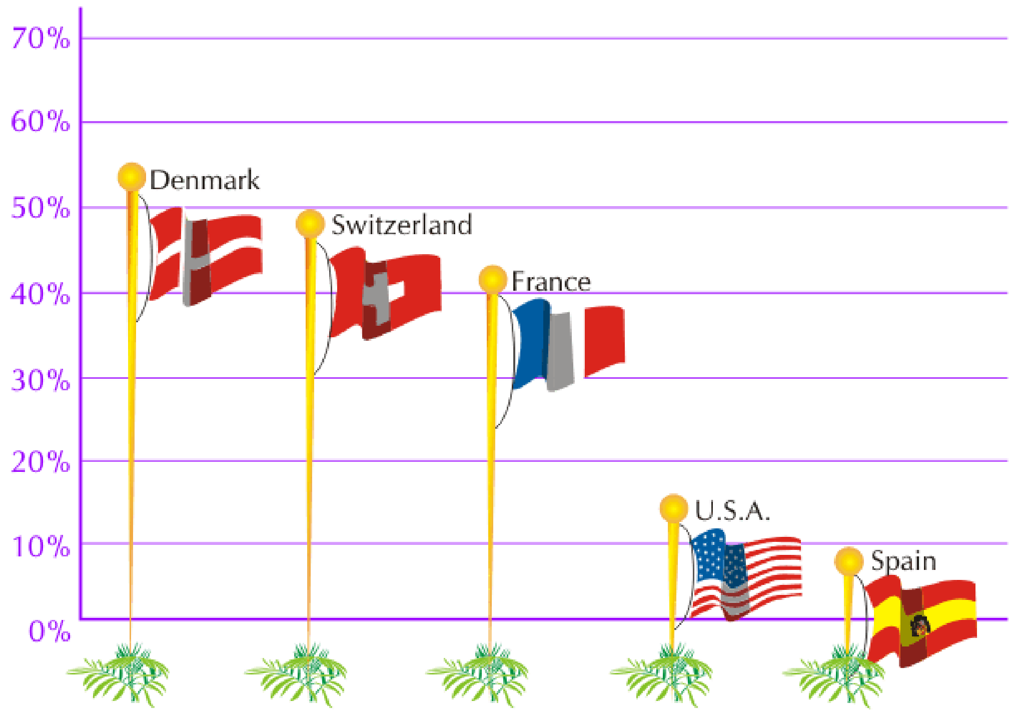

Figure 12: Countries with the Highest use of Waste-to-Energy

3.4.3 Cost Range

In general, waste-to-energy systems require a large capital investment. The incinerators used can cost anywhere from \$50 million to \$280 million based on the capacity of the system. Not only are the initial capital costs expensive, but maintenance fees are expensive as well. The boilers used to generate the steam need to be constantly maintained and in order to do so millions of dollars can be spent to keep the system up to date.[44]

On a smaller scale, a general rule of thumb is that the capital costs of a waste-to-energy plant will cost be between $110,000 and $140,000 per daily ton of capacity. For example if a large scale community wants to install a system that processes 500 tons of waste per day it will cost between $55 and $70 million. Another standard is that for every ton of waste about 500 to 600 kWh of electricity will be generated. If this electricity is sold for $0.04 per kWh, then the revenue per ton will be between $20 and $30.[45]

The National Resource Council has found that waste-to-energy technology is not always the most cost effective option when it comes to waste disposal. The annual cost to dispose of 1.8 million tons (1.6 billion kg) of waste for a waste-to-energy system would cost over $210 million, opposed to a landfill gas energy recovery system costing a about $175 million.[46]

3.4.4 Efficiency

In a waste-to-energy system approximately 80% of the garbage that is burned can be used to generate electricity. So for every 1,000 pounds (454 kg) of garbage that is used in the plant, about 800 pounds (363 kg) will be burned and generate power. To put this into perspective, 2,000 pounds (454 kg) of garbage will generate around 550 kWh of electricity, which can power 17 US households with electricity for a day.[40]

3.4.5 Downsides/Environmental Impacts

Despite the fact that waste-to-energy plants reduce the amount of garbage in landfills, it does produce some harmful emissions. Due to the burning process, bottom ash, metals, and iron are exposed in the plant along with other harmful toxins. Because there is a potential for this to be released into the environment a pollution control system (sometimes in the form of scrubbers) is installed in the waste-to-energy plant to reduce its potential effect.[47]

The environmental impacts of a waste-to-energy plant are extremely positive, however not only is the size of landfills reduced, but natural resources and fossil fuels are saved from being used and air emissions are reduced.[46] The average American creates over 1,600 pounds (726 kg) or waste per year. If 100% of this waste were to be put into a landfill, it would require over 2 cubic yards of space (a box with dimensions of 3 feet long, 3 feet wide and 6 feet high or 0.9 m long, 0.9 m wide, and 1.8 m long), whereas if the waste were incinerated, the residue ash would fit into a box with dimensions of 3 feet long, 3 feet wide and 9 inches high (0.9 m long, 0.9 m wide, and 0.2 m high).[39]

3.4.6 Case Studies

A waste-to-energy plant was built in Spokane, Washington in 1991. The total cost of this specific facility was $30.1 million, with electricity revenue of $12.1 million and materials recovery of $0.1 million. The net cost of operations evens out to about $17.9 million.

This plant has a maximum capacity of 800 tons per day and is operational 24 hours a day, 7 days a week, with an average of 720 tons of waste processed per day. The temperature of combustion is 2500° F. This plant is13% efficient and produces 141,000 MWh of sellable electricity on average each year. In addition, 25 MW of heat energy is also produced.[48]

3.5 Biodiesel

3.5.1 Description of Technology

Biodiesel is a non-toxic and biodegradable fuel that is made from vegetable oils, waste cooking oil, animal fats or tall oil (a by-product from pulp and paper processing). Biodiesel is produced from these feedstocks through a process called transesterification. In this process oil reacts with an alcohol (usually methanol, although ethanol can also be used) and a catalyst (such as sodium hydroxide). The resulting chemical reaction produces glycerine and an ester called biodiesel.[49] This process is illustrated in Figure 13.

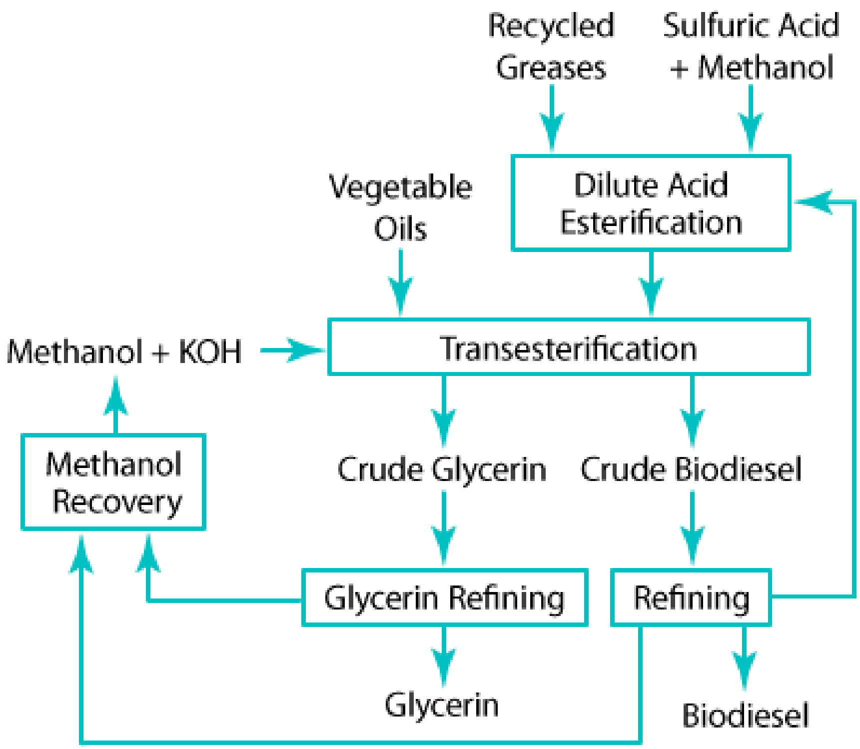

Figure 13: Production of Biodiesel[50]

Biodiesel can be blended with traditional diesel at many different levels, with B100 (100% biodiesel) being the purest form. It can also be blended at 2% (B2), 5% (B5), and 20% (B20). Biodiesel can also reduce wear on an engine by increasing it's over all lubrication. A 65% increase in lubrication can be achieved from a 1% mix of biodiesel.[51]

3.5.2 Best Location

Any vehicle that currently operates on petroleum-based diesel can use biodiesel without experiencing a significant decrease in fuel economy. Biodiesel has become popular for fleet vehicles that have their own fueling stations. It may become more common place for individual consumers as more fueling stations offer biodiesel as an option. A diagram illustrating the lifecycle of biodiesel can be seen in Figure 14.[52]

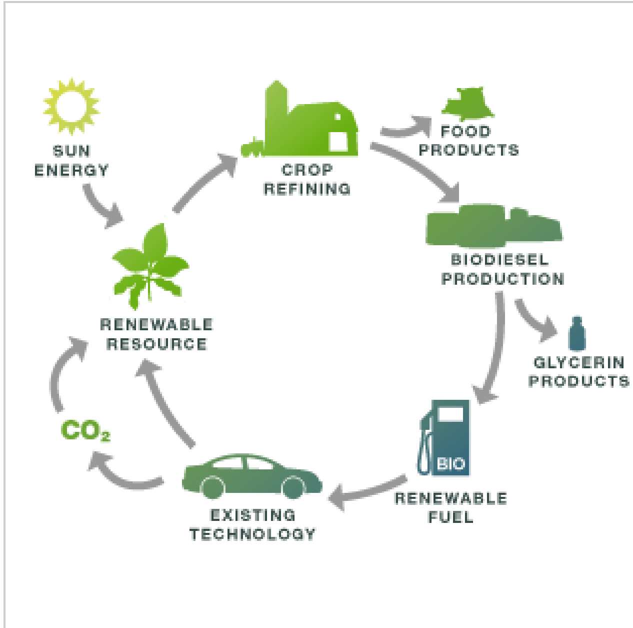

Figure 14: Life Cycle of Biodiesel

Biodiesel is not ideal for regions with frequent cold weather. When used in colder climates biodiesel tends to lose viscosity, which is especially true with higher blend levels of biodiesel.[53] Since biodiesel loses viscosity in low temperatures, it is most ideal to be used in regions that do not have extended periods of lower temperatures. These affects can be avoided however by using block and filter heaters, storing the vehicle indoors, or mixing biodiesel with other fuels.[54]

3.5.3 Cost Range

The U.S. DOE office of Energy Efficiency and Renewable Energy publishes an annual report on the fuel prices for various types of fuel. The report includes national and regional averages. The most recent publication in July 2009 found the values shown in Table 2. The prices are National at pump averages and include all taxes.

Fuel ($/Gal)	Price for July 2009
Gasoline	$2.44
Diesel	$2.54
Ethanol(E85)	$2.13
Biodiesel (B2-B5)	$2.55
Biodiesel (B20)	$2.69
Biodiesel (B99-B100)	$3.08

Table 2: National Fuel Averages July 2009[55]

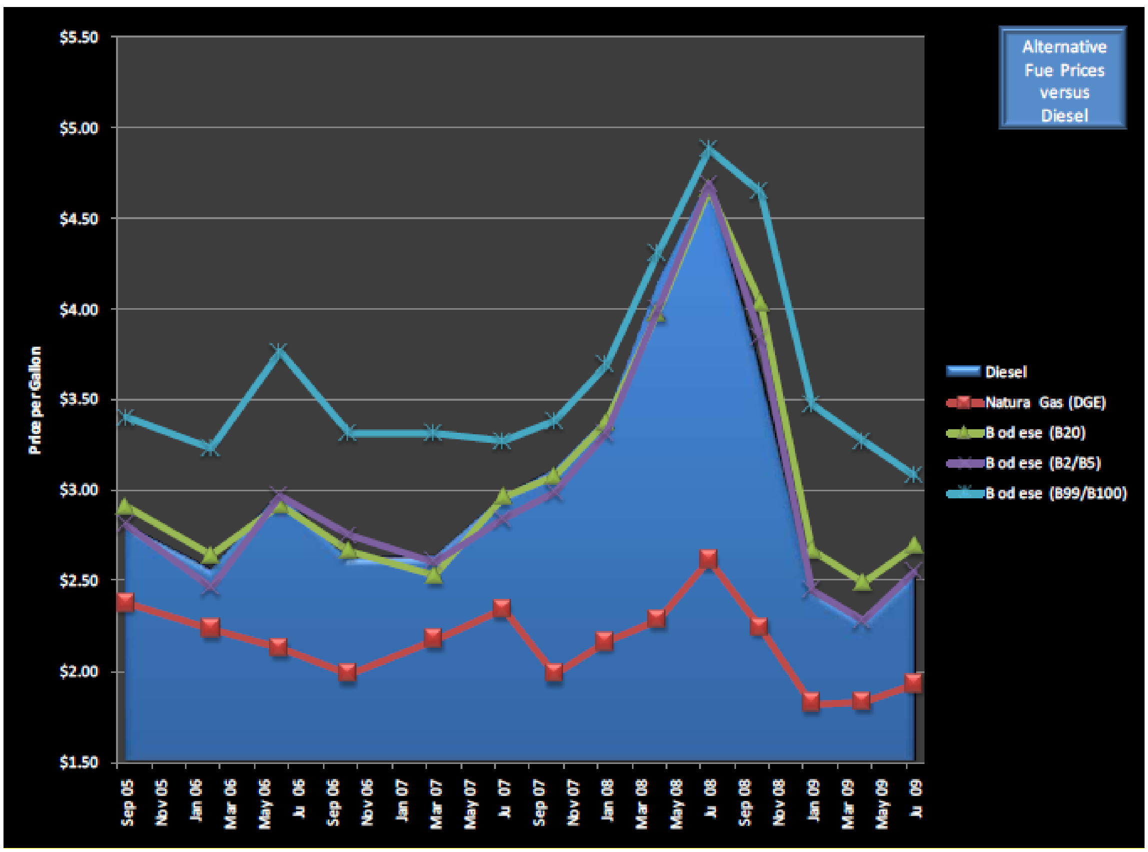

Figure 15: Monthly National Fuel Averages since Sept. 2005[53]

Figure 15 displays the monthly national averages since September 2005. Mixed biodiesel (B2-B20) will have lower cost because of the amount of petroleum diesel mixed in. This will cause biodiesel to have higher prices than traditional petroleum diesel until the price of B100 drops below petroleum diesel. The cost of B100 is high due to the cost of oil procurement and extraction, transportation, and storage which is responsible for ¾ of the price. Vegetable seed oil is most commonly used in biodiesel, however soybean oil and waste grease feedstock have the potential to decrease the cost of biodiesel. [56]

3.5.4 Efficiency

The National Biodiesel Board found that pure biodiesel has a 8.65% lower net heating value, which is the available energy per unit. Mixes of traditional and biodiesel will increase the net heating value on a liner comparison. Even with this difference in fuel consumption, horsepower, and torque are still comparable to petroleum diesel.[57]

3.5.5 Downsides/Environmental Impacts

There is a decrease in the strength of the smell from the smoke emitted by biodiesel compared to conventional diesel because biodiesel burns significantly cleaner. Biodiesel contains no sulfur, so unlike normal diesel, no sulfur is released when pure biodiesel is burned. CO_2 emissions are 78% lower from B100 produced from Soybean Oil when compared to petroleum diesel.[49]

Fewer pollutants such as particulate matter, carbon monoxide, airborne toxins and hydrocarbons are emitted from biodiesel than from conventional diesel, but there is a slight increase in the emissions of nitrogen oxides.58 A 2% to 4% increase of oxides of nitrogen (NO_x) occurs when using a 20% mix. Research is being conducted on additives to stop this problem and for low percentage mixes the increase is extremely low.[49] Table 3 shows the average emissions of multiple toxins from a report published by the U.S. EPA.

Average Biodiesel Emission Compared to Conventional Diesel - According to EPA	B100	B20
Emission type		
Regulated		
total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	10%	2%
Non-Regulated		
Sulfates	-100%	-20%*
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (Nitrated PAH's)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%

* Estimated form B100 result
** Average reduction across all compounds measured
*** 2-nitroflourine results were within test method variability

Table 3: Average Biodiesel Emissions[59]

Pure biodiesel is a safe and renewable fuel. Its is one tenth as toxic as table salt, only causes very little skin irritation over long periods of direct exposure, and degrades four times faster than traditional diesel in the environment.[60] Biodiesel is the only alternative fuel that has passed the EPA Tier I&II health effect test mandated by the Clean Air Act. These tests require that there is a reduction of all emissions and that there is no danger to human health. [61]

3.5.6 Case Studies

A case study on biodiesel and emissions is the "effects of Biodiesel Blends on Vehicle Emission." This report conducted by the NREL studies the emissions from eight different heavy duty vehicles including school buses, transit buses, large trucks, and a motor coach. Each vehicle was put under various driving cycles and was tested using a 20% mix (B20) of biodiesel.[62]

NREL also published “100,000 Mile evaluation of Transit buses Operated on biodiesel blends (B20)” which evaluates and compares the performance of transit buses operated on biodiesel and petroleum base diesel. The study found that the biodiesel fleet performed better, cost lest, and had lower overall emissions.[63]

4 Geothermal

Geothermal energy is simply earth-heat or heat that is generated from within the Earth. This heat can be contained as either steam or hot water and can then be used to generate electricity or heat buildings. Geothermal energy is most often obtained by drilling wells in the earth, comparable to the way that oil wells are drilled.[64]

Despite the fact that geothermal energy is not the leading source of renewable energy in the United States, in 2008 there was an estimated 2,958 MW of electricity was being generated in 7 states alone. On top of this, in 2008 the United States was the world leader of geothermal energy, both in generation of electric power and online capacity. A majority of our geothermal energy comes from one of two sources, ground source geothermal (geothermal heat pumps or ground source heat pumps) or deep well geothermal, both of which have been around since the early 1900’s.

4.1 Ground Source Geothermal

In 2004 the “Geothermal Heat Pumps – A World Overview” study was published and stated found that over 1,100,000 ground source heat pumps were installed throughout the world, with over half of them installed in the United States. That same study also showed that there had been a 10% annual increase the number of ground source heat pumps being installed in 30 countries over a 10 year period. In the United States alone it has also been recorded that over 80,000 geothermal heat pumps are installed yearly, with the most commonly installed system being a closed loop vertical system. [65]

4.1.1 Description of Technology

Ground source heat pumps are typically systems installed about 10 feet (3.05m) below the Earth's surface and are generally used for more small scale applications (such as residential homes and commercial buildings). Despite the fact that the temperatures above ground change drastically throughout the year, the temperature below the surface will generally be around 50° and 60°F (10° to 15.6° C) making it a very reliable and consistent source of energy. Ground source heat pumps can either transfer heat from the ground to heat a building or remove heat from a building to cool it.[66]

When looking to install a ground source heat pump there are two different types of loop systems to choose from. You could either have a closed-loop system or an open-loop system. In order to determine which system is the most applicable at your site, factors such as climate, available land, local installation costs, and soil characteristics are all taken into consideration.[67]

4.1.1.1 Closed-Loop System

A closed-loop system is comprised of horizontal, vertical, and pond/lake systems. Although each of these systems can be applicable for both residential and commercial buildings, it varies as to which system would be the most efficient. A pond/lake system is generally the most cost effective, but is only suitable if there is a sizeable body of water nearby. For this application coiled pipe is run from the building to the body of water at a depth of at least 8 feet (2.4 m).[65]

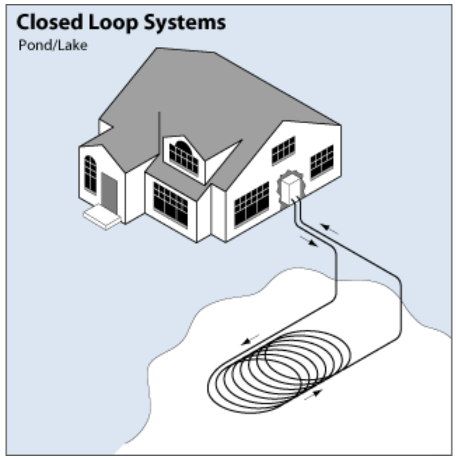

Figure 16: Closed Loop Pond/Lake System

A vertical system is typically used for large commercial buildings and schools because it decreases the required land area necessary for installation. Vertical loops also minimize the disturbance of landscaping and are used when the soil is to shallow for digging trenches (see Figure 17). A horizontal system is the most cost-effective system to use for residential homes when a pond/lake is not available for use. If adequate space is available this system is the most efficient to install during new construction because it requires trenches that are at least 4 feet (1.2 m) deep (see Figure 18).[65]

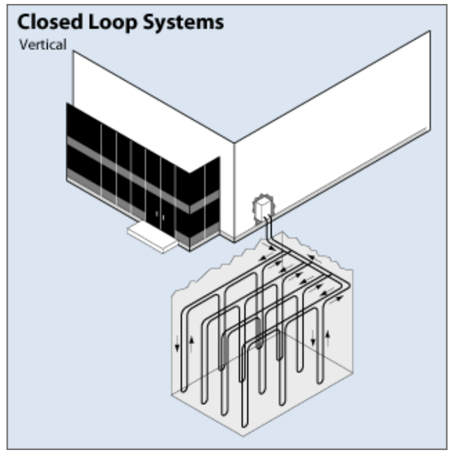

Figure 17: Closed Loop Vertical System

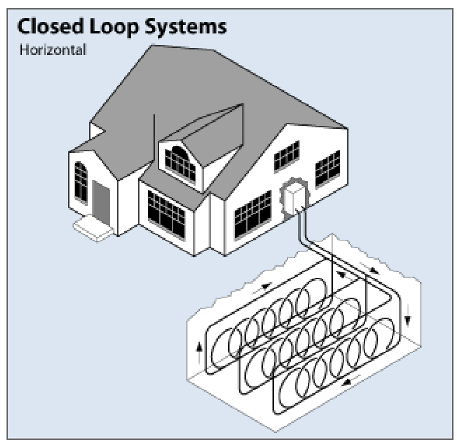

Figure 18: Closed Loop Horizontal System

4.1.1.2 Open-Loop System

An open-loop system uses either a well or surface water as the fluid that circulates through the system. After the fluid is circulated, the water is returned through a different pipe to where it came from. This option is really only feasible when there is a sufficient supply of fairly clean water. There are also local regulations and codes that have to be met due to the fact that water is being discharged back into the environment.[65]

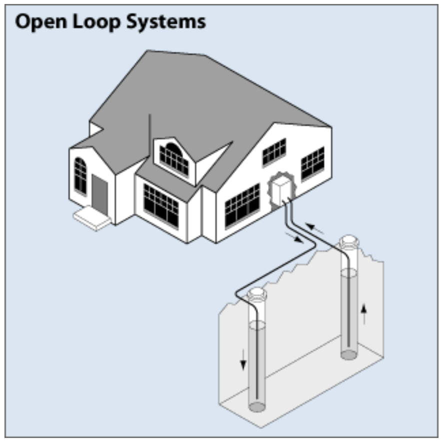

Figure 19: Open Loop System

4.1.2 Best Location

Unlike most other renewable energy options, geothermal heat pumps can be installed almost anywhere in the United States (see Figure 20). The reason behind this is that ground temperatures 10 feet (3.05) below the surface are somewhat consistent throughout the entire United States. The type of system used will depend on site specific variables. Some of the factors to look into are hydrological, spatial, and geological characteristics.[65]

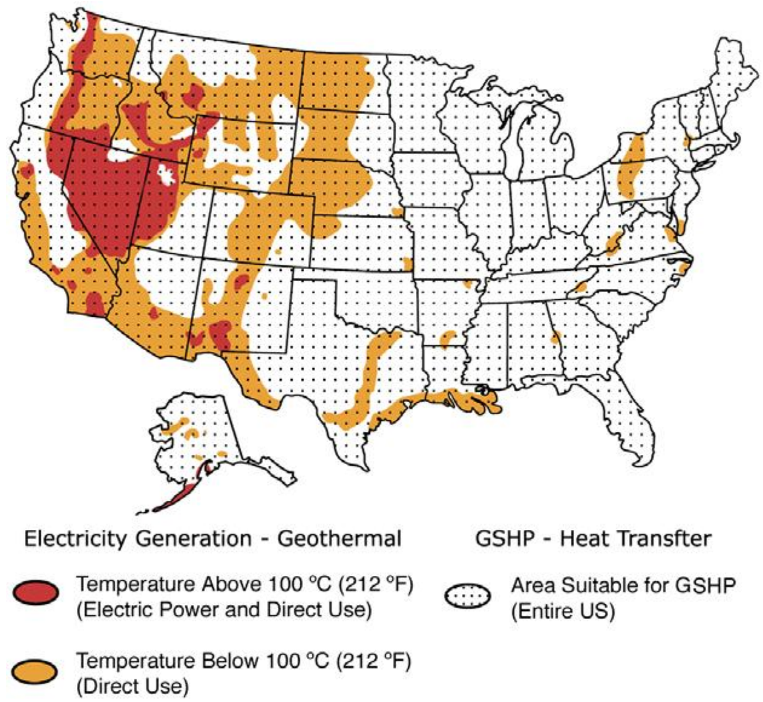

Figure 20: Geothermal Locations in the U.S.[68]

The geology of the site is important to consider mainly when designing a ground-loop system. The properties of the soil and rock in a specific location will affect the heat transfer rates of the ground, which dictates the amount of piping that is required (good heat transfer rates require less piping). The amount of soil available will also affect the design of the system. If there isn't a lot of soil available or if there is a lot of hard rock at a site then a closed-loop vertical system may be appropriate instead of a closed-loop horizontal system.[65]

Spatial factors will vary depending on the amount of land available to install the system. The layout of the land, location of underground utilities (including location of sprinkler systems), and landscaping are major contributing factors. If the site is under new construction with an adequate amount of land a closed-loop horizontal system can be easily installed. If the site already has existing buildings (and/or landscaping) and a smaller amount of land available, then a closed-loop vertical system can be installed.[65]

Hydrological factors are significant to consider because the amount of surface or ground water will help determine what type of loop system to use. For example if there is a body of surface water near a specific site that has an adequate depth, volume, and proper water quality, then an open-loop system can be installed. Ground water can often be used as a source of water in an open-loop system, as long as the water quality is adequate and ground water discharge regulations are complied with. It is important to keep in mind to check with the ground water discharge regulations of the particular area you are working with to ensure a geothermal heat pump system will be feasible.[65]

4.1.3 Cost Range

The cost range of the system will vary slightly depending on the type of system installed, location, and manufacturer. In general a closed-loop horizontal system will cost less than a closed-loop vertical system, with a closed-loop pond/system being the most cost effective if the location is suitable. Some of the important cost factors to look into are cost per kWh of power, typical cost of the system, and payback period.[65]

According to the U.S. Department of Energy, in 2008 the average geothermal heat pump system cost about $2,500 per ton (907 kg) of capacity heating/cooling. A typical residential home will require the unit to have a capacity of about 3 tons (2721 kg), which amounts to a cost of about $7,500. Besides the heat pump unit cost, there is also a cost associated with the installation of the system. This will depend mostly on the location and site that is being worked on. A system that is being installed where there is a lot of hard rock will cost more than a site with only soil because of additional excavation costs. Although geothermal heat pump systems are generally double the cost of a conventional system, they are less expensive to maintain and operate. The U.S. Department of Energy also indicated that there is an annual energy savings of anywhere between 30% and 60%.[65]

The Table 4 represents the cost variation for 3 ton (2721 kg) installed ground loop systems. An installed unit includes the ground loop, associated components, the units, and the ductwork. This data is from 2001 and estimated by the Geo-Heat Center. Although this data is slightly out of date, it still is a good representation of the average costs for the various systems. [69]

Type of System	Installed Cost ($)
Horizontal	8136
Slinky	8625
Vertical	8997

Table 4: Installed Cost for 3 Ton Geothermal Ground Loop Systems

Due to the fact that many geothermal heat pump systems are installed for private usage, there are not very many studies available on the cost per kWh of power. One study that was completed in 1995 studied over 150 residential geothermal heat pump applications. The cost per kWh of a system was computed based on a new, well insulated home with a 30 year fixed rate mortgage at 8%. The costs per kWh rates were calculated for two different climate zones for the electrical break-even values. In the warmer climate zones, the break-even values were $0.097 per kWh for vertical systems and $0.084 per kWh for horizontal systems. In the colder climate zones, the break even values were $0.061 per kWh for the vertical systems and $0.058 per kWh for the horizontal systems. These are not the most accurate values for today's market, however they do provide an idea of the range of costs per kWh.[69]

The payback period for a geothermal heat pump system will vary depending on the size of the system that is installed and the region's fuel prices. Based on the U.S. Department of Energy's statistics, in some instances a homeowner may be able to recover their initial investments anywhere from 2 to 10 years later simply through lower utility bills. The average heat pump unit will also last over 20 years and the piping will often have warranties that are between 25 and 50 years.[65]

There are various techniques and additional devices that can also help reduce the cost of a geothermal heat pump system. Devices such as the "desuperheater" can be added onto the heat pump unit. These are used to heat the household water by taking excess heat that is generated and using it to heat the water. Some units already have these installed, while others have these as an additional feature.[70]

4.1.4 Efficiency

Similar to most renewable energy options, the energy efficiency rating of the systems can vary greatly. When analyzing the efficiency of a geothermal heat pump system there are figures based on the coefficient of performance (COP) and the energy efficiency ratio (EER) rating. The COP is the ratio of heating/cooling output compared to the required work. An example of this is a COP heating ratio of 3.5, which means that for every unit of energy consumed 3.5 units of heat are provided. The EER rating measures how efficiently a cooling system works when the outdoor temperature is at a specific level. For this rating the higher the EER, the greater the efficiency of the system.[71]

Geothermal heat pump used for ground water or open-loop systems will typically have a heating COP rating ranging from 3.6 to 5.2 and a cooling EER rating ranging from 16.2 and 31.1 (see Figure 21). A system used for a closed-loop application will generally have a heating COP rating ranging from 3.1 to 4.9 and a cooling EER rating ranging from 13.4 to 25.8 (see Figure 22).[69]

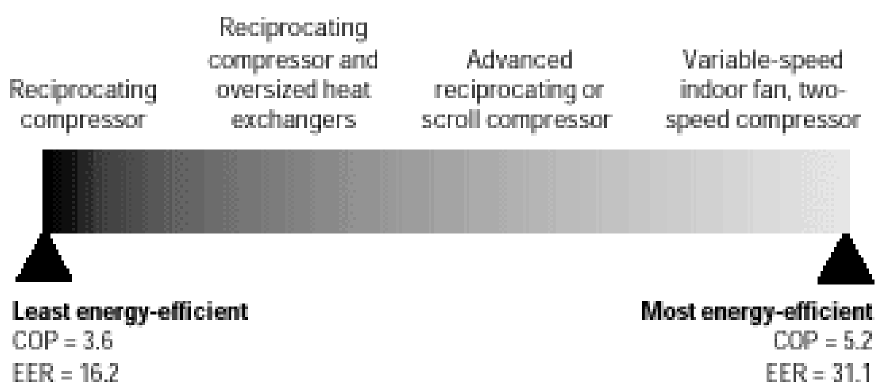

Figure 21: Open Loop System Efficiency

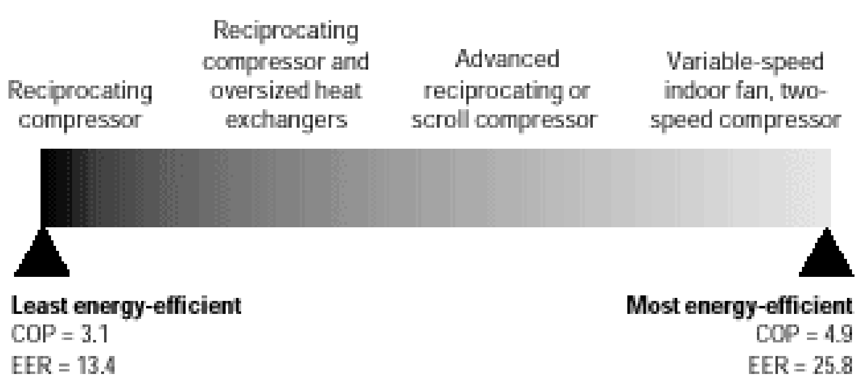

Figure 22: Closed Loop System Efficiency

On average the efficiencies of geothermal heat pumps are relatively high. On cold winter days a system can reach an efficiency of 300% to 600%, compared to an air-source heat pump efficiency of 175% to 250%. In some situations these two systems are combined to create a hybrid system. The advantage of this is that the system still has a higher efficiency than an air-source heat pump, but costs less than your average geothermal heat pump.[65]

4.1.5 Downsides/Environmental Impacts

As a whole, installing a geothermal heat pump is a very energy efficient way to heat and cool a building. There are a few downsides to the system however. If an open-loop system is to be installed then a large amount of clean water is required in order to make the system cost effective. This will sometimes limit the location of where the system can be installed. The major downside of this concept is that eventually the water needs to be discharged back into the environment and there might not be an acceptable place to put the water back into the environment. This is of concern if there is any sort of contamination or particles corroded from the system then it will be displaced into the environment.[72]

Also similar to any new construction, the installation of a ground-loop system will affect the surrounding environment. For each geothermal heat pump system to be installed the exact site and surrounding area must be excavated. This will disrupt any plant or animal life that is living in that exact area. Over time the environment will go back to its original state, however there will have been a short disruption.[70]

4.1.6 Case Studies

A case study done by the Oak Ridge National Laboratory on Geothermal Heat Pumps in K-12 Schools in Lincoln, Nebraska. This particular case study is compares the energy used in geothermal heat pump and non-geothermal heat pump schools. There is also data on load capacities, equipment models, and costs (both maintenance and total life cycle costs). The final sections concludes whether or not it was advantageous for these schools to install geothermal heat pumps or not.[73]

Another notable case study is the Ground-Source Heat Pump Case Studies and Utility Programs which was published by the Geo-Heat Center of the Oregon Institute of Technology in 1995. Although this document is slightly out of date it is very thorough with its information and statistics. One important part of the case study is that it is done on a residential, school, and commercial scale. Some of the information that is addressed is economics, system variables, system performance, incentives, and installations.[74]

4.2 Deep Well Geothermal

A deep well geothermal system requires a well (or series of wells) to be drilled miles into the earth. These wells will tap into underground reservoirs that contain steam and hot water. This heat will then be brought to the surface and be used for various applications (most common is to generate power). Deep wells typically tap into the hot water and rock miles below Earth's surface, however even deeper wells can be drilled to tap into really hot molten rock (also called magma). Deep well geothermal systems are typically installed for larger scale systems looking to generate a lot of power.[75]

Deep well's are drilled in order to attain fluid with a greater temperature. The further down in the Earth you drill the hotter the temperature is going to be. One standard is that if the temperature the first few meters in the Earth is the average temperature of the air, then the temperature about 6,562 feet (2,000 m) below the surface will be 140° to 167° F (60° to 75° C) and the temperature about 9,843 feet (3,000 m) below the surface will be 194° to 221° F (90° to 105° C). Theoretically the hot zones of the earth should transfer some of the heat to the cold zones to create uniform conditions, however this is not always the case.[76]

4.2.1 Description of Technology

Due to the high cost of drilling and installing a deep well geothermal system, they are typically used for large scale applications. In all geothermal systems there needs to be a heat source, a reservoir, and a fluid to transfer the heat. Once all of these components are acquired, the fluid can be pumped up to the surface and then be used to generate power.[74] There are three different types of reservoirs that can be drilled into. The first two are water-dominated reservoirs, which can either be high-temperature (beyond 5,000 feet (1,524 m) in the Earth) or low-temperature (usually less than 1,000 feet (305 m) in the Earth). The third type of reservoir is steam-dominated and is usually beyond 5,000 feet (1,524 m) in the Earth.[77]

In order to harness the power generated from underground reservoir, a power plant needs to be constructed. There are three different types of geothermal power plants. The first type is a flash steam plant which is used if there is a high-temperature, water-dominated reservoir. A flash steam plant will draw hot (typically above 360° F or 182°

C) high-pressure water from deep in the Earth, into lower-pressure tanks. This will create "flashed" steam, which will be used to drive turbines. [76]

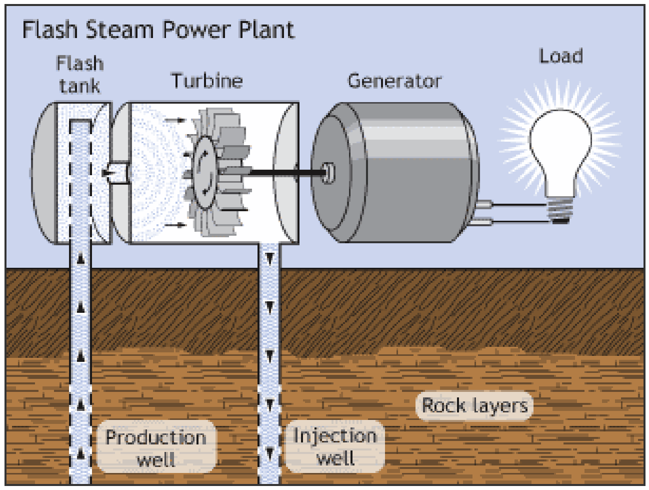

Figure 23: Flash Steam Power Plant

The second type of power plant is a dry steam power plant, which is typically used if there is a steam-dominated reservoir. This is the oldest type of geothermal power plant and perhaps the most simple. The steam from within the Earth is brought to the surface and sent directly to a turbine. The turbine powers a generator, which then produces electricity.[76]

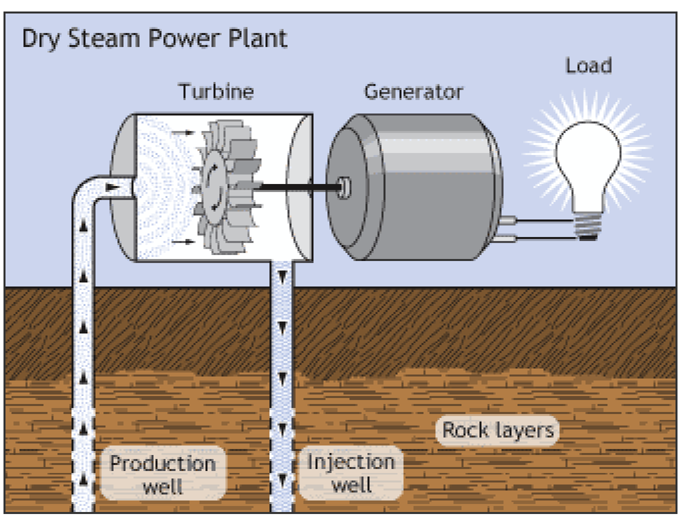

Figure 24: Dry Steam Power Plant

The last type of power plant is a binary-cycle power plant. Hot geothermal water and a secondary fluid (with a low boiling point) go through a heat exchanger. The heat from the hot geothermal water will cause the secondary fluid to vaporize. This vapor will then be passed through the turbine which is used to generate power. This system uses a moderate temperature water (below 400° F or 205° C), which is the most common geothermal source.[76]

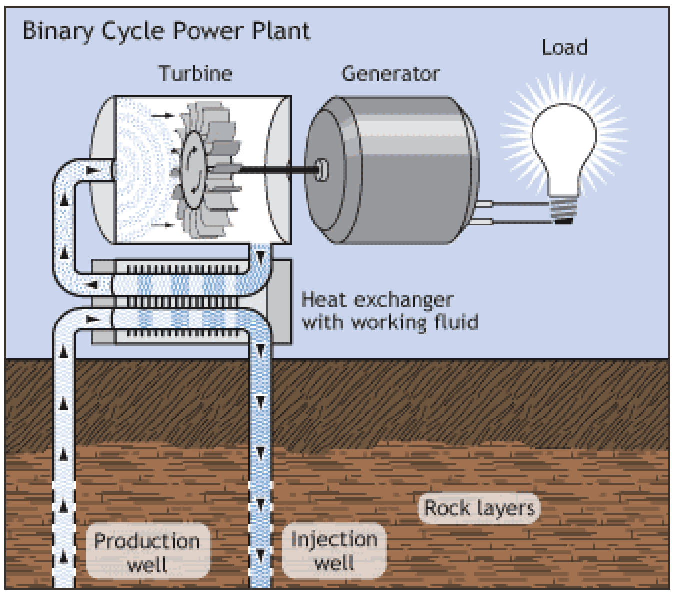

Figure 25: Binary Cycle Power Plant

4.2.2 Best Location

The ideal location to install a geothermal power plant is near a reservoir. Most reservoir locations are unknown unless there is some clue to give away their location. Volcanoes, hot springs, geysers, and holes where volcanic gases are released (known as fumaroles) are often found above reservoirs. In general, these features are located in the

Western United States, as well as in Alaska and Hawaii making them ideal locations to generate geothermal power.[76]

Figure 26 represents the United States geothermal resources available. The temperatures that are represented are estimations at a location 3.7 miles (6 km) below the Earth's surface. As you can see there is a great potential for geothermal power in the Western United States and a much lower potential in the Eastern United States. Although it is not shown on this map deep well geothermal power has a great potential in Western Canada.[78]

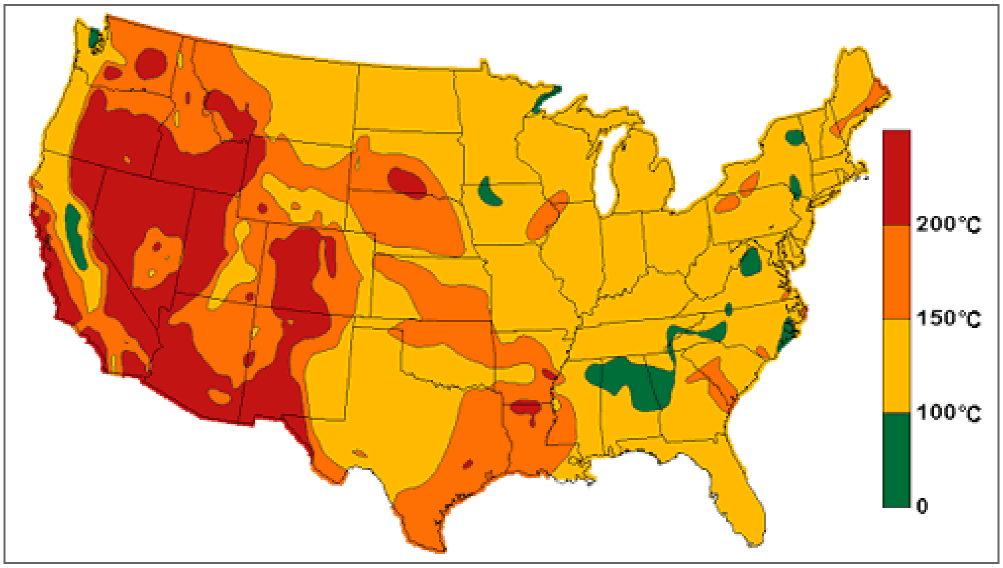

Figure 26: U.S. Geothermal Resource Map

Geothermal resources are also commonly found along major plate boundaries. A majority of the geothermal activity that occurs throughout the world is along the Ring of Fire. The Ring of Fire is the area that encompasses the Pacific Ocean basin where there is a series of volcanic arcs, volcanic belts, ocean trenches, and plate movement (see figure below for exact location of the Ring of Fire). These are ideal locations for geothermal power generation due to the amount of activity that occurs deep within the earth.[73]

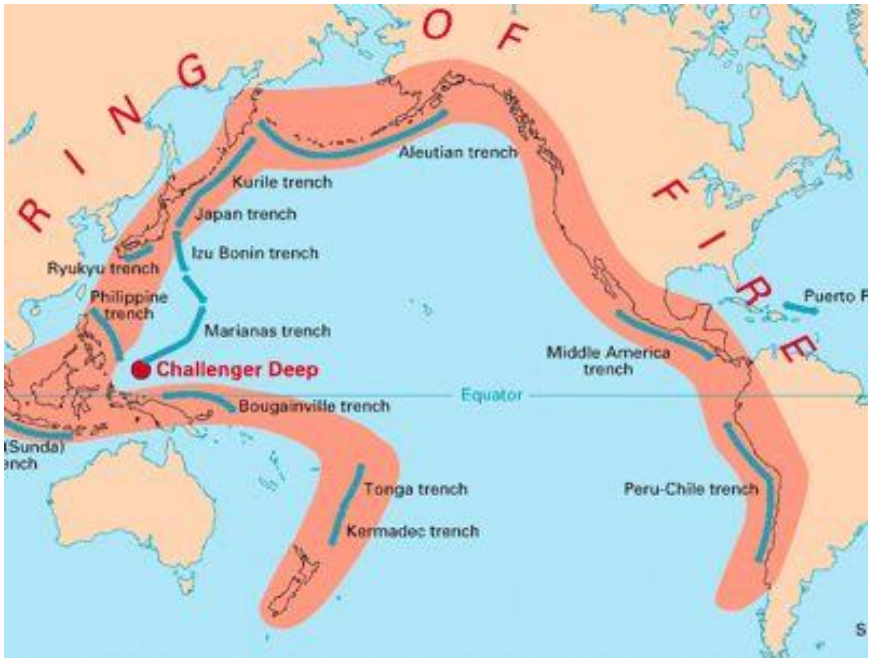

Figure 27: Ring of Fire

4.2.3 Cost Range

The cost range of the system will vary depending on the type of plant that is installed. The location and depth of the well are also a huge contributing factor to the cost of the overall system. Well drilling is very expensive and depending on the type of rock you are drilling into it will alter the cost drastically. Some of the important cost factors to look into prior to installing a system are cost per kWh of power, typical cost of the system, and payback period.[79]

Past studies have shown that the cost of well drilling can make up 42% to 95% of the total cost of the geothermal power plant system. The reason for the large variation depends on the type of reservoir that is being drilled into, along with well casing required. A model has been created to estimate the cost of drilling a geothermal well based on data from the Joint Association Survey (JAS) on Drilling Costs. This survey compares the cost of drilling gas and oil wells, to the cost of drilling into hot dry rocks and hydrothermal wells.[78]

Using the JAS data a drilling cost index called the MIT Depth Dependent (MITDD) index was developed to determine the cost of geothermal and hydrothermal wells. This index is more up to date and shows that the model for cost versus depth is non-linear and can change depending on casing design and site characteristics. Using this index it was found that the cost of drilling a geothermal well is anywhere between 2 and 5 times the amount of drilling a gas or oil well of a similar depth.[78]

Although the cost of drilling a geothermal well can vary greatly, there are various cost standards to go by. A competitive geothermal power plant can cost around $3,400 (or more) per kW installed, with about 2/3 the total system cost being the initial construction fees. Another standard is that a new geothermal project can cost anywhere from $0.06 to $0.08 per kWh of energy produced. This is very comparable to the standard of $0.06 per kWh of energy produced for a coal or oil power plant.[80]

In 2007 the California Energy Commission compared power levelized cost generations for geothermal plants and natural gas power plants. A 50 MW binary geothermal plant produced energy for about $92 per MWh and a 50 MW flash geothermal plant produced energy for about $88 per MWh. Meanwhile a 500 MW combined cycle natural gas power plant producing energy for about $101 per MWh and a 100 MW simple cycle natural gas power plant producing energy for about $586 per

MWh. When these values are compared, the cost for geothermal energy is very competitive alongside natural gas energy.[79]

Type of System	Cost of Power in $ per MWh
50 MW Binary Geothermal	$92
50 MW Flash Geothermal	$88
500 MW Combined Natural Gas	$101
100 MW Simple Cycle Natural Gas	$586

Table 5: Cost Comparison of Geothermal Systems

4.2.4 Efficiency

The efficiency of a deep well geothermal system can change greatly depending on the temperature of the steam/water leaving the boiler and the temperature of the condenser. One general standard is that the hotter the temperature of the steam/water, the greater the system efficiency. The efficiency for a geothermal steam plant can range anywhere from 10% to 17% depending on the technology and equipment used.[81]

4.2.5 Downside/Environmental Impacts

Like any system there are some downsides and environmental impacts associated with installing a deep well geothermal system. One downsides to a deep well geothermal system is that the technology isn’t fully developed to move large volumes of hot water through the earth. A pump that is strong enough has yet to be developed, but the sophistication of technology is ever increasing.[82]

Another downside to deep well geothermal systems is the noise factor associated with the construction and operation of the plant. Drilling a well can be extremely noisy, but actions can be taken to reduce the noise. Noise shields can be installed around part of the drilling rig and noise controls can be used on general construction equipment. In terms of the general operation of the power plant, the cooling fans can create a certain amount of noise, but similar to other systems equipment can be installed to reduce the noise. Although this is not always a factor in every situation, it is something that can have an effect.[83]

On the other hand a major environmental impact is that drilling deep well's has is that earthquakes can be generated. Drilling deep into the earth will expose fractures that are being created in the rock. It is estimated that each year over 3,000 small earthquakes occur at The Geysers in California. With earthquakes continuously occurring, the surrounding ground can weaken due to the constant seismic activity.[81]

Another environmental impact is that geothermal power plants emit very low levels of nitrous oxide, sulfur dioxide, hydrogen sulfide, carbon dioxide, and particulate matter. Although binary and flash systems have an emission rate of nearly zero, dry steam systems have some emissions. Geothermal plants emit 0 to 0.35 lbs (0 to 0.16 kg) per MWh of sulfur dioxide, however this negligible when compared the 10.39 lbs (4.7 kg) per MWh of sulfur dioxide coal plants emit. Similar to this carbon dioxide is emitted at a rate of 0 to 88.8 lbs (0 to 40.3 kg) per MWh from geothermal power plants and 2,191 lbs (994 kg) per MWh from a coal power plant. Overall geothermal power plants emissions are extremely small compared to more conventional power plant emissions.[82]

4.2.6 Case Studies

There is one particular case study that is a good example of a deep well geothermal system that was designed to heat a greenhouse in New Mexico. The Rio Grande rift is an active tectonic region with a high flow of heat and located near the greenhouse. This is a particularly good case study because it discusses all of the steps required to pick a site and drill a deep well. It also gives the geological reports and goes over the geothermal resources that were discovered.[84]

5 Hydropower

Today, hydroelectric power is the leading renewable energy source used to generate electric power. It has been cited that approximately 20% of the world's electricity production and 10% of the United States electricity production comes from hydroelectric power. Hydroelectric power, more commonly known as hydropower, is the process of generating electricity by utilizing the power of moving water.[85]

The most commonly known type of hydropower is conventional hydropower, where water is either diverted from a stream or from behind a dam and flows though a turbine which is connected to a generator. Once the water leaves the turbine it is then sent back into the stream or riverbed. Although conventional hydropower currently generates a majority of the hydroelectricity in the United States, there are two other methods of generating hydropower. The first is through the use of waves and the second is through the use of tides.[84]

5.1 Micro-Hydropower

Micro-hydro power is the smallest available conventional hydropower plant. Conventional hydropower is typically associated with large power plants, however there are small scale and micro scale hydropower plants as well. Conventional hydropower is generally known as large scale hydropower and generates the majority of the 10% of hydroelectricity in the United States. The largest hydropower plants in the United States are located in the Pacific Northwest and generate about 75% of the required demand.[84]

The use of micro-hydro power however has become increasingly widespread over the past few decades, especially in developing countries. The use of these schemes are important in the economic development of remote areas that are looking to become more advanced. Micro-hydro power allows regions (like mountainous and rural areas) to have power that might now normally be able to.[86]

5.1.1 Description of Technology

Micro-hydropower systems are typically very basic and use direct mechanical power or a turbine that is connected to a generator to produce electricity.[85] The term micro-hydro is the term that is given to a hydropower system that generally produces 100 kW of power or less. The value 100 kW means that the system will produce 100 standard units of electricity in the period of one hour.[87]

In most situations micro-hydro power does not require the storage of water in order to generate power. Typically a run-of-river system will be used to simply to divert a small portion of the streams water towards the turbine. In a run-of-river system a portion of the water is diverted through a penstock (also known as a pipe) or canal and directed through a hydropower plant. The water that is diverted does not greatly decrease the flow rate of the river, nor is a dam required. A low-head turbine will often be used for "micro" scale projects because there is small head (height of the water), but a sufficient flow of water.[85]

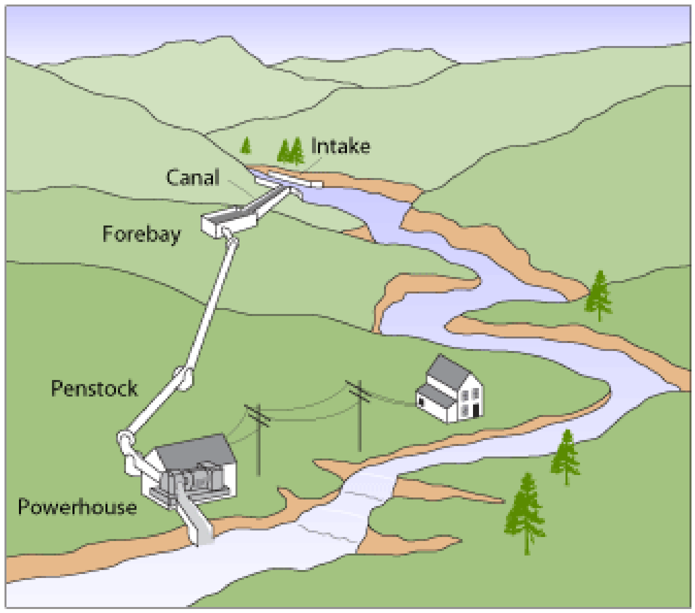

Figure 28: Typical Micro-Hydropower System[88]

There are various types of turbines that can be used in order to generate power. Depending on the head and design flow of the proposed location, will determine the type of turbine required. The two main types of turbines are impulse turbines and reaction turbines. An impulse turbine is adequate for high, medium, and low head pressure, while a reaction turbine is only adequate for medium and low head pressure. The table below compares the two different types of turbines and the "sub" turbines that you can choose from depending on the head that is available.[89]

	Impulse Turbine	Reaction Turbine
High Head (> 100m/325ft)	Pelton or Turgo	N/A
Medium Head (20 to 100m/ 60 to 325ft)	Cross Flow or Turgo or Multi-Jet Pelton	Francis or Pump-as-Turbine
Low Head (5 to 20m/16 to 60ft)	Cross Flow or Mulit-Jet Turgo	Propeller or Kaplan
Ultra Low Head (less than 5m/16ft)	Water Wheel	Propeller or Kaplan

Table 6: Comparison of Impulse and Reaction Turbines

5.1.2 Best Location

Micro-hydropower systems can only be installed in specific locations throughout the world. In order to have a micro-hydropower system there needs to be a river or stream nearby that flows all year round. Although a system can be installed at a location where the river conditions aren't always consistent, it would not be beneficial since the power generated would not be consistent either. More often than not, micro-hydropower systems are installed in rural areas which are typically off the grid and do not receive sufficient power.[85]

Ideal locations for a micro-hydropower system are in hilly areas of regions that receive a lot of year-round rainfall. In most scenarios the greatest quantity of flowing water is usually near mountainous sites, however this is not true in all situations. The most suitable locations are areas similar to the Andes or Himalayas, or moist marine climates similar to the Philippines, Indonesia, or the Caribbean Islands.[85]

There are a few items that need to be considered before a given site can be determined adequate for a micro-hydropower system. The hydrology of a site, along with a site survey need to be considered to determine the head data and flow of the river. A survey should be done to give the most detailed information about the site and the hydrological information can be acquired from the local irrigation department or meteorology department. Once this information is acquired, then the site calculations can be done in order to determine if the site is adequate or not.[85]

5.1.3 Cost Range

The exact cost of the system depends on the type of turbine that is installed, as well as the location and manufacturer. The major cost of the system is due to initial installation and cost of the equipment. Micro-hydropower systems vary greatly in cost, however there are certain measures that can be taken to reduce the overall cost of the system. Some of the important cost factors to look into are cost per kWh of power, typical cost of the system, and payback period.[85]

A general rule of thumb is that the overall cost per kW of installed capacity is proportional to the size of the scheme. In general a typical cost of a micro-hydropower turbine is about $1,000 per kW of output.[90] Under most circumstances a 5kW unit is adequate for a typical home. In 2006 a 5 kW AC (alternating current) micro-hydropower unit cost about $10,000, not including any of the site work. Another variation to the units are whether it is AC or DC power. While a 1 kW AC unit may cost $2,000 to install, a 1 kW DC (direct current) unit will cost around $3,000 to install. An AC unit is used if the power is being delivered directly to a home for use, while a

DC unit would be used if the power is going to be stored prior to distribution.[91]

For the most part micro-hydropower units do not change greatly in price over time. The major variation in cost will depend on the site work necessary to install the system. These additional costs will vary based on the location/topography of the site, the existing infrastructure available, the use of contractors, and the amount of water passing though the site. Considering all of these factors, the cost of a micro-hydropower system is more than just simply the cost of the unit.[92]

The cost to produce electricity from a micro-hydropower system varies slightly. Looking at the typical life cycle cost of the system the cost will generally range from \$0.03 to \$0.25 per kWh. When this value is compared to the average cost of a generator, which ranges from \$0.60 to \$0.95 per kWh, the system is well worth the investment. Sometimes systems can be as cost effective as \$0.03 to \$0.05 per kWh for ideal conditions. After the system payback period, there will be minimal maintenance costs and no monthly electric bills.[93]

The payback period for a micro-hydro system is usually around 5 to 10 years. If the system is connected to the grid the payback period will often be shorted because there will be an income from the power that is sold back to the grid. Although this is not feasible at every site it is often an option if there is a grid connector nearby.[94]

5.1.4 Efficiency

The efficiency of a micro-hydropower system can change greatly depending on the location of the site, how consistent the flow of water is, and the type of turbine used. Typically efficiency's can range from 50% to 80% and sometimes can be as high as 90%. One standard that the U.S. DOE uses is that there is an estimated output efficiency of

53%. This efficiency rating is often used in various calculations to compute the estimated power, however it is not accurate in every scenario. Often when looking into the efficiency rating of as system, it is important to base it off of the efficiency of the specific turbine which will be used.[95]

5.1.5 Downsides/Environmental Impacts

There are a few downsides to the installation of a micro-hydropower system. For one energy expansion is not usually a viable option. Typically the greatest power output will be determined strictly by the size and flow of the stream, which will restrict future site expansion. There is also a possibility of low power output in the summer. In the summer there will most likely be less flow, which will mean less power output. Another possible downside is that the turbines will sometimes generate noise, however this can be eliminated with a few changes to the system.[96]

The main environmental impacts are made to the area around the site. For the most part there are very few ecological impacts, however they must be considered before the system is built. Run-of-river systems will divert part of the water away from the stream and reduce the flow of river, which can affect the movement of fish. One thing that can be created to help reduce this effect is to install fish ladders. These are obstructions that are built in the river to divert the fish away from the intake of the system and to keep them moving in a “safe” pattern.[97]

5.1.6 Case Studies

There are a few micro-hydropower case studies to make note of. One particular case is in Long Lawen, Malaysia and generates power for a community of about 350 people. This is a particularly good example of a micro-hydropower system because it discusses resource identification, rate structure, environmental factors, system design and construction, as well as the energy used before and after the system was put in place. It also gives a follow up for the pros and cons of the system, along with "lessons learned" throughout the project. It is a good example of what to do and what not to do.[98]

Another helpful document to look at is the "Micro-Hydropower Systems: A Buyer's Guide" which is produced by Natural Resources Canada. It not only gives you the basics of how a micro-hydropower system works, but it also gives you pointers on how to determine how much power and energy you need and what type of system would work best. This document is particularly useful because it goes through the step by step process of how to determine if a site is appropriate for a micro-hydropower system and examples of feasibility study questions.[88]

5.2 Tidal Power

The use of tides to produce power has been around for over 1,500 years making it one of the oldest ocean energy technologies used today. One of the earliest systems used was a tide mills which would be used to mill and grind grain as the tide went in and out. Although tide mills are not as commonly used today, there have been many technological advances made for the use of tides as a power producer. Unlike other renewable energy resources, the use of tides to generate power is extremely predictable.[99]

5.2.1 Description of Technology

All coastal areas experience two low and two high tides in the period of one day. In order to generate power by the use of tides there needs to be a minimum tide change of more than 15 feet (3 m). Due to this requirement, not every coastal location is suitable for the use of tidal power generation.[100]

Currently there are three major tidal technologies that are being used to harness tidal power. The first one is a tidal barrage or dam. This system uses the potential energy that is created by the change of tides. A system of gates is installed along a dam and forces the water through a turbine which then activates a generator.[99]

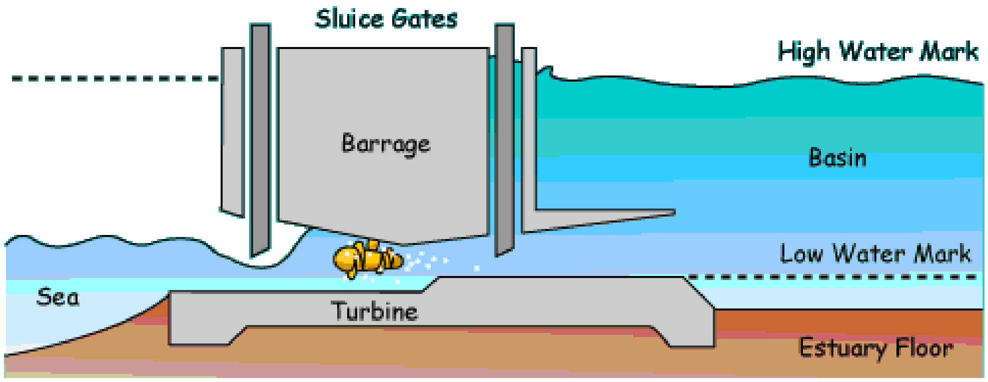

Figure 29: Tidal Barrage

The second is a tidal fence which is similar to a turnstile and will often stretch across a channel or between small islands. The turnstiles will spin due to the tidal currents which can sometimes be as fast as 9 miles per hour (14.5 kilometer per hour). And the third is tidal turbines which are very similar to wind turbines and usually set up in a similar fashion as wind farms. Similar to tidal fences, these turbines will spin due to tidal currents. A current of about 5 miles per hour (8 kilometer per hour) will allow the turbine to function the best and typically turbine farms function best in water that is 65 to 99 feet deep (19.6 m to 30m).[99]

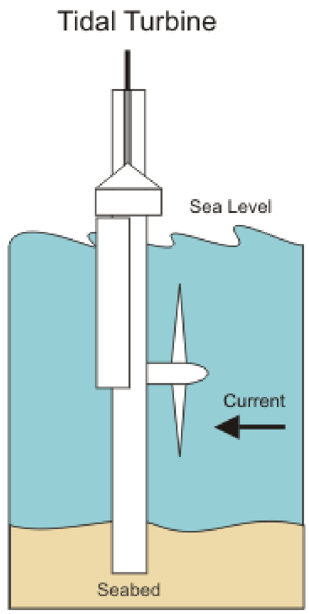

Figure 30: Typical Tidal Turbine

5.2.2 Best Location

Despite the fact that not every coastal location is suitable to produce tidal energy, there are still over 40 sites throughout the world that could possibly harness the power of the tides. Off the coast of Washington, British Columbia, and Alaska there is a great potential for the use of tidal turbines due to a 12 foot (3.7 m) tide difference. There is also a great potential in Maine due to the dramatically fluctuating tides. Presently no tidal plants have been installed in the United States, but are some projects in the design stage.[101]

Although not very many tidal power plants have been installed there are a few select sites throughout the world that have found success in using the tides to produce power. The largest and oldest plant is located on the Rance River in France and makes use of a barrage system. There are also plants located in the White Sea in Russia, as well as in Canada and Norway. A great promise for potential power is also located in Asia, England, and as previously mentioned the United States.[102]

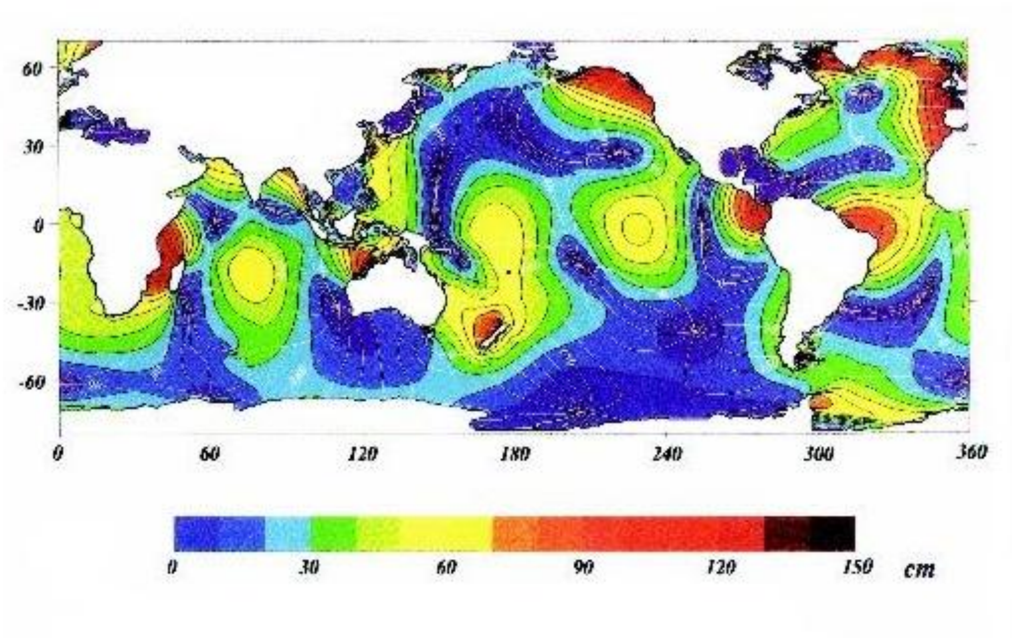

Figure 31: World Tidal Range Difference in cm[103]

5.2.3 Cost Range

The cost of a tidal power system will strictly be based off the technology that is installed. One major factor for all of the technologies is the height difference between low and high tide. In most scenarios the cost of tidal power is still more than typical energy generation. Tidal power costs about $0.10 per kWh, while coal or oil power costs about $0.06 per kWh.[104]

For tidal barrages, the cost effectiveness also weighs heavily on the length and height of the barrage required. The difference in height of the tide and the size of the barrage are expressed as the Gibrat ratio. This ratio represents the length of the barrage (in meters) to the annual energy production in kWh. The smaller this ratio is, the more desirable the site is. The major cost in installing a tidal barrage system is the high costs associated with building a dam if there isn't already one constructed.[105]

5.2.4 Efficiency

The efficiency of a tidal power system can change greatly depending on the location of the site, the type of system used, the speed of the current, and the type of turbine installed. It is often common for a system to have an efficiency of as high as 80%. In a conventional pump-storage system the overall efficiency will often exceed 70%, however if there is a low-head storage system the overall efficiency is likely to be below 30%. Often when looking into the efficiency rating of as system, it is important to base it off of the efficiency of the specific turbine which will be used.[106]

5.2.5 Downsides/Environmental Impacts

Similar to most systems, there are some downsides to the installation of a tidal power system. The main disadvantage of a tidal power system is that the tides at the site location are directly proportional to the amount of power generated. Although the use of tides is a very predictable way to produce power, it is not adequate at every coastal site around the world making it difficult to harness a majority of the power that could be generated.[107]

Along with the fact that not all of the tidal power can be harnessed, there are some environmental impacts with the installation of these systems. Due to the fact that tidal power systems disrupt the tides, the natural ecosystem of fish and marine wildlife can be disrupted as well. There is also a chance that tidal turbines can cause danger to fish because of the constant rotation of the blades. Because of these impacts on the surrounding ecosystem, newer equipment and methods are being developed to help minimize the impacts on the surrounding environment.[106]

One other environmental impact is the creation of dams for tidal barrages. Not only does the construction of the dam impact the local ecosystem, but a dam estuary can disrupt the migration of fish and marine life and cause a silt build-up behind the dam.[108] The construction of a dam will also affect the flow of water out of the estuary which can change the salinity and hydrology of the estuary.[109]

5.2.6 Case Studies

The Rance tidal power plant in France is perhaps the most well know tidal power plant. The construction for it was completed in 1966 and has been operating ever since. It is a good case study to look into for the construction on a large tidal power plant.[110] Another case study to look into is "The Potential for Tidal Power in the Queen Charlotte Islands/Haida Gwaii" produced by the University of Victoria in Canada. Although this case mainly focuses on a tidal turbine it does go over the current power system in Queen Charlotte Islands. This case study is more of an example of a feasibility study used to determine whether or not tidal power would be beneficial in this location.[111]

5.3 *Wave Power*

Wave power is generated by using either the energy on the surface of the wave or the pressure changes directly below the surface. With an estimated potential of 2 terawatts (TW) of electricity generation, wave power technology is proving to show great promise. Despite the fact that wave power cannot be harnessed in all locations, there are many "wave rich" areas throughout the world, including many in North America.[107]

5.3.1 Description of Technology

There are both off-shore and onshore systems which can be installed, each having their own advantages and disadvantages. Off-shore systems are typically located deep underneath the water, however there are more advanced technologies that have been developed that are floating devices. [107] The two most noted systems are the Salter Duck, which uses the bobbing motion of waves to power a pump and the Pelamis which is a semi-submerged system linked with hinges that pumps pressurized oil through hydraulic motors that drive a generator.[112]

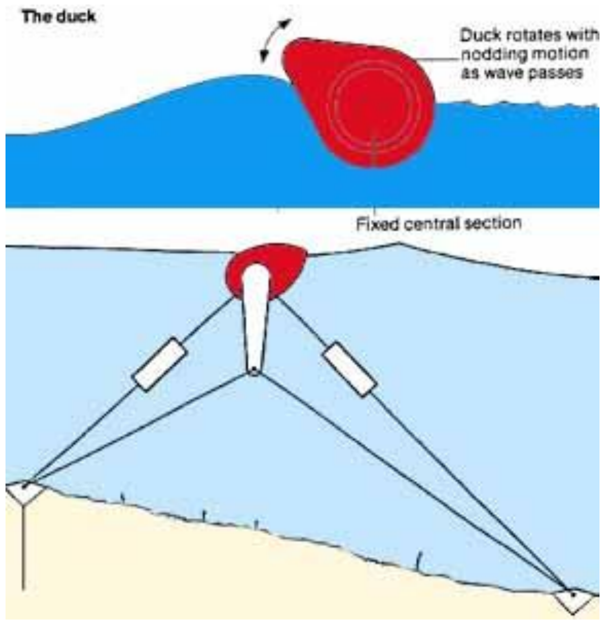

Figure 32: Salter Duck System

Onshore systems are built along the shorelines and will use the energy of breaking waves to create power. There are three main technologies which are used onshore: an oscillating water column, a tapchan, and a pendulor device. An oscillating water column uses a device that is partially submerged and allows waves to enter the air column. After the waves enter the air column, it will rise and fall, which will change the pressure of the device. The wave then leaves the device and air will be pulled back trough the turbine generating power.[107]

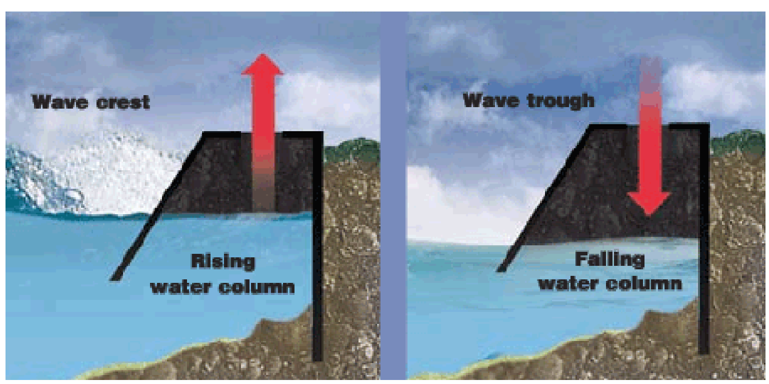

Figure 33: Oscillating Water Column

A Tapchan, which is also known as a tapered channel system, is comprised of a channel which directs waves into a reservoir constructed above sea level. The channel will narrow as it moves towards closer to the reservoir, which will cause the height of the wave to increase. The waves will hit the wall of the reservoir and spill over the top. From here the water is then fed through a turbine where power is then generated. A pendulor device is a much simpler design that is comprised of a rectangular box with one end open. A hinged flap is placed over the opening and as waves hit the flap it will swing back and forth which will power a hydraulic pump and generator.[107]

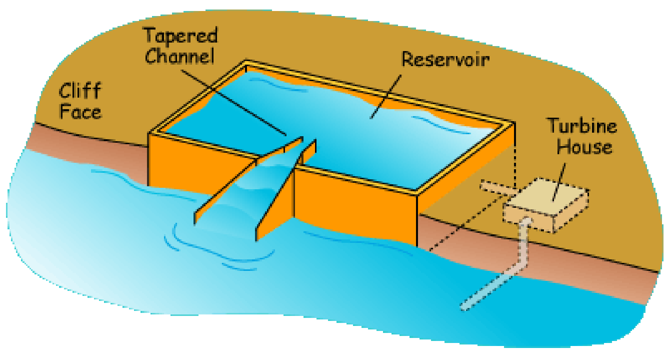

Figure 34: Tapchan System

5.3.2 Best Location

Waves are created through the interaction of wind on an open body of water. Due to the size and direction of wind on the Atlantic Ocean, England and Scotland have an enormous potential for the use of wave power. There is also great potential off the coast of the Northwest coast of North America. A general rule of thumb is that the Western coastline of continents between the latitudes of 40° and 60° and above and below the equator is the best sites to harness wave power. [113]

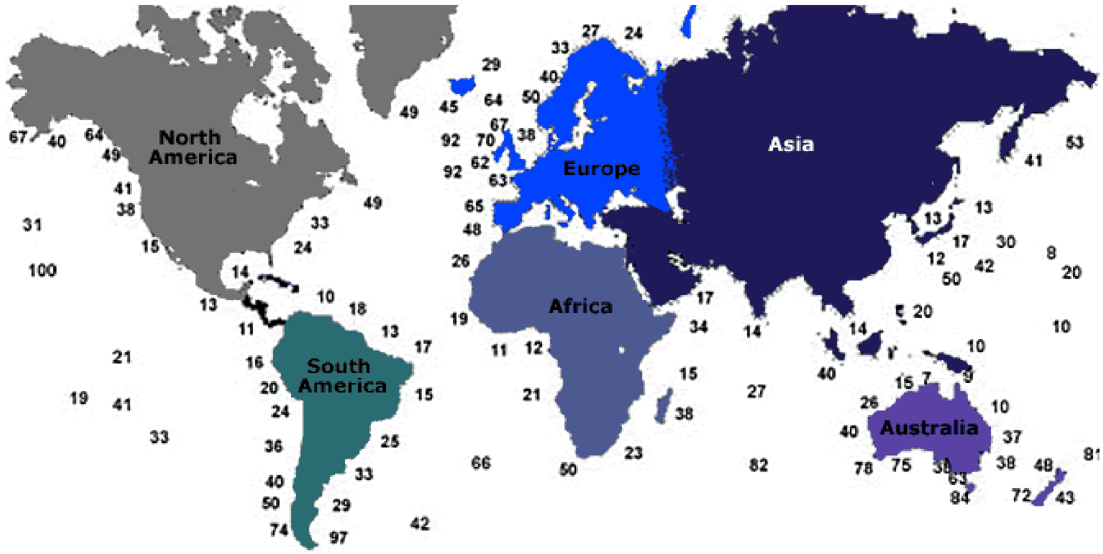

Figure 35: Average Wave Power Ability in kW/m of Wave Front[114]

Not every location that has a great wave capacity is a feasible location to harness the power. For example in Figure 35 the Pacific Ocean has a huge potential of available wave power, however due to the location it may be difficult to harness, store, and distribute the power properly. In terms of location, it is important to keep in mind the feasibility of a chosen project.[115]

5.3.3 Cost Range

The cost range of the system will vary slightly depending on the type of technology, as well as the location and turbine manufacturer. The major cost of the system is due to initial installation and cost of the equipment. Wave power systems vary greatly in cost depending on the type of construction necessary to install the system. Some of the important cost factors to look into are cost per kWh of power, typical cost of the system, and payback period.[107]

Due to the fact that wave power technology is a relatively "new" type of technology, it has a hard time competing with traditional power generation. When this technology was first developed the cost to generate power was more than $300 per kWh. Over time however this cost has gone down, but only to about $0.50 per kWh of power produced if the project was financed commercially. In the future there is expected to be another decrease in this figure to be comparable with other renewable energy resources, but until then subsidies can be used to help lower the costs.[105]

There are various techniques and additional devices that can also help reduce the cost of a wave power system. It is important to check local, state, and government incentives that are given for installing a renewable energy option. The Database of State Incentives for Renewable Energy (DSIRE) website has a list of all of the incentives currently available. Incentives can often greatly reduce the cost of the system and sometimes even pay for a majority of the necessary technology.[116]

5.3.4 Efficiency

The efficiency of a wave power system can change greatly depending on the location of the site, the type of technology used, and the type of turbine installed. Overall wave power systems are extremely efficient and retain almost all of the power that is generated. It is not uncommon for a wave power system to have efficiencies as high as 90%. In ideal conditions the Salter Duck will achieve an efficiency of 90% and a Well's turbine (which is a key feature of an Oscillating Water Column) will have an operational efficiency of around 80%.[112]

5.3.5 Downsides/Environmental Impacts

There are slight public concerns with onshore systems, as people feel these systems are not aesthetically pleasing. There is also a concern with the amount of noise an onshore system creates. Oscillating Water Column systems often generate a lot of noise due to the ebb and flow of the water in the column. In order to avoid many of these concerns the off-shore systems are becoming more developed.[107]

Some of the disadvantages with off-shore systems are that these systems must be able to withstand the force of a wave and over time the equipment might start to fall apart. Although wave sizes can be estimated, there are often waves much greater than what is predicted. Due to this variation, any off-shore floating device must be able to withstand the worst of storms.[107]

5.3.6 Case Studies

There are a few wave power case studies to make note of. The first one is "A Case Study of Wave Power Integration into the Ucluelet Area Electrical Grid" produced by the University of Victoria, Canada. This study discusses the potential to use wave energy in the Tofino/Ucluelet area of Canada and the type of models that could be used to harness the power. There is an analysis of the system and how it could be used, as well as simulation data and the economics behind the system.[117]

Another wave power case study to look into is the "Wave Energy Conversion and the Marine Environment" by Olivia Langhamer. This study discusses the basics of wave power and the different types of systems that can be used. It also describes The Lysekil Project which began in 2002 to test a wave energy system developed at Uppsala

University. The project describes the design of the system and the impact on the environment, as well as the findings that were made.[118]

6 Solar

Solar energy is making use of the sun's rays to create other forms of energy and according to NASA this energy has been powering life on Earth for millions of years. This energy can be converted into both heat and electricity and can be used on either a residential or industrial scale. Currently there are various technologies used to harness solar power. The two main ways to convert solar power into electricity is through concentrated solar power (CSP) plants and photovoltaic (PV) devices. Solar power can also be used to heat water which is called solar thermal.[119]

6.1 Concentrated Solar Power (CSP)

Concentrated solar power (CSP) or concentrating solar power systems uses the sunlight to create high temperatures (generally between 752° and 1832° F or 400° and 1000° C) that will be used to produce electricity or heat. This is done by using mirrors to reflect and concentrate the sun's rays into a small beam opposed to trying to harness the power over an extensive area.[105] In order to produce electricity in a CSP system, the sunlight is used to heat a fluid to a certain high temperature. Once this fluid is hot enough it will be used power an engine or spin a turbine, which then drives a generator. The generator then produces electricity for output.[120]

6.1.1 Description of Technology

There are various CSP systems and technologies used today, however there are three "main" systems to look into. These systems are linear concentrator systems, dish systems, and central receiver or tower systems. [121]

A linear concentrator system is comprised of a large quantity of collectors in parallel rows that direct the sunlight onto a linear receiver tube. Typically linear CSP systems are broken down into two different types of technologies, parabolic troughs and linear fresnel reflector (LFR) systems. When using parabolic troughs the reflectors are situated with a receiver tube which contains a fluid. This fluid is then heated (either into water/steam or a heat transfer liquid) and transferred out of the trough field to a location where steam can be generated for power. [119]

A linear fresnel reflector system is very similar to a parabolic trough; however it uses flat or slightly curved mirrors that reflect the sunlight onto a receiver tube fixed above the mirrors. The fluid in the receiver tube is then heated and transferred out of the tube in a similar manner to the parabolic trough system.[119]

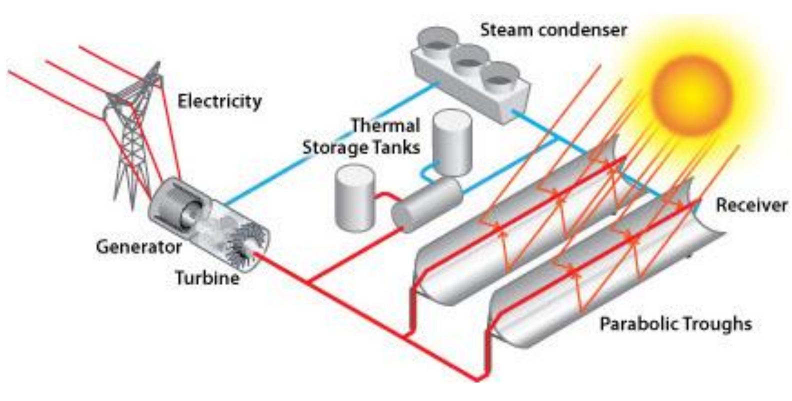

Figure 36: Parabolic Trough System

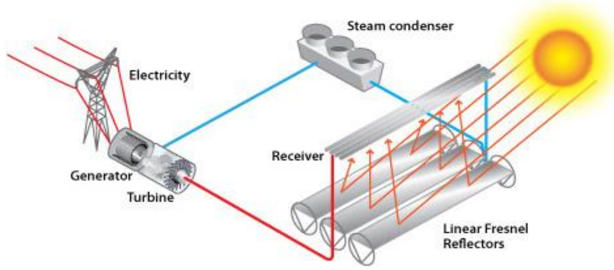

Figure 37: Linear Fresnel Reflector System

A dish system simply uses a dish, or solar concentrator, to collect the solar energy. The concentrated solar energy beam is then directed towards a thermal receiver which gathers the heat produced. Commonly, the dish is assembled to a structure that tracks the sun throughout the day to gather the greatest amount of solar energy possible.[119]

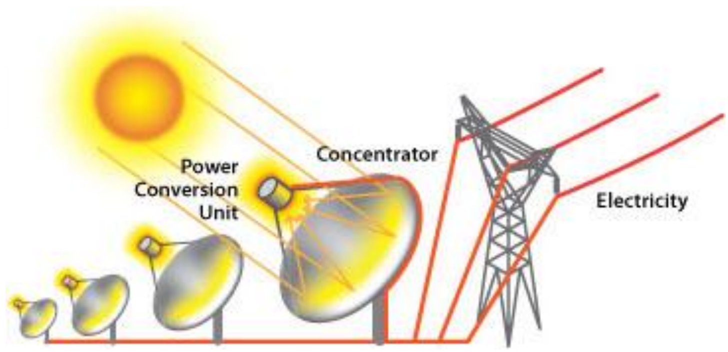

Figure 38: CSP Dish System

Lastly a central power or tower system uses heliostats, which are flat sun tracking mirrors, to direct the sunlight onto a receiver located at the top of a tower. The receiver contains a heat-transfer fluid which in turn generates steam. Any number of heat-transfer liquids can be used including water/steam, molten salts, or air. The steam that is generated is then used in a turbine generator to produce electricity.[119]

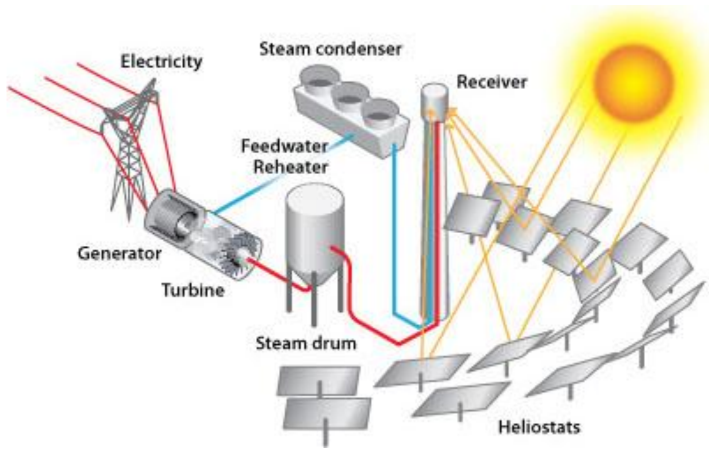

Figure 39: CSP Tower System

6.1.2 Best Location

The best location for CSP plants is in the sunbelts of the world. [119] The best locations for large CSP sites are between 40° latitude south and 40° latitude north. CSP need direct sunlight that has not been obstructed by clouds, dust or fumes. This type of sunlight is known as Direct Normal Irradiation (DNI). For CSP to be efficient there must be at least 2,000 kWh's of sunlight radiation per m^2.[120] The Southwestern United States is an optimal area for using CSP because it receives as much as twice the sunlight compared to other areas of the country. [119]

Figure 40 is a map of the concentrating solar resource of the United States. This map shows the annual averages of DNI in 10 km (6.2 mile) plots from 1998-2005.

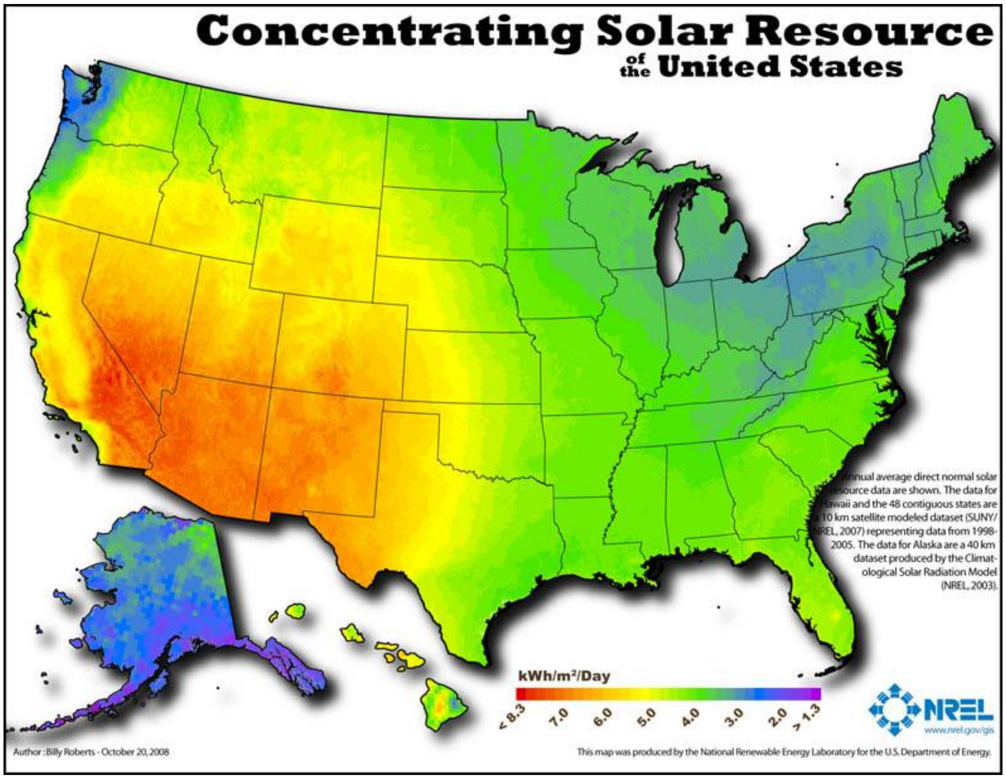

Figure 40: Concentrating solar Resources of the U.S.[122]

The following figure shows the DNI in kWh/m/day. The areas colored on the map represent land suitable for large scale CSP plants. Potentially sensitive environmental lands, water features, major urban areas, areas with a slope greater than 3% and the areas less than 1 square kilometer are color grey and could not be used for CSP. The NREL also has additional, more detailed maps available for CSP located at http://www.nrel.gov/csp/maps.html.

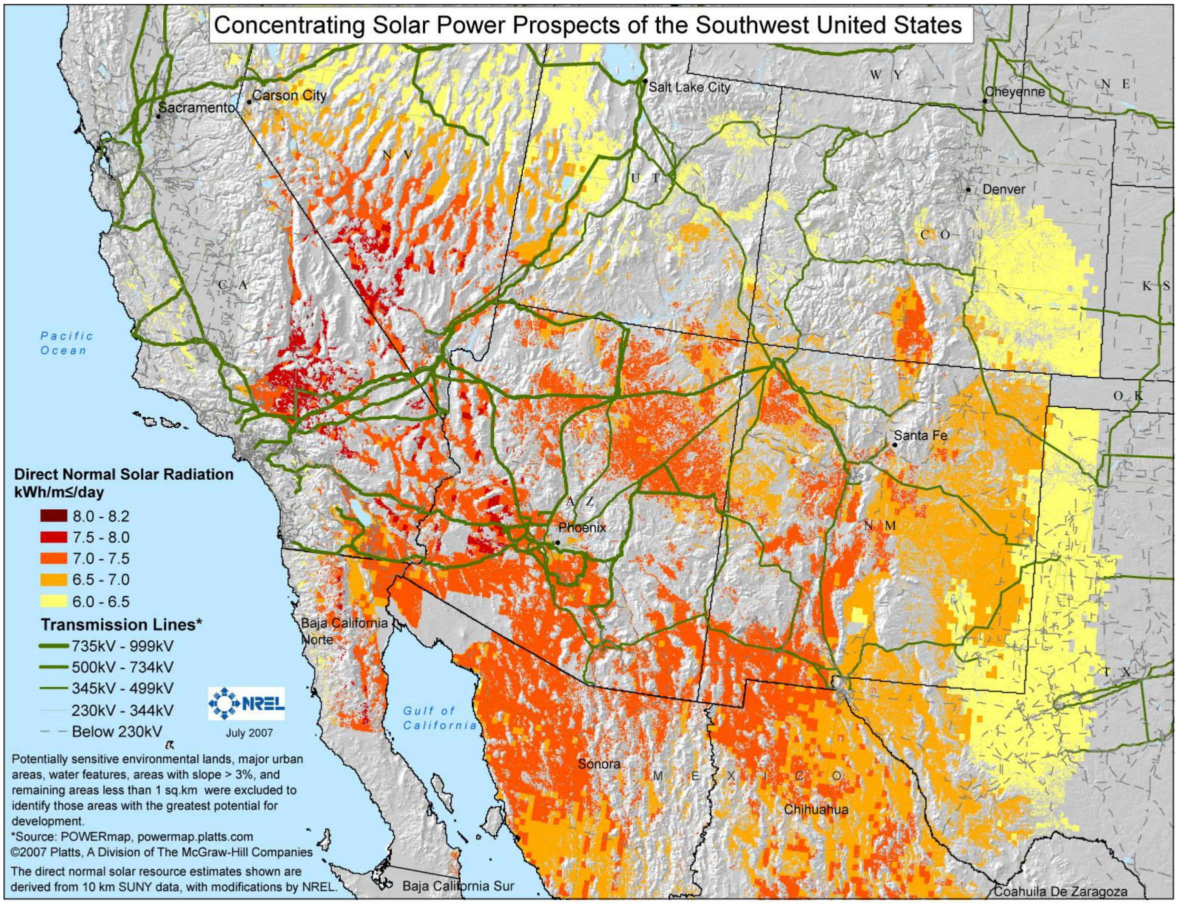

Figure 41: CSP Prospects of the Southwest U.S.[123]

6.1.3 Cost Range

The cost of CSP has dropped significantly in the past few years making it a viable option for large scale renewable power generation. The NREL puts current CSP prices around $0.12 per kWh and expect it to be cut in half by 2015. They expect the price to continue to drop due to scale-up, an increase in the volume of production, and technical developments.[124]

CSP is currently the most cost efficient solar power available for large scale power generation of 10 MW and above. New hybrids systems and larger plants could reduce costs to $0.08 per kWh. Additional technological advances in areas such as energy storage will make CSP a more reliable power source by allowing it to generate more power during peak hours at night. This could lower the price of CSP to $0.04 or $0.05 kWh in the next half century.[125]

The NREL estimates $2 to $5 million per MW in capital cost to construct new plants. They note that newer plants using Compact Linear Fresnel Reflectors (CLFRs) could reduce capital cost another 20%.[126] A current 64 MW commercial scale CSP plant in Nevada has a price range of $220 to $250 million and between $0.03 and $0.09 per kWh.[127]

6.1.4 Efficiency

The efficiency of CSP varies depending on the specific type of technology that is used. Energy storage systems also factor into the efficiency of CSP systems. The efficiency of a CSP plant will vary because of the mentioned factors and annual solar radiation, however it is generally between 20% and 40%.[128]

6.1.5 Downsides/Environmental Impacts

CSP like other solar powers have very few environmental impacts, most of which can be avoided by proper planning and mitigation. The major concern with CSP plants is the effect on the fragile desert ecosystem. CSP plants planned for California are being delayed due to a concern for the endangered desert tortoises' because environmentalists say CSP plants could destroy their habitat. New power lines are also causing public concern, however they are needed for any energy source, and are not exclusive to CSP.[129]

CSP plants with central collecting towers also cause a threat to birds and insects. The concentrated beam of sunlight can kill birds and insects if they fly through it. Systems that use hazardous fluids for heat storage or transfer also present a danger to the environment. With proper handling and safety procedures this threat can be avoided.[130] CSP plants using water from underground wells to clean and cool equipment may affect the dry ecosystem of the desert. [129]

6.1.6 Case Studies

The "Assessment of Potential Impact of Concentrating Solar Power for Electricity Generation" is a report to the United States Congress from the DOE Energy Efficiency, and Renewable Energy department. This report addresses the challenges due to conflicting guidance on the economic potential of CSP. Also this report assesses the potential impact of the CSP before, during and after the year 2008.[131]

NREL has also done a lot of studies on CSP. The "Concentrating Solar Deployment System (CSDS) A New Model for Estimating U.S. Concentrating Solar Power (CSP) Market Potential" report presents the Concentrating solar deployment systems (CSDS). This model incorporates many regions, time periods, and GIS information. It addresses the market and policy issues related to CSP, as well as grid penetration.[132] And the "Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California" study addresses implementation of CSP in California. The report covers topics pertaining to, CSP technology assessment, recourse assessment, development of CSP plants, economic impacts, cost and value of CSP, environmental benefits, and hedging benefits.[133]

Finally the "Concentrating Solar Power for the Mediterranean Region" is an executive summary of a study commissioned by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany. This study researched the available renewable energy resources in the Mediterranean, noting that CSP could be one of the largest suppliers of clean renewable energy.[134]

6.2 *Photovoltaic (PV)*

Photovoltaics are a form of solar power where sunlight is directly generated into electricity. PV cells are commonly made from semiconducting materials including silicon, copper, and cadmium.[135]

6.2.1 Description of Technology

The materials used to make a PV cell can be arranged in a variety of shapes including single crystal, poly crystal, ribbon, and amorphous. Different materials and different shapes are used to create higher efficiencies for different applications.[134] When sunlight hits a PV cell, electrons are given off. The PV cells are placed on a panel with wires running through the cells to form a solar module. When many cells give off electrons they move between different cells creating electricity. The wires in the panel then gather this electricity and carry it out of the panel. When modules are linked in an electrical series they are known as a solar array.[136]

Each module is rated for its maximum power generations or Watts-peak (Wp or just W). When modules are connected in series to form an array the Wp is the sum of all of the modules WPs. Electricity generated from PV cells is in direct current (DC) form. In order to be used in most electrical appliances or put back into the grid the electricity must be inverted to alternating current (AC).[135] Batteries can be added into the system for energy storage to allow for energy during times of the day without sunlight.

6.2.2 Best Location

PV solar panels can be installed almost anywhere in the United States, however the same amount of power won't be generated everywhere. In locations such as the Southwest the amount of power generated will be much greater than the power generated in the Northeast. This is because the annual solar radiation is greater in the Southwest than the Northeast. Figure 42 shows the PV resources throughout the United States. For additional Maps of Solar Resources in the U.S. the National Renewable Energy Lab has an extensive data base of solar maps (http://www.nrel.gov/gis/solar.html). Available Maps include maps with monthly averages of solar radiation in the U.S. but 10km plots. Other interactive maps allow the user to zoom to a zip code or latitude/longitude.

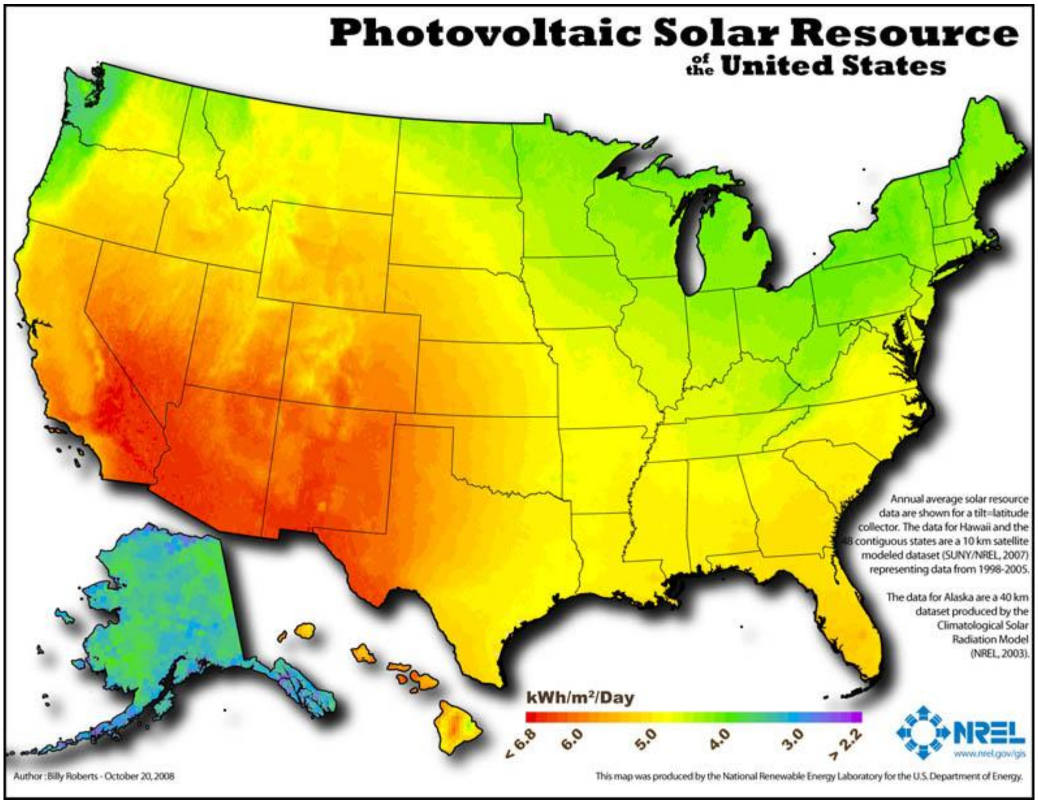

Figure 42: Photovoltaic Solar Resources[137]

Figure 43 shows the available solar resources in the 6 largest deserts in the world. The numbers next to the name of the desert represents the potential annual generation by a very large scale PV plant in PetaWatt Hours (PWh). The total global predicted annual generation was 752 PWh which is estimated to be five times the world's energy demand in 2010.[138]

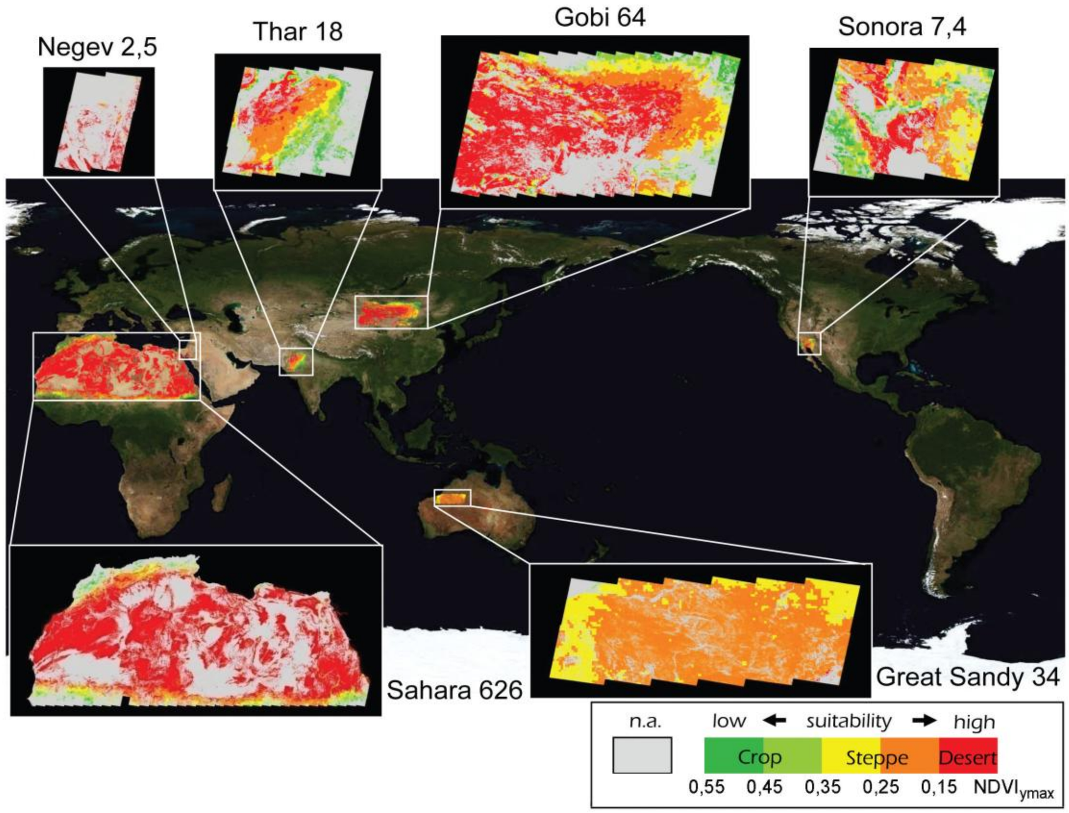

Figure 43: Available Solar Resources

6.2.3 Cost Range

As for most solar technologies the majority of the cost comes from the initial investment. PV plants have very low operation and maintenance cost, but high initial purchase and installation costs. Table 7 shows the current and estimated price of solar energy from the US Department of Energies Solar Energy Technologies Program Annual Report 2008.

Market Sector	Current U.S. Market Range (c/kWh)1,2	Solar Electricity Cost—Current and Projected (c/kWh)1		
		Benchmark 2005	Target 2010	2015
Residential3	5.8–16.7	23–32	13–18	8–10
Commercial3	5.4–15.0	16–22	9–12	6–8
Utility4	4.0–7.6	13–22	10–15	5-7

Table 7: Cost of Solar Energy

[1] Costs are based on constant 2005 dollars.

[2] Current costs are based on electric-generation with conventional sources.

[3] Cost to customer (customer side of meter).

[4] Cost of generation (utility side of meter).

The average price for modules (dollars per peak watt) decreased about 4%, from $3.50 in 2006 to $3.37 in 2007. For cells, the average price has increased more than 9%, from $2.03 in 2006 to $2.22 in 2007.139 Energy payback periods for PV range between 1 to 4 years depending on the type of PV cell and the annual solar radiation.[140]

The generation cost of a VLS-PV system with 1 GW capacity and a 100km transmission line is around $0.18–0.22 per kWh at a $4 per W PV module price. If the module price is reduced to $1 per W, the generation cost is reduced to $0.11 per kWh.[137]

6.2.4 Efficiency

PV efficiency varies widely depending on the material and structure of the solar cell. The efficiency of PV cells is the amount on energy converted from the amount of available sunlight that hits the cell. The efficiency of different PV cells are constantly changing due to research and development. The efficiency of PV products in production range anywhere from 5% to 20%.[141] The highest efficiency ever recorded was by a solar cell produced by Spectrolab. The NREL tested and confirmed a 41.6% conversion of sunlight.[142]

6.2.5 Downsides/Environmental Impacts

PV systems has very few downsides. For small scale uses PV systems only need a few modules and take up a small amount of space. For residential applications PV modules are often mounted on the roof of the existing house, using space that was unusable before.

There are very few negative impacts of large scale PV. For large scale PV the best locations are often in dry, desert like areas. The impact to the land depends on site specifics, however they can be minimized by proper planning and design. These areas are often not inhabited by humans and present very small visual value. The worst visual and noise impacts come during construction and decommission of a site. These impacts can be minimized by locating a plant away from densely populated areas and areas of natural beauty.[143]

PV systems have very few negative environment impacts. PV emits no gas, liquid or radioactive pollutants. Hazardous materials are used during the manufacturing of PV, however they can be controlled and limited through following safe manufacturing policies. Small amounts greenhouse gases are emitted during manufacturing of PV, in the range of 25-35 g/kWh.[144] That small amount is insignificant due to the reduction of greenhouses gases by the generation of clean power.[142]

PV systems have many positive impacts on the environment. Large scale PV plants are often constructed on land with very little value. The use of degraded land to produce power decreases the amount of fertile or valuable land needed to be used by other forms of power generation.[142]

6.2.6 Case Studies

Due to the fact that PV is quite advanced there are a lot of valuable case studies. "Decade Performance of a Roof-Mounted Photovoltaic Array" is a study conducted by Georgia Institute of Technology in 2006. After 10 years GIT conducted a study to review the performance of the PV array mounted onto the roof of its aquatic center. This report gives very detailed data on power outputs and reasons for low performance or downtimes.

Another case study is "Energy from the Desert." This Study back by the International Energy Agency took a detailed look at the feasibility of Very Large Scale Photovoltaic Systems. In the report socio-economic, financial, technical and environmental aspects were studied.

One final case study is "Comparing Photovoltaic Capacity Value Metrics: A Case Study for the City of Toronto." This study conducted by the Environment Canada Experimental Studies Division researched the capacity levels of PV systems. It found it PV is used to accommodate only peak our loads a PV system capacity value could raise from around 12% to 40%.

7 Wind

Wind power is broken up into two main categories, onshore wind power and offshore wind power. The main difference between the onshore and offshore systems is the foundations. The foundation size and shape varies between land and ocean applications. The most common foundations are gravity base, rock anchored, and deep foundation. The same turbines are used for both, however larger models are often used in the ocean.

7.1 Offshore Wind

7.1.1 Description of Technology

Wind turbines all work in a similar manner. Wind power is generated by turbines that are powered by blades. The blades are connected to a rotor with a shaft that travels back into the nacelle, which contains the gear box. The gear box then increases the RPMs to a level at which the generator operates. The blade and generator assembly are placed on top of a tower and are generally 164 feet to 262 feet (50 m to 80 m) above ground. This height varies depending on manufacture and the optimization of available winds.[145]

Wind turbines have a range of wind speeds that they can operate at. They are known as the cut-in and cut-out speed. They vary by manufacture, but cut-in speeds average around 8mph and cut out speeds around 55 mph (88.5 kilometer per hour).[146] The cut in speed is the lowest speed at which the generator is able to operate. The cut-out speed is the speed at which the stresses on the structure become to high. When this happens a brake will stop the blades from spinning. Some models also rotate 90° to lessen the forces on the structure.

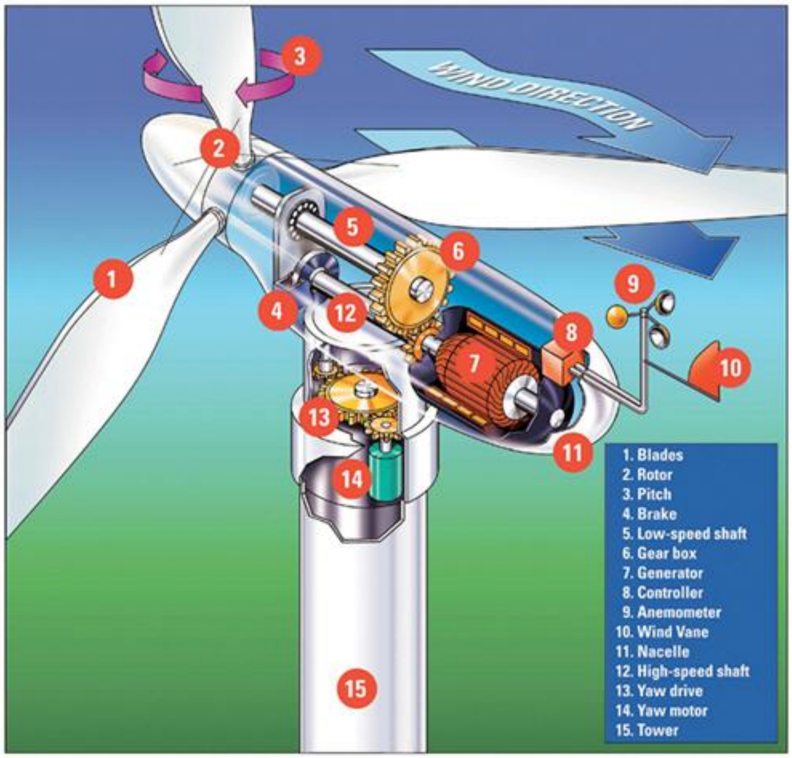

Figure 44: Wind Turbine[147]

Current day offshore wind turbines are similar to onshore wind turbines with the exception of the foundations. However in order for offshore wind turbines to become more efficient and cost effective new design approaches must be used. If advanced foundation designs become viable, offshore turbines could be sited far from land and out of sight. This would decrease the public's negative thoughts on visual aspects and abolish the need for quiet turbines.

Offshore wind turbines have different and more challenging design problems. Additional factors such as water depth, currents, maximum wind speed, seabed migration levels, and wave heights must be accounted for when designing for structural integrity. In certain areas such as the East coast of the United States tropical storms can cause extreme stresses on an offshore wind turbine that must be accounted for. Site specific factors can include marine-growth, icing, corrosion, and tidal forces.[148]

7.1.2 Best Location

The DOE estimates the offshore wind resources in the United States could be as large as 900,000 MW, which is about the nation's current capacity. The most attractive sits for offshore wind are also in close proximity to the nation's largest electricity demand regions. Approximately 78% of the nation's electrical demand comes from the 28 states that have ocean boundaries.[147] Figure 45 below shows all available wind resources in the United States.

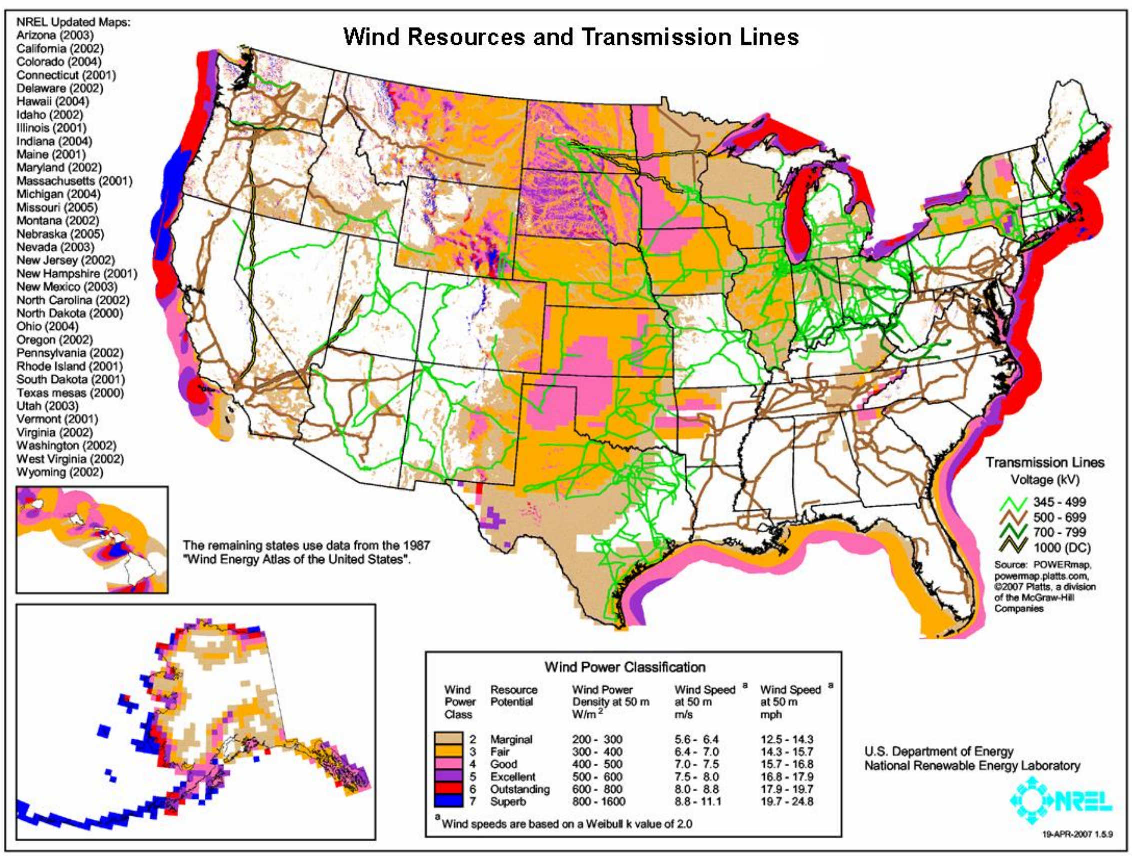

Figure 45: U.S. Wind Resource Map[149]

7.1.3 Cost Range

Offshore wind farms are more expensive than onshore wind farms. The U.S. DOE puts the capital cost of offshore wind farms around $2,400 per kW, significantly more than $1.650 per kW for onshore wind farms.[150] Table 8 shows the cost breakdown of a typical offshore wind turbine project.

Component	Percent of Total Project Cost
Turbines	33%
Operations & Maintenance	25%
Support Structures	24%
Electrical Infrastructure	15%
Engineering/Management	3%

Table 8: Offshore Wind Project Cost Breakdown

In 2005 the NREL conducted a study to determine the cost of a 3 MW shallow water offshore wind turbine. They took into account materials cost, construction cost, operations and maintenance cost, and land cost. They found the cost of electricity to be $.095 per kWh. Additionally they found the cost of the turbine to be $2.7 million. The cost of the foundation, transportation, port/staging equipment, assembly and installation, electrical interface/connections, engineering/permits/site assessment, scour protection, and personnel access equipment would be an additional $3.33 million. This makes the total initial capital cost $6.4 million.[151]

7.1.4 Efficiency

The maximum theoretical efficiency of wind energy is governed by the Betz limit, which is 59 %. Due to characteristics of wind, the Betz limit is the mathematical limit of the amount of energy that can be harnessed from wind. If 100% of the energy available were to be extracted from wind, the turbine would have to stop the wind. If this were to happen the wind would blow around the turbine.[152]

Power available from wind greatly increases with the increase of wind speed. The power available in wind is the cube of its wind speed. This means that if the wind speed doubles, the power available is multiplied by eight. Wind turbine efficiency is ultimately measured by its capacity factor. The capacity factor is used for all power generation and is the amount of power produced over a period of time divided by the power that would have been produced if the turbine operated at a maximum output of 100% during the same period. Because the wind does not constantly blow a capacity factor of 25 to 40% is normal. [153] Offshore wind is especially attractive because its capacity factors. Higher consistency and strength often make offshore winds 25% stronger than onshore winds.

7.1.5 Downsides/Environmental Impacts

Wind power has very few environmental impacts. Bird deaths have been one area of concern for wind turbines. The following table shows the causes of bird fatalities from the Canadian Wind Energy Association.

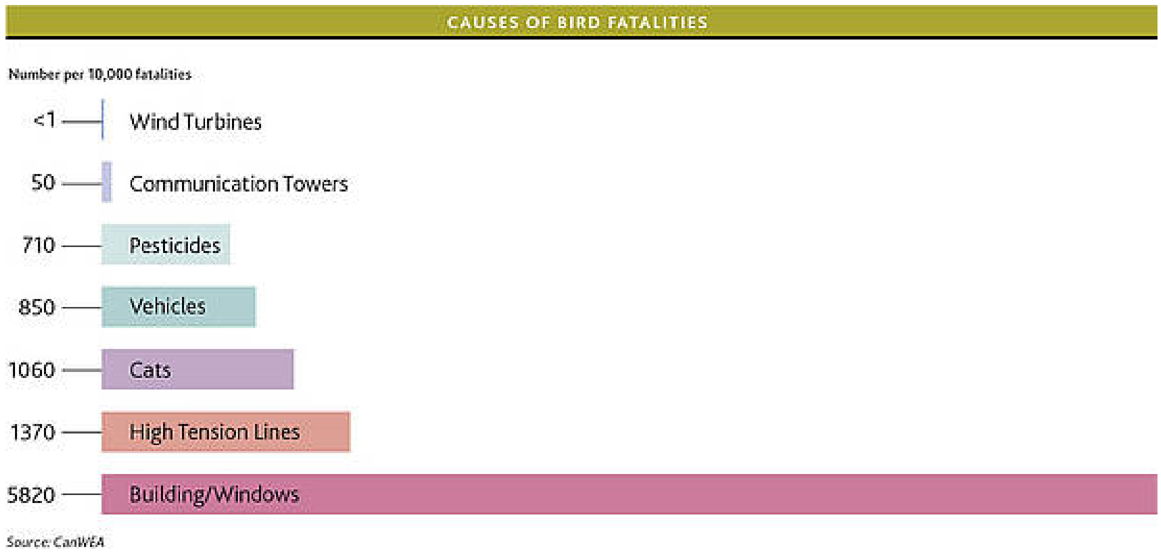

Figure 46: Causes of Bird Fatalities[154]

When compared to other major causes of bird deaths in the country wind farms account for less than 0.001% of all bird deaths.[155] Noise pollution is also a negative aspect of wind mills, however decibel level produced by wind mills is the same level as the background noise in a residential house.[156]

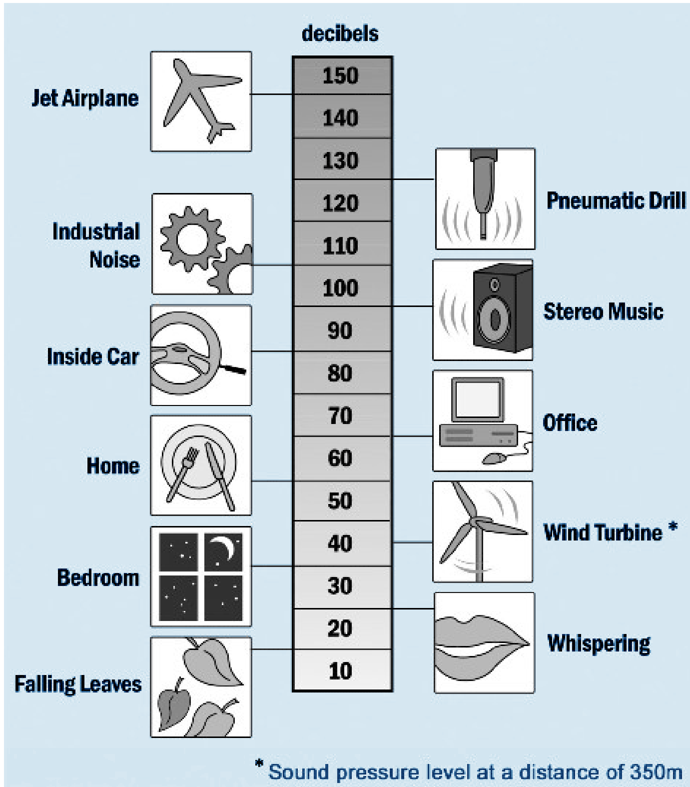

Figure 47: Noise Levels[155]

The decibels level of wind turbines does increase with there is an increase in wind speed, however when wind speed increases the background noise from wind becomes louder. This is because as wind speed increases the noise created from wind traveling over plants and over natural topography becomes louder. This increase in noise is larger than that of the turbine causing it to mask the sound of the wind turbine.[157] In the future offshore turbines could be sited far out at sea, reducing the impact of noise.

Offshore wind farms have a unique set of environmental impacts to address. There is little information available on the long term effects of wind turbines. In 2006 the Danish Energy Authority released a report on a six year study of the environmental impacts of two offshore wind farms. The report stated that the two wind farms had minimal environmental impacts. The report noted localized or temporary impacts due to construction.[147]

7.1.6 Case Studies

One particular case study to look into is "Offshore Wind Energy Potential for the United States". This study conducted by the National renewable energy Laboratory, published in 2005. This PowerPoint presentation highlights the current offshore wind farms in the world. The report also notes where the greatest potential for offshore wind energy in the United states is located, as well as what advances need to be made to make offshore wind farms a viable option.

7.2 Onshore Wind

7.2.1 Description of Technology

Wind turbines all work in a similar manner. Wind power is generated by turbines that are powered by blades. The blades are connected to a rotor with a shaft that travels back into the nacelle, which contains the gear box. The gear box then increases the RPMs to a level at which the generator operates. The blade and generator assembly are placed on top of a tower and are generally 164 feet to 262 feet (50 m to 80 m) above ground. This height varies depending on manufacture and the optimization of available winds.[158]

Wind turbines have a range of wind speeds that they can operate at. They are known as the cut-in and cut-out speed. They vary by manufacture, but cut-in speeds average around 8 mph and cut out speeds around 55 mph (88.5 kilometer per hour).159 The cut in speed is the lowest speed at which the generator is able to operate. The cut-out speed is the speed at which the stresses on the structure become to high. When this happens a brake will stop the blades from spinning. Some models also rotate 90° to lessen the forces on the structure.

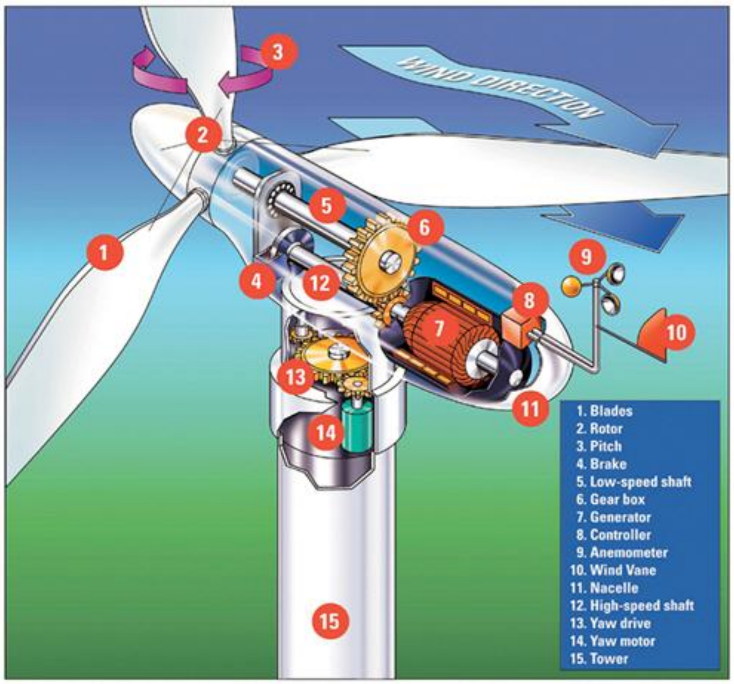

Figure 48: Wind Turbine[146]

7.2.2 Best Location

Extensive information is available on wind resources. The Wind Energy Resource Atlas of the United States has a data base of annual wind maps for states and regions in the US. The greatest wind power is located in the Midwest making it an ideal location for wind power (see figure below). [160]

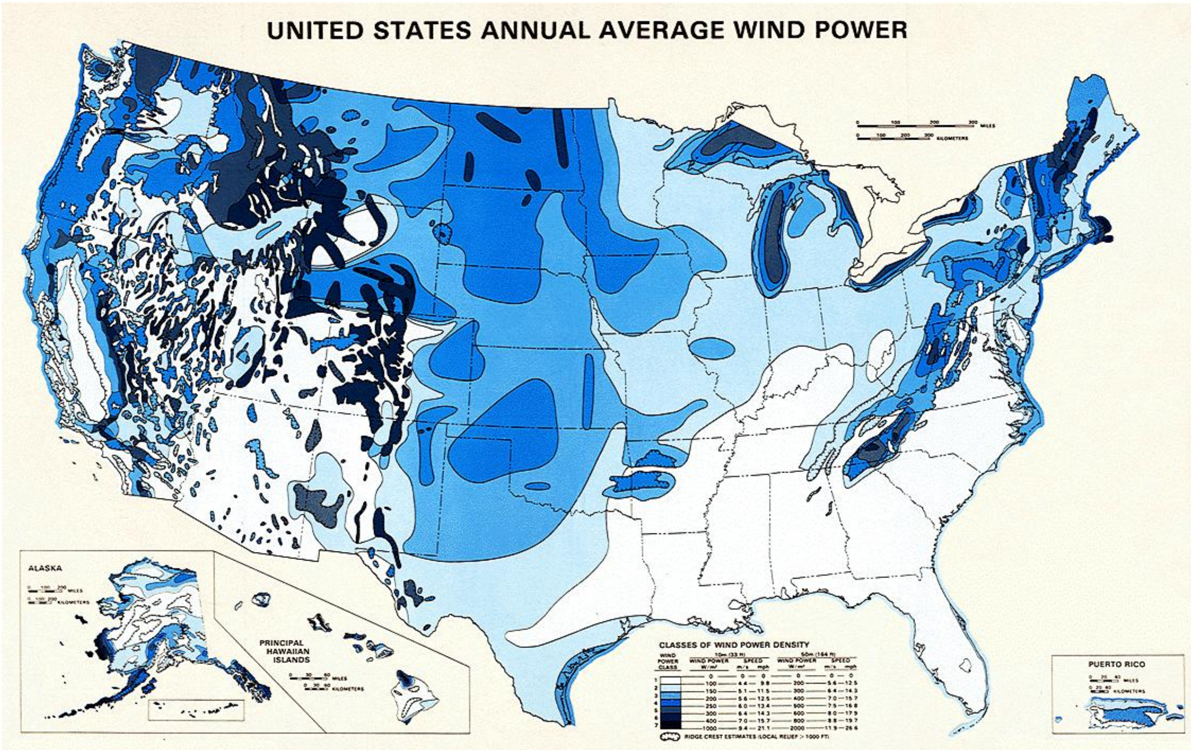

Figure 49: U.S. Annual Average Wind Power[161]

Also the Canadian Wind Atlas offers extensive information on wind resources. It displays maps of Canada with information on mean wind speed and energy for three different heights off the ground, along with roughness length, topography, and land/water mask. [162]

7.2.3 Cost Range

Over the past 20 years, the cost of onshore wind energy has dropped from $0.40 per kWh to in some cases as low at $0.04 per kWh. In 2005 the NREL conducted a study to determine the cost of a 1.5 MW onshore wind turbine. They took into account materials cost, construction cost, operations and maintenance cost, and land cost. They found the cost of electricity to be $0.04 per kWh. Additionally they found the cost of the turbine to be $1.03 million. The cost of the foundation, transportation, civil work (roads), assembly and installation, electrical interface/connections, engineering and permits, to be an addition $367,000. This makes the total initial capital cost $1.4 million.[150]

7.2.4 Efficiency

The maximum theoretical efficiency of wind energy is governed by the Betz limit, which is 59 %. Due to characteristics of wind, the Betz limit is the mathematical limit of the amount of energy that can be harnessed from wind. If 100% of the energy available were to be extracted from wind, the turbine would have to stop the wind. If this were to happen the wind would blow around the turbine.[163]

Power available from wind greatly increases with the increase of wind speed. The power available in wind is the cube of its wind speed. This means that if the wind speed doubles, the power available is multiplied by eight. Wind turbine efficiency is ultimately measured by its capacity factor. The capacity factor is used for all power generation and is the amount of power produced over a period of time divided by the power that would have been produced if the turbine operated at a maximum output of 100% during the same period. Because the wind does not constantly blow a capacity factor of 25 to 40% is normal. [164] Offshore wind is especially attractive because its capacity factors. Higher consistency and strength often make offshore winds 25% stronger than onshore winds.

7.2.5 Downsides/Environmental Impacts

Wind power has very few environmental impacts, one being the direct impact to the land they occupy. While wind farms can cover large areas, the footprint of the towers is very small. This allows farming and other objects to occupy the same land.[165] Bird deaths have also been an area of concern. When compared to other major causes of bird deaths in the country wind farms account for less than 0.001% of bird deaths.[166]

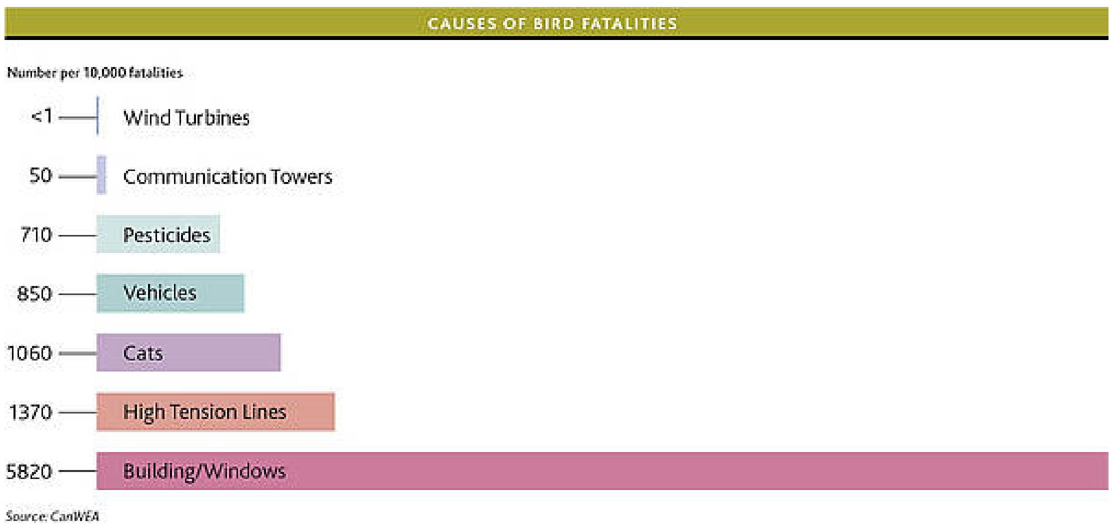

Figure 50: Causes of Bird Fatalities[153]

Noise pollution is also a negative aspect of wind mills, however decibel level produced by wind mills is the same level as the background noise in a residential house.[155]

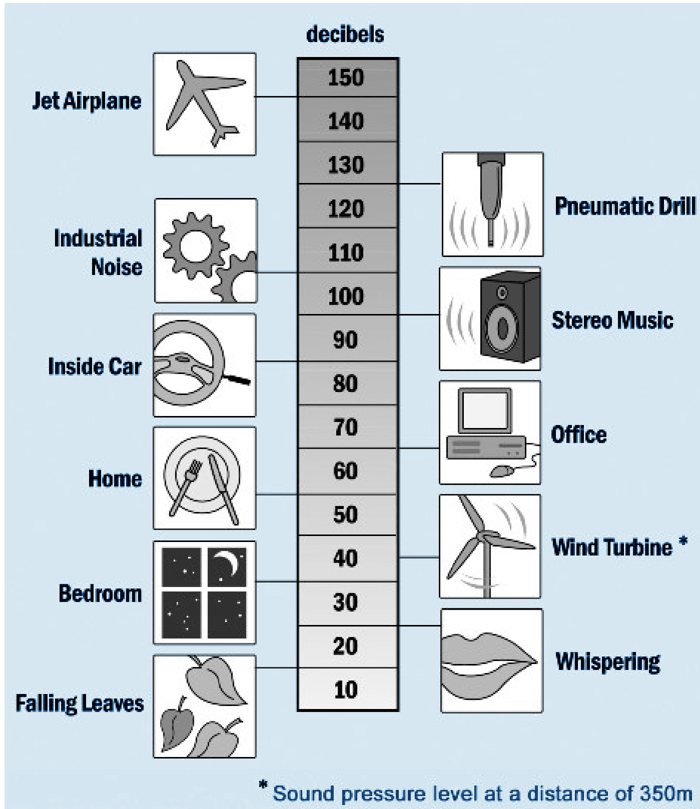

Figure 51: Noise Levels[155]

The decibels level of wind turbines does increase with the increase in wind speed, however when wind speed increases the background noise from wind becomes louder. This is because as wind speed increases the noise created from wind traveling over plants and over natural topography becomes louder. This increase in noise is larger than that of the turbine causing it to mask the sound of the wind turbine.[167]

7.2.6 Case Studies

There are two onshore wind case studies to make note of. The first one is "Community Wind Case Study in Hull, MA" done by the University of Massachusetts at Amherst. It looked into a wind turbine located in Hull MA. This Turbine was owned by the town and used to offset the cost of purchasing power from a power plant in another town.

The second case study is “Nolan County: Case Study of Wind Energy Economic Impacts in Texas.” This economic case study was prepared by New Amsterdam Wind Source LLC for the West Texas Wind Energy Consortium. This study explored the economic changes due to a large amount of wind energy introduced into a country in Texas over the past 10 years.

8 Checklist/Comparison Chart

Below is the checklist to be used as a quick analysis of which renewable resource option is feasible and which option isn’t feasible.

Biomass

Wood

___ Wood can be converted to energy through combustion, gasification, cogeneration, and cofiring

___ Applicable within a 50 mile radius of wood source

___ Residential, commercial, and industrial applications are most common

___ Costs about $50,000 to $75,000 per .3 MW of heat input for an installed heat/boiler system between .3 MW and 1.5 MW

___ Wood combustion plants generate power for between $0.06 to over $0.11 per kWh

___ Wood combustion systems typically have an efficiency between 65% to 75% and CHP systems have efficiencies between 60% to 80% for large scale applications and between 65% to 75% for small scale

___ Wood cannot be harvested too rapidly because it will deplete the local ecosystem

___ CO_2 emitted is 90% less than fossil fuel power plants

Algae

___ Algae produces fatty lipid cells full of oil - this oil can be used as fuel

___ Can be harvested in open ponds or closed bioreactors

  ___ Closed bioreactors can have the temperature and water levels regulated

  ___ Open ponds are shallow channels which are more difficult to regulate

___ An almost “unlimited” supply of water is required

___ Large plots of land with adequate sunlight are needed

___ The best location to install and algae farm is in a hot or tropical environment

___ Estimated construction costs for algae pond can be around $80,000 per hectare

___ Depending on the oil extraction technology, approximately 95% of the oil will be extracted

Landfill Gas

___ Vertical wells or horizontal systems can be installed

  ___ Horizontal systems are used for active landfill areas

___ Candidate landfills should have at least 1 million tons of waste or more

___ Landfill must either still be in use or be closed for 5 years or less

___ Landfill cannot have a ban on organic material

___ For a 10 meter deep landfill collection systems cost ranges between $20,000 and $40,000 per hectare and suction systems cost $10,000 to $45,000 per hectare

___ Average cost of power is $0.04 per kWh

___ About 40% to 50% of the gas that is released is recovered and collection efficiencies are between 60% to 80%

___ Landfill gas will only have about 50% the heating capacity of natural gas

Waste-to-Energy

___ Municipal solid waste/garbage is needed in mass quantities

___ Garbage is burned to heat a boiler and generate steam – This steam powers a turbine generator which generates electricity

___ 2,000 lbs of garbage will reduce to 300 to 600 lbs of ash

___ The waste used in these systems will come from either land fills or direct collection

___ Small scale plants cost between $110,000 and $140,000 per daily ton of capacity
___ For every ton of waste about 500 to 600 kWh of electricity is made
___ Systems are about 80% efficient
___ Pollution control systems or scrubbers will need to be installed so no harmful byproducts (metals/iron) are released into the air

Biodiesel

___ Biodiesel is created from oils including vegetable oil, waste cooking oil, animal fats, or byproducts of pulp and paper processing by the process of transesterification
___ Can be used in any diesel engine after an inexpensive retrofitting.
___ Biodiesel available to the general public at regular pumps ranges in cost from the same as petroleum diesel to $1 more per gallon depending on the area.
___ The horsepower, torque and engine outputs are equally if not slightly lower than with petroleum diesel
___ CO_2 emitted is 78% less than petroleum diesel

Geothermal

Ground Source Heat Pumps
General for All Systems

___ Systems cost around $2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installatoin
___ No underground utilities or sprinkler systems are in the area of the "chosen" location
___ Most promising application is in buildings that are maintained between 68°F and 78°F for at least 40 hours a week
___ Common for residential, commercial, and school applications
___ Ground temperature 10 feet below the surface typically remain around 50°F to 60°F year round
___ Systems can be used to either heat or cool a building
___ The geological, spatial, and hydrological factors all play a role in the type of system installed
___ Annual energy savings between 30% and 60%
___ Investment paybacks are anywhere from 2 to 10 years

Closed-Loop Pond/Lake

___ Adequate body of water required to install 100 feet to 300 feet of piping (3/4” to 1 ½” in diameter) per ton of heating/cooling

___ Water 8 feet deep or more is favored

___ State/federal regulations allow using water from pond/lake

Closed-Loop Vertical

___ Adequate for very rocky or difficult to dig soil

___ Depths between 100 feet and 300 feet (using ¾” to 1 ½” diameter piping) per ton of heating/cooling need to be reached

___ Adequate space for boreholes to be 15 feet to 20 feet apart

___ About 250 square feet of land is needed for every ton of capacity

___ Typically favored to lessen the disruption of landscaping

___ Commonly used for large commercial buildings and schools

Closed-Loop Horizontal

___ Soil depths of at least 4 feet are needed in order to dig trenches

___ Enough area for trenches to be 4 feet to 6 feet apart and 6” to 24” wide

___ Adequate land to install 400 feet to 600 feet of pipe (3/4” to 1 ½” in diameter) for every ton of heating/cooling capacity (if a slinky system is installed this figure can be reduced by 1/3 to 2/3)

___ About 2,500 square feet of space is needed for every ton of capacity

___ More cost effective to install as opposed to a closed-loop vertical system

Open Loop

___ Well/surface water is available for use

___ Sufficient supply of clean water (soft water is best to minimize any possible corrosion problems)

___ Local/federal regulations allows water discharge back into the environment

___ Water is warm (over 5°C)

Deep Well Geothermal

___ Underground water/steam reservoir is located near site

___ Once a reservoir is located and wells drilled there are three different types of power plants that can be installed to harness the power

- ___ Flash Steam Plants are used for a high-temperature, water-dominated reservoir
- ___ Dry Steam Power Plants are used if there is a steam dominated reservoir
- ___ Binary-cycle power plants are used if there is moderate temperature water (below 400° F) which is most common

___ Geothermal reservoirs are commonly found in the western united states, Alaska, and Hawaii

___ The cost of well drilling will make up 42% to 95% of the total system cost

___ A competitive plant will cost around $3,400 (or more) per kW installed

___ New geothermal projects can cost from $0.06 to $0.008 per kWh of energy produced

___ Local/federal regulations allow drilling miles into the Earth

Hydropower

Micro-Hydropower

___ 100 kW or less of power will be produced

___ Stream, river, or falling water source needs to be located within a mile of the site

___ Ideal locations are mountainous regions that receive a lot of year round rainfall

___ Adequate stream flow of 10 gpm or a drop of at least 2 ft (10 ft is favorable) in order to generate power

___ An impulse turbine is adequate for high, medium, and low head pressure, while a reaction turbine is only adequate for medium and low head pressure

___ Permits and water rights managed to be obtained

___ Costs $1,000 per kW of output plus installation fees

___ Looking at the typical life cycle cost of the system the cost will generally range from $0.03 to $0.25 per kWh

___ The payback period is generally between 5 and 10 years

___ Typically efficiency’s can range from 50% to 80% and sometimes can be as high as 90%

Tidal

___ Coastal/offshore location – Off the coast of Washington, British Columbia, and Alaska are ideal – Maine, England, and Asia also show potential

___ Tidal power is very predictable making it a very reliable source of power

___ The three potential technologies that can be used are: Tidal Barrages/dams, tidal fences (which stretch across a channel or between small islands), and tidal turbines (which are similar to wind turbines and spin due to currents)

___ Tidal turbines work best if the current is about 5 mps and in water that is 65 ft to 99ft deep

___ Tidal difference of at least 15 ft or fast currents

___ Tidal power costs about $0.10 per kWh

___ Efficiency can be as high as 80%, however if there is low-head storage then the efficiency will be below 30%

___ Permits and water rights are obtainable for the given site

___ Turbines can cause damage to fish and construction of dams will affect the natural ecosystem

Wave

___ Coastal (onshore)/offshore location

___ Offshore systems can be located underwater or on the surface (uses the bobbing of the waves to generate power (Salter Duck))

___ Onshore systems use the breaking of waves to create power (an oscillating water column, tapchan, or pendulor device can be installed)

___ Location with adequate wave supply – Ideally on the western coastline of continents between the latitudes of 40° and 60° above and below the equator

___ The Northwest coast of North America, England, and Scotland show great potential

___ Power costs about $0.50 per kWh of power

___ Efficiencies for the Salter Duck can be as high as 90% and an Oscillating Water Column will be around 80%

___ Onshore systems create a lot of noise and are considered unattractive

___ Systems must be built to withstand a lot of force for long periods of time

___ Permits and water rights are obtainable for the given site

Solar Power

Concentrated Solar Power

___ CSP power plants need a large area of land, up to hundreds or thousands of acres.

___ Cost of CSP plants range from $2M to $5M per MW

___ Cost of electricity from CSP plants is around $0.12/kWh, but is expected to drop in the near future due to increased research, manufacturing, and development.

___ The best locations for CSP plants are often deserts which otherwise have very limited use

___ Current CSP technologies can convert 20-40% of the sunlight into power

___ When thermal storage units are incorporated into a CSP plant it can increase its capacity factor and continue to produce energy in the dark

___ CSP plants emit no greenhouse gases during operation

Photovoltaics

___ PV arrays can be used anywhere the sun shines, however they will be most cost effective in areas such as the U.S. Southwest which receives high levels of solar insolation

___ PV modules cost $3.37 per Watt in 2007

___ PV becomes cost effective in area's without high solar insolation where the cost of installing transmission lines would increase the price of grid power

___ Commercially available PV can convert 5-20% of the sunlight into power

___ PV emits no greenhouse gases during operation

Wind Power

Offshore Wind

___ Current technology only allows offshore turbines in water up to 30 Meters deep

___ Minimum wind speeds of 8 mph are required for a turbine to generate electricity

___ The coast of the Northeastern U.S. and the Cost of the Pacific Northwest from Oregon to Alaska are good locations to site offshore wind farms

___ Farms cost around $2.4M per MW of capacity and the cost of electricity is $.095/kWh

___ Wind turbine capacity factors are around 30% however strong and more consistent offshore winds could increase that number.

___ Farms can be properly sited to avoid fishing grounds and shipping lanes

___ There is often public concern for the marine environment and visual aesthetics

Onshore Wind

___ The best location for wind turbines in the U.S. is the Midwest and northern Texas as well as ridgelines in hilly and mountainous areas that are accessible by construction equipment.

___ Minimum wind speeds of 8 mph are required for a turbine to generate electricity

___ Farms cost around $1M per MW of capacity and electricity costs $.04/kWh

___ Wind turbine capacity factors are around 30% however stronger and more consistent winds can increase that number.

___ Wind farms cover large areas of land however the footprint of foundations is a small percentage. The land can be used for other things and is often integrated into farmland

___ At a distance of 350 meters the sound of a wind turbine is similar to the background noise in a house

Along with the checklist is the comparison table of the different renewable resource options and their various systems. This is to be used if a client is looking between two different options and wants to be able to look up information quickly opposed to going through the entire manual.

	Wood Biomass	Algae Biomass	Biodiesel Biomass	Waste-to-Energy Biomass	Landfill Gas Biomass
Technology	- Combustion - Gasification - Cogeneration - Cofiring	- Open Ponds - Closed Bioreactors	- B100 (pure biodiesel) - Mixed with petroleum biodiesel. B20 (20% biodiesel, B5, and B2 are most common)	- Garbage is burned to heat a boiler and generate steam – This steam powers a turbine generator, which generates electricity	- Vertical Wells - Horizontal system (for active landfills)
Location	- Anywhere within a 50 mile radius of a source of wood	- Ideally installed in a hot or tropical environment, especially for open pond systems	- Can be used in any diesel car after small and inexpensive upgrades. Cold weather (below freezing) can cause biodiesel to congeal, however techniques are used to avoid this.	- Close to an existing landfill so transportation costs can be reduced	- At least 1 million tons of waste - Landfill must still be in operation or closed within the last 5 years
Cost	- \$50,000 to \$75,000 per .3 MW of heat input for installed heater/boiler system between .3 MW and 1.5 MW - Generate power for between \$0.06 and over \$0.11 per kWh	- The average cost of 100 acre farm is about \$1 million with a payback ranging from 5 to 15 years - Construction fees for a pond can be around \$80,000 per hectare	- In July 2009 the U.S. national average for biodiesel was \$3.08(B100)	- Small scale plants cost between \$110,000 and \$140,000 per daily ton of capacity	- For a 10 meter deep land fill collection system, the cost is between \$20,000 and \$40,000 per hectare and the suction systems cost \$10,000 to \$45,000 per hectare - Average cost of power is about \$0.04 per kWh
Efficiency	- Combustion between 65% and 75% - GHP between 60% and 80% for large scale or 65% and 75% for small scale	- Varies based on the extraction technology, but can be as high as 95%	- B100 produces 8.65% less heat when combusted than petroleum diesel	- Typical efficiencies are about 80%	- About 40% to 50% of the gas that is released is recovered - Collection efficiencies are between 60% to 80%
Downsides	- Wood can't be harvested too rapidly because it will deplete local ecosystem	- A large amount of land and endless supply of water is required	- 2-4% increase in NO_x. If engine is not retrofitted for biodiesel it can clog fuel lines and filters	- Metals/iron are released during the burning process, but they can be trapped by scrubbers	- Landfill gas will only have about 50% the heating capacity of natural gas
General Info.	- CO_2 emitted is 90% less than fossil fuel plants	- Algae produce fatty lipid cells which are full of oils – these oils are used as fuel	- CO_2 emitted is 78% less than petroleum diesel	- 2,000 lbs of garbage will reduce to 300 to 600 lbs of ash	

	Closed Loop Pond/Lake GSHP	Closed Loop Vertical GSHP	Closed Loop Horizontal GSHP	Open Loop GSHP
Technology	- 100 feet to 300 feet of piping (3/4" to 1 ½" in diameter) per ton of heating/cooling	- Depths between 100 feet and 300 feet (using ¾" to 1 ½" diameter piping) per ton of heating/cooling	- 400 feet to 600 feet of pipe (3/4" to 1 ½" in diameter) for every ton of heating/cooling capacity - If a slinky system is installed this figure can be reduced by 1/3 to 2/3	-Well/surface water is available for use - Typically water warmer than 5°C is required
Location	- Near a pond/lake, favorably that is 8 ft deep or more	- Adequate for very rocky or difficult to dig soil - About 250 square feet of land is needed for every ton of capacity - Boreholes need to be 15 feet to 20 feet apart	- Soil depths of at least 4 feet in order to dig trenches - Enough area for trenches to be 4 feet to 6 feet apart and 6" to 24" wide - About 2,500 square feet of space is needed for every ton of capacity	- Ideal locations are near a surface body of water or in an area with a high ground water table
Cost	- Systems cost around $2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years	- Systems cost around $2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years	- Systems cost around $2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years	- Systems cost around $2,500 per ton of heating/cooling capacity (with the average system being 3 tons) plus the cost for installation - Investment paybacks are anywhere from 2 to 10 years
Efficiency	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights	- Systems can be anywhere from 300% to 600% efficient on the coldest of nights
Downsides		- Not as cost effective as horizontal or pond/lake system		- Local/federal regulations must allow for water discharge back into the environment which is not always possible
General Info.	- State/federal regulations must allow for taking water from body of water	- Typically favored to lessen the disruption of landscaping - Commonly used for large commercial buildings and schools	- More cost effective to install as opposed to a closed-loop vertical system	- Sufficient supply of clean water (soft water is best to minimize any possible corrosion problems)

	Deep Well Geothermal	Micro-Hydropower	Tidal Hydropower	Wave Hydropower
Technology	- Deep wells drilled miles into the earth to tap reservoir - Flash steam, dry steam, or binary-cycle power plants are installed to harness power	- 100 kW or less of power will be produced - An impulse turbine is adequate for high, medium, and low head pressure, while a reaction turbine is only adequate for medium and low head pressure	- Tidal Barrages/dams - Tidal fences (which stretch across a channel or between small islands) - Tidal turbines (which are similar to wind turbines and spin due to currents)	-Onshore systems use the breaking of waves to create power (an oscillating water column, tapchan, or pendulor) - Offshore systems can be located underwater or on the surface (uses the bobbing of the waves to generate power (Salter Duck))
Location	- Near an underground water/steam reservoir - Commonly found in western US, Alaska, and Hawaii	- Stream, river, or falling water source needs to be located within a mile of the site - Ideal locations are mountainous regions that receive a lot of year round rainfall	-Coastal/offshore location - Ideally off the coast of Washington, British Columbia, and Alaska - Maine, England, and Asia also show potential	- Coastal (onshore)/offshore location - Location with adequate wave supply – Ideally on the western coastline of continents between the latitudes of 40° and 60° above and below the equator
Cost	- The cost of well drilling will make up 42% to 95% of the total system cost - A competitive plant will cost around $3,400 (per kW installed - New geothermal projects can cost from $0.06 to $0.008 per kWh of energy produced	- Costs $1,000 per kW of output plus installation fees - Based on typical life cycle cost of the system the cost will generally range from $0.03 to $0.25 per kWh - The payback period is generally between 5 and 10 years	- Tidal power costs about $0.10 per kWh	- Power costs about $0.50 per kWh of power
Efficiency		- Typically efficiencies can range from 50% to 80% and sometimes can be as high as 90%	- Efficiency can be as high as 80%, but if there is low-head storage the efficiency will be below 30%	- Efficiencies for the Salter Duck can be as high as 90% and an Oscillating Water Column around 80%
Downsides	- Drilling wells will weaken the surrounding area, which may cause earthquakes	- Will affect the general make up of the stream due to the fact that water will be diverted to power the turbine	- Turbines can cause damage to fish and construction of dams will affect the natural ecosystem	- Onshore systems create a lot of noise and are considered unattractive -Systems must be built to withstand a lot of force for long periods of time
General Info.	- Local/federal regulations must allow drilling miles into the Earth	- Adequate stream flow of 10 gpm or a drop of at least 2 ft (10 ft is favorable) in order to generate power	- Tidal power is very predictable and very reliable - Tidal turbines work best if the current is 5 mps and is 65 ft to 99ft deep	- Permits and water rights managed to be obtained

	CSP Solar Power	PV Solar Power	Offshore Wind Power	Onshore Wind Power
Technology	- Parabolic Trough - Linear Fresnel Reflector - CSP Dish - CSP Tower	- Single crystal - Poly Crystal - Ribbon - Amorphous	- Wind turbines are sited off the coast in waters up to 30m deep.	- Wind turbines capture wind and produce electricity
Location	- In the sunbelts of the world which are generally between the latitudes of 40°North and 40° South. The American Southwest has a very large potential for CSP	- PV can be used anywhere the sun shines - Most effective in stand alone applications where the cost of installing additional power lines would become very costly.	- The U.S. Northeast and Pacific Northwest from Oregon to Alaska are suitable.	- In the U.S. the most extensive wind resources are located in the Midwest. - Any accessible hilltop or ridge line will have the highest winds of a given area (an 8mph minimum speed is best)
Cost	- Power cost around $0.12 per kWh of power - Capital cost of plants vary between $2M and $5M per MW of capacity	- Power costs between $0.06 and $0.17 per kWh of power -the average price for modules in 2007 was $3.37 per peak watts	-Power costs $0.09 per kWh. - Capital cost range between $1M and $2M per MW of capacity	-Power costs $0.04 per kWh. - Capital cost is around $1M per MW of capacity
Efficiency	- varies between technologies but is generally between 20-40%. Energy storage systems can increase the efficiency.	- Commercially available PV efficiencies range between 5%-20%. - Labs have produced cells that can transform 40% of sun light hitting the cell	- Capacity factors range between 25-40% however offshore wind is generally high due to stronger, more consistent, and less turbulent winds offshore.	- Capacity factors range between 25-40% however are generally in the lower range onshore.
Downsides	- Large CSP plants take up large areas of land, however are often located in deserts. - Concentrated beams of sunlight can kill birds and insects	- Toxic and hazardous chemicals are used during manufacturing, however damage can be avoided by following safe manufacturing procedures	- Visual aesthetics of shorelines are of concern - 0.001% of bird deaths are accounted from wind turbines - Marine ecosystems can be harmed, but initial research shows it to be very low.	- Turbine noise can also be an issue however is similar to the background noise in a house at a short distance away. - 0.001% of bird deaths are accounted from wind turbines
General Info.	- Many downsides can be mitigated - The use of deserts increases the value of previously degraded and unusable land.	- Still expensive compared to other energies however can become cost effective in areas where grid power is not readily available.	- 78% of U.S. electricity demand comes from the 28 states with shorelines.	- Proposed wind turbines must pass local zoning laws

	Coal	Natural Gas	Oil
Technology	- Typically coal is burned in a boiler to heat water and produce steam which powers a turbine and generator and produces electricity	- Steam generation units - Centralized Gas Turbines (hot gases are used to turn a turbine) - Combined Cycle Units (both a gas turbine as well as a steam unit)	- Crude oil is refined into petroleum products which can be used to power engines - The three basic steps of a refinery are separation, conversion, and treatment
Location	- A coal power plant can be installed almost everywhere - The cost to transport the coal will factor into the cost of the entire system	- Natural gas is used throughout the US, but the states that consume the most are Texas, California, Louisiana, New York, Illinois, and Flordia	- Oil is mainly produced in the US, Iran, China, Russia, and Saudi Arabia - Oil refineries can be located almost anywhere however it can occupy as much land as several hundred football fields
Cost	- An average plant costs $ 4 M per MW of power - The price of electricity can be as low as $0.048 to $0.055 per kWh	- Costs $200 per ton of annual liquification capacity - The price of electricity can be as low as $0.039 to $0.044 per kWh	- Large facilities cost between $4 and $6 Billion - The cost of electricity can vary, but it can be as high as $0.18 per kWh
Efficiency	- Most coal power plants are only about 30% efficient - Newer technologies may increase the efficiency to 50% or 60%, but this may vary greatly	- The efficiency of a steam generation unit is about 33% to 35% - Centralized gas turbines are less efficient then steam generation units - Combined cycle units can have efficiencies up to 50% or 60%	- Oil refineries typically have extremely high efficiencies - These efficiencies range from 80% to 90% and sometimes even higher
Downsides	Various emissions are released - 0.82 lb CO2 released per kWh .004 lbs NO_x per kWh .006 lbs SO_x per kWh	- Cleanest burning of the fossil fuels, but CO_2 still produced - Exploring and drilling for natural gas has a large impact on the land and marine habitats nearby – There are technologies to reduce the "footprint though)	- Burning emits: CO_2, NO_x, SO_x, VOCs, PM, and Lead - Each of these pollutants will have negative impacts on the environment and human health - Drilling for oil may disturb land and ocean habitats, however technologies can be employed to help reduce this
General Info.	- Approximately 50% of the electricity in the US comes from coal plants and 40% of the World's electricity comes from coal plants - The cheapest fossil fuel to burn for generating electricity but also the dirtiest	- Low levels of nitrogen oxides are emitted and virtually no particulate matter (both are harmful greenhouse gases) - The combustion of natural gas emits almost 30% less carbon dioxide than oil, and just under 45 % less carbon dioxide than coal - Cogeneration is possible	- Refining crude oil will produce more products than what was put in. There is a gain of about 5% from processing - Processing crude oil produces Diesel, heating oil, jet fuel, residual fuel, gas, and liquefied petroleum gases

9 Recommended Applications

Below is a list of recommended and ideal applications for each of the renewable resources. Although it may not be applicable for every situation, it does give you a good idea of when a system will work the best.

9.1 Biomass

Biomass energy or bioenergy is one of the most recent renewable energy options. Due to this fact, the technology is constantly changing and being improved upon. In 2008, biomass energy generated a total of 55,875,118,000 kWh. The break down for this power sector is represented in Figure 29. Municipal solid waste biogenic represents power from paper, paper board, wood, food, leather, textiles, and yard trimmings. Other biomass represents agriculture byproducts/crops, sludge waste, and other biomass solids, liquids, and gases.[168]

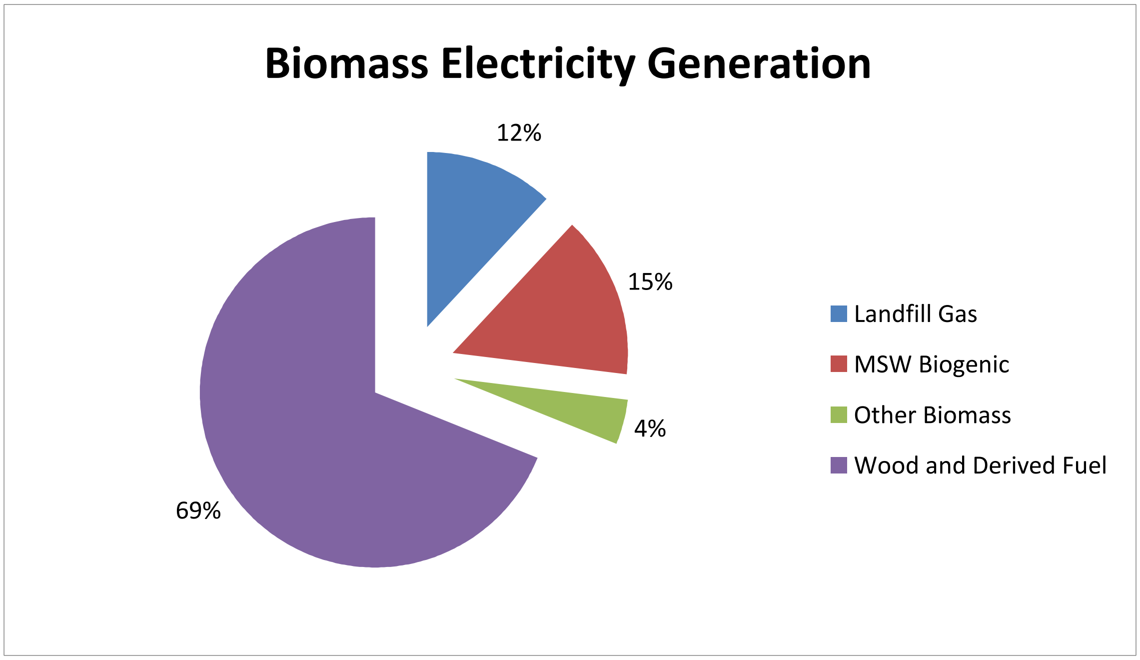

Figure 52: Breakdown of Biomass Electricity Generation in US

Currently wood and derived fuel (such as biodiesel) makes up the greatest amount of biomass electricity generation. Below are the subtopics that make up biomass energy and when their applications and most applicable.

9.1.1 Wood

A wood biomass system can be used on any scale, however the most common installations are for residential, commercial, and industrial applications. One of the limiting factors is whether or not there is an adequate wood source near the "chosen" site. Unless the site is within a 50 mile radius of a wood source, installing a wood biomass system is not an economically feasible option. The cost to transport the wood will increase the overall cost of the technology, as well generate emissions.[14]

It is very common for small wood biomass systems to be installed for residential applications to generate heat. Lumber mills will also use the wood scraps and wood chips to heat boilers to generate steam and fire kilns and to generate heat for direct use. Small scale wood systems will be between 65% and 75% efficient, making them good options for generating heat. Wood fueled power plants however are not as efficient and will only achieve a maximum efficiency of about 24%.[14]

9.1.2 Algae

Algae systems are typically large scale operations due to the amount of land required to install a system. The type of algae being grown will be the basis for what the ideal environmental conditions need to be, as well as whether the water it is being grown in needs to be fresh water or salt water. The two main types of systems that can be installed are closed bioreactors and open ponds. Closed bioreactors are often favored over open ponds because a closed system can be regulated unlike an open system that is subject to environmental changes.[18]

Ideally an algae "farm" is installed in a hot or tropical climate so the algae can be grown year round. The three main requirements for any algae system is a lot of land, warm temperatures, and adequate sunlight. Although an open pond algae farm can be installed in areas where the weather is not always warm, it is not an economically feasible option due to the fact that algae cannot be grown all year long. Closed bioreactors typically are not influenced due to the surrounding environment, however depending on the technology used to build the bioreactor outdoor conditions could affect the indoor conditions.[21]

Algae is grown to extract the oils that are found inside the plant, from which fuel can be generated. Due to the fact that the oils are the most important of the plant, the extraction technologies used to remove the oils are key to making an algae system feasible. The extraction technology used will vary based on the manufacturer of the equipment. One specific company, OriginOil, specializes in algae extraction and will have systems as efficient as 94% to 97%. Systems like this are ideal to use because there will be very little waste and more return.[26]

9.1.3 Landfill Gas

Landfill gas makes up about 12% of the electricity generated by biomass systems, producing 6,590,366,000 kWh of power.[169] Landfill gas systems are ideal to use in large landfills because they are harnessing harmful gases that would otherwise be released into the environment. Methane is one of the main components that make up landfill gas and also happens to be a harmful greenhouse gas, with a potency 21 times greater the carbon dioxide. By capturing these gases the negative impacts on the environment are being lessened and power is generated for consumption.[37]

The US EPA created a profile for "candidate" landfills, which are ideal landfills for generating power. These landfills should have at least one million tons of waste and either still be in service or be closed for five years or less. For landfills still in service, horizontal extraction systems are ideal to use because none of the equipment is out in the open or in the way. The US EPA's Landfill Methane Outreach Program (LMOP) program estimates that there are 560 adequate landfills that can generate over 1,300 MW of power, which is the equivalent to 250 billion cubic feet per year of gas being captured.[170]

Landfill gas is not always the most efficient option due to the fact that it has less than 50% of the heating capacity of natural gas. Despite the fact that there is a reduced efficiency, landfill gas systems are extremely feasible in the appropriate situations. The fact that these systems not only prevent harmful toxins from being released into the environment, but also generate power make them multi-functional and an ideal system to use in landfills.[37]

Table 3 represents the waste energy consumption (in trillion Btu) by type of waste and energy use sector in 2007. As shown, landfill gas accounted for the largest generator, generating a total of 173 trillion Btu in 2007.[171]

Type	Sector				
	Commercial	Industrial	Electric Power		Total (Trillion Btu)
			Electric Utilities	Independent Power Producers	
Total	31	162	16	221	430
Landfill Gas	3	93	9	69	173
MSW Biogenic	21	6	5	134	165
Other Biomass	7	63	3	19	92

Table 9: Waste Energy Consumption by Type of Waste and Energy Sector in 2007

9.1.4 Waste-to-Energy

Waste-to-energy systems are ideal to install anywhere near an existing landfill (to reduce transportation costs) and not only eliminate landfill waste, but also generate power. These systems are typically installed on a larger scale and make use of waste that takes up space in one of the many landfills located in the US. Over 55% of the waste generate in the US will end up in a land fill and about 14% of the waste generated will be burned in a waste-to-energy plant. Waste-to-energy plants are also cogenerators and will either create electricity for the grid or generate heat for buildings.[40]

Waste-to-energy plants are feasible to install due to the fact that they generate power from waste that would otherwise just emit methane and other harmful gases in landfills. The waste that is burned is not completely eliminated. Typically every 2,000 pounds of waste burned generates about 300 lbs to 600 pounds of ash. The fact that 4,000 lbs of waste is reduced by nearly 90% makes these systems extremely advantageous to install.[40]

9.1.5 Biodiesel

Biodiesel is a renewable energy option that is ready for wide spread use. Biodiesel can be used in any existing diesel engine. A few small and inexpensive parts in an engine need to be replaced and biodiesel will run just as well as petroleum diesel. Biodiesel has the advantage of reducing greenhouse gases emissions up to 75% and increasing lubrication in the engine, possibly extending its life span. Biodiesel can congeal and freeze up engines in cold weather however, with proper mitigation techniques, this can be avoided.[51]

Figure 30 shows the increase in biodiesel production between 2002 and 2006. As indicated there was a huge increase between 2005 and 2006 nearly tripling the production in one year alone. Due to this increase there was also an increase in the number of biodiesel distribution centers.[172]

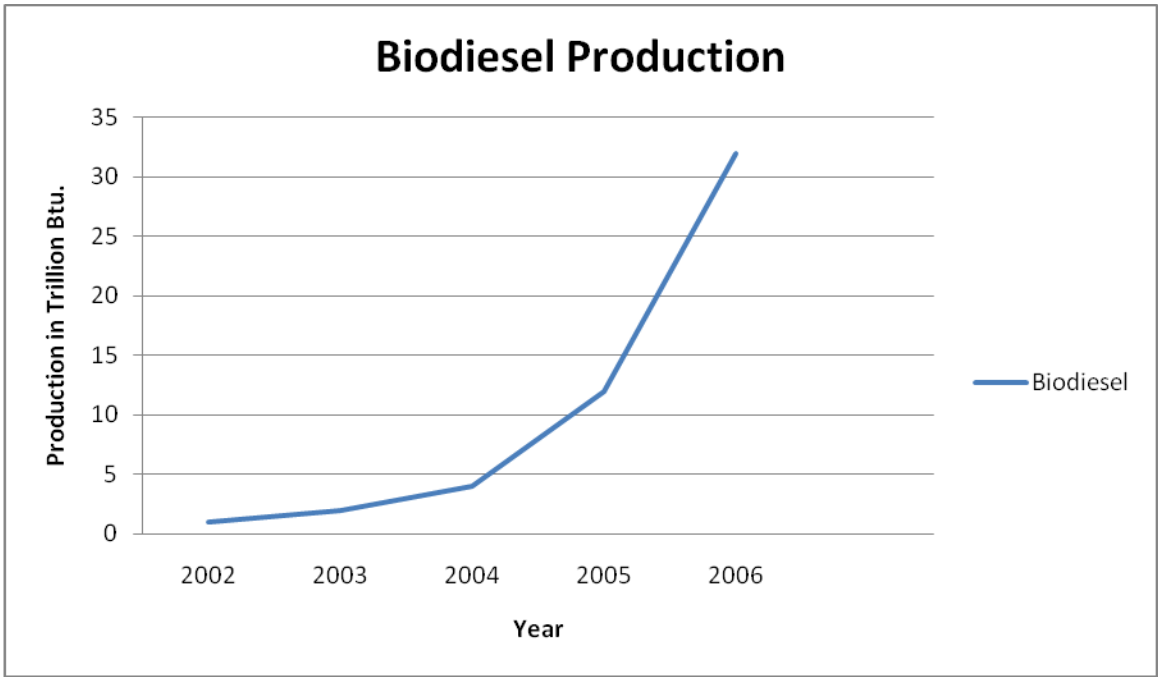

Figure 53: Biodiesel Production

9.2 Geothermal

Geothermal power only makes up about 4% of US renewable energy generation, with a net electricity generation 14,859,238,000 kWh in 2008. The two types of geothermal power researched were ground source heat pumps and deep well geothermal.[168]

9.2.1 Ground Source Heat Pumps

Ground source heat pumps are most applicable to use on a residential or commercial scale. These systems can be installed in most locations throughout the US due to the fact that the ground temperature 10 feet below the surface is somewhat consistent throughout the year.[64] These are an economically feasible option to install for most applications due to the fact that there is an annual energy savings anywhere between 30% and 60%.[65]

For small scale applications these systems also have a higher efficiency than air-source heat pumps and will decrease the cost in heating/cooling a building. A ground source heat pump will be most promising to use in buildings where temperatures are maintained between 68°F and 78°F for at least 40 hours a week. This means that these systems can be installed in both a residential home and an office building. There are 4 main types of systems that can be installed. Each system will be feasible under certain circumstances and generate the most power based on the environmental conditions.[65] Figure 31 represents the increase in the energy consumed by ground source heat pumps from 1990 to 2008.[168]

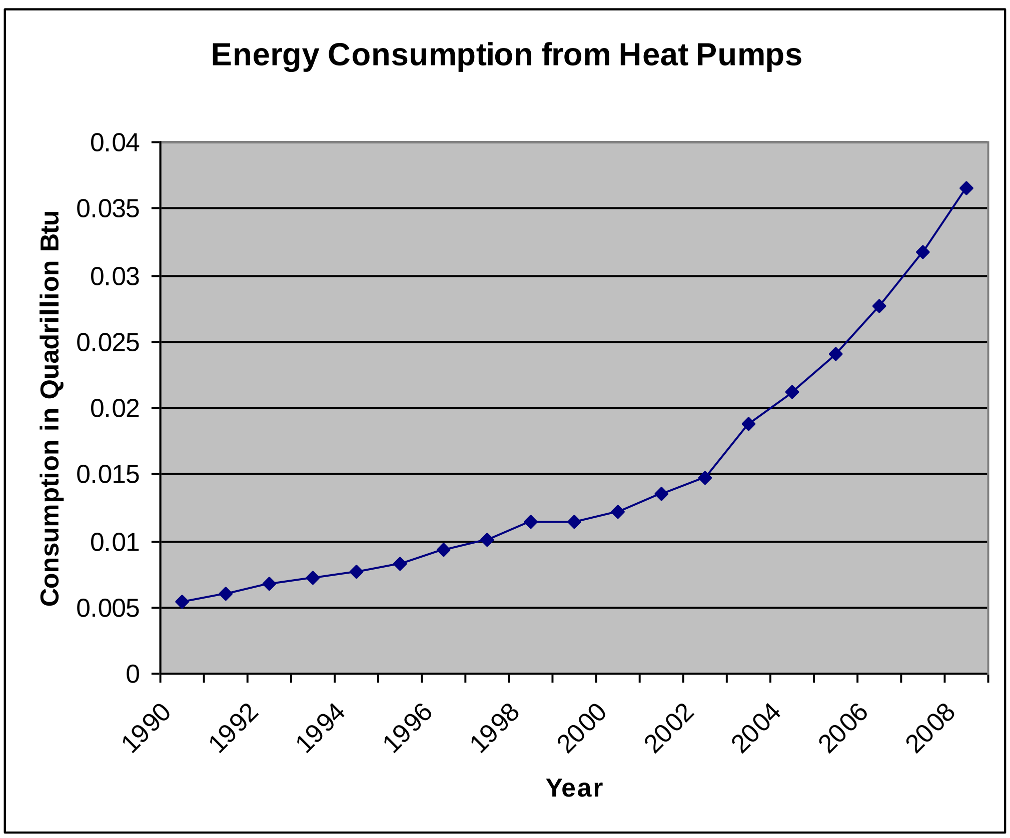

Figure 54: Energy Consumption from Ground Source Heat Pumps

9.2.1.1 Pond/Lake Systems

A pond/lake system is the most cost effective option to install, however not applicable in all situations. These systems require a sizeable body of water located near the chosen site. The body of water is ideally at least 8 feet deep and requires about 100 feet to 300 feet of piping per ton of heating/cooling.[65]

9.2.1.2 Horizontal Closed-Loop System

If a pond/lake system is not applicable, then a horizontal system is the next most cost effective option. Horizontal systems are ideally installed in locations where there is a lot of land available and there is at least 4 feet of soil to excavate. These systems are also best to install in situations where there is new construction due to the fact that trenches have to be dug to install the system. For a horizontal system there needs to be about 2,500 square feet of land available for every needed ton of installed capacity.[65]

9.2.1.3 Vertical Closed-Loop System

Vertical systems are ideally used for large commercial building and schools because it decreases the required land area necessary for installation. These systems are also best to install if there if the soil is difficult to dig into or if it is really rocky. In order for these systems to be installed about 250 square feet of land is required for every ton of capacity of heating/cooling. Generally depths of 100 feet to 300 feet per ton of heating/cooling need to be reached as well.[65]

9.2.1.4 Open Loop System

Open loop systems require either a well or surface water to be used as the fluid that circulates through the system. These systems are only feasible to use when there is a sufficient supply of clean water to minimize any corrosion problems. The water for the system also needs to be “warm” water, which is water that is typically warmer than 5°C. The feasibility of this type of system will also vary based on whether or not is it “legal” to discharge water back into the environment.[65]

9.2.2 Deep Well

Deep well geothermal systems are only feasible to install if there is an underground reservoir located near the chosen site. A deep well is drilled to attain temperatures greater than those near the surface. In general a deep well will be over 5,000 feet deep and attain fluid over 90° C. There are three different types of reservoirs that can be drilled into to generate power. There are high-temperature water-dominate reservoirs (beyond 5,000 feet in the Earth) or low-temperature water-dominate reservoirs (usually less than 1,000 feet in the Earth). There are also steam-dominated reservoirs which are usually deeper than 5,000 feet.[74]

Deep well geothermal systems are only feasible for large scale applications due to the high cost of the investment. Not only do deep wells need to be drilled, but power plants need to be installed near the wells in order to harness the power. The ideal areas to drill deep wells are near hot springs, geysers, volcanoes, and fumaroles (holes where volcanic gases are released) because these features occur near reservoirs. In general, these features are found in the Western US, Alaska, and Hawaii. Despite the fact that large scale geothermal plants are typically not very efficient, the amount of gases released from the power plant are negligible compared to those that traditional power plants emit.[64]

9.3 Hydropower

Approximately 68% of the renewable energy generated in the US is from hydropower power plants. Although this energy is typically generated by conventional power plants, micro-hydropower, tidal power, and wave power all contribute to the energy generated as well.[168]

9.3.1 Micro-Hydropower

Micro-hydropower systems are those that generate 100 kW of power or less. These are usually small scale applications and generate power for a farm, small community, or large residential home. A micro-hydropower system is ideally located in a mountainous or hilly region that receives a lot of year round rainfall.[85]

Despite the fact that one of these systems are feasible near any stream/river or falling water source, the most power will be generated in areas where there is always a consistent flow of water. The time of year will sometimes have an effect on the amount of water that is flowing and in these situations consistent power won't be generated. Ideally there should be a minimum stream flow of 10 gpm or a drop in head of 10 feet in order to generate an adequate amount of power.[64]

Typically micro-hydropower systems are reasonably priced and very efficient, making them a feasible option to install in rural communities and developing countries.

These systems also have minimal to no emissions making it an "environmentally friendly" way of generating power. The only impact that these systems will have is on the surrounding environment and stream flow and even then, the impacts are limited.[85]

9.3.2 Tidal Power

Unlike other renewable energy resources, the use of tides to generate power is extremely predictable making it a favorable system to install. Tidal power systems require either a coastal or offshore location in order to be installed. These systems can also be installed on a substantial river, similar to the Rance Power Plant in France. Tidal power can be generated either from the change of tides or from tidal currents.[101]

In order to harness the power of the tides and for the system to be feasible, there needs to be a tidal difference of 12 feet or more. Due to this requirement, not every coastal or offshore location is feasible for the use of tidal power generation. Some of the ideal locations to generate tidal power are off the coast of Washington, British Columbia, and Alaska. There are also suitable locations off the coast of Maine and England as well.[100]

If the conditions are right, tidal power plants are an economically feasible option to install and will have efficiencies as high as 80%. There are also minimal environmental impacts associated with the installation of tidal power systems making them an even more viable option to install. One of the main factors that is associated with tidal power plants is that the turbines that are installed may harm the aquatic wildlife, however there are methods to reduce this effect. Tidal barrage/dams will have the greatest impact of the local environment especially if a dam needs to be built. In situations like this, a tidal power plant may not be the most feasible option.[105]

9.3.3 Wave Power

Wave power is a relatively "new" form of renewable energy technology, however there is an estimated 2 terawatts of potential electricity generation from this form of power. It is feasible to install either onshore or offshore wave power systems, however the most promise is shown for offshore systems. Offshore systems are more feasible to develop due to the fact that there is minimal public concerns that can effect the construction of these systems.[107]

The ideal locations to install wave power systems are on the Western coastlines of continents between the latitudes of 40° and 60° above and below the equator. Some feasible locations to install these systems are off the Northwest coast of the US, as well as England and Scotland due to the winds from the Atlantic Ocean. Although the middle of the Pacific Ocean shows great potential for wave power, it is not a feasible location because it would be difficult to distribute the power back to the US after it is generated.[112]

In ideal conditions, wave power systems can have efficiencies as high as 80% and 90% depending on the type of technology that is used. The environmental impacts created by wave power systems are extremely limited. There are zero emissions produced during the electricity generation process and technically the power source is unlimited. The only disadvantage to this type of system is that it must be able to withstand the constant force of the waves, therefore these systems need to substantially built to stand up to the steady force.[112]

9.4 Solar

9.4.1 Photovoltaic

With the current cost of PV modules the best applications are stand alone and small scale power needs in areas that have a very high annual solar insolation. In areas that do not have high solar insolation, PV becomes cost effective when you compare it to the cost of traditional electricity and the cost of installing additional power lines. If excess power can be sold back to a utility company it also increase its feasibility, however rates vary from company to company. Studies have shown that very large scale PV power plants in the world's deserts would be economically feasible, but extremely large initial capital costs and the uncertainty due project complications scare away investors.[136]

Areas such as the Southwestern U.S. have enough annual solar insolation that it becomes feasible for residential applications to supplement or cover daily electricity needs. PV becomes more cost effective when utility companies allow you to sell excess electricity and when state and national incentives are available. All of this depends on the region of installation. PV emits no greenhouse gases during operation, however small amounts are emitted from equipment during construction and manufacturing.[136]

Figure 32 represents the increase in the use of PV panels. Over the last 10 years the shipments of PV solar panels have increased by nearly 1,400%.[173]

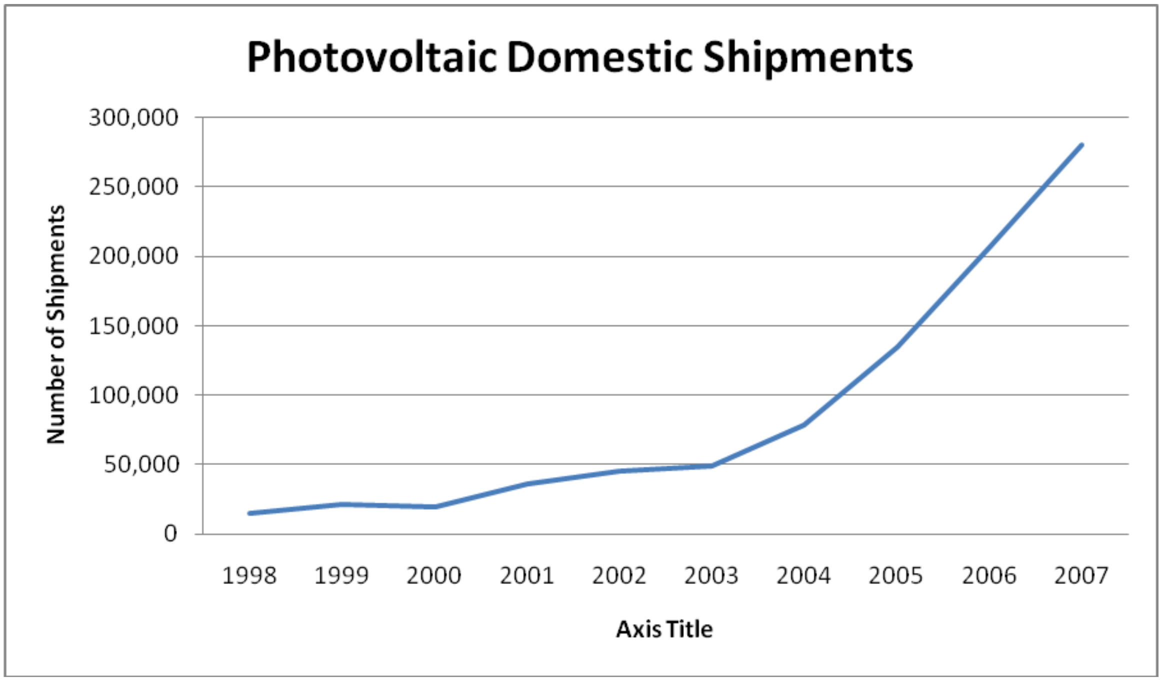

Figure 55: Annual Photovoltaic Domestic Shipments between 1998 - 2007

9.4.2 Concentrated Solar Power (CSP)

CSP is a feasible renewable energy option to be used in large scale in areas with very high solar insolation. CSP has not been tried on a small scale since high manufacturing costs and amount of area needed render it infeasible. Large scale CSP plants are economically feasible to install because of reduced construction cost. Also there are so few CSP systems that there is not a competitive market for CSP collectors, and many plants that have been built to date are all somewhat unique.[119]

The best sites for CSP plants are areas with the highest annual solar insolation. Deserts generally have very high annual solar insolation and have very little to no value. CSP plants can be sited on otherwise useless land for very low costs. This increases its feasibility and also saves other land from being used for power production. CSP emits no greenhouse gases during operation, however small amounts are emitted from equipment during construction and manufacturing.[119]

9.5 Wind

9.5.1 Offshore

Offshore wind power is still in the development stage and is not considered ready for widespread use. Current foundation technology limits offshore wind turbines to waters less than 30 meters deep. Larger capacity wind turbines are used offshore in an attempt to make them more cost effective, however the cost of construction and installation of additional transmission lines is expensive. These additional costs make offshore wind energy almost twice as expensive as onshore. Higher capacity factors due to stronger more consistent offshore winds could offset this price, but the best winds can not be utilized due to water depth restrictions.[147]

Another obstacle to overcome is the area of public concern. One major concern is environmental impacts. Environmental impact studies have been conducted on offshore wind farms in northern Europe but there have not been many extensive and long term impact studies. Many of the areas with waters less than 30 meters deep are local fishing grounds and if damaged could have large effects on local economies. Also people are concerned with ruining the visual aesthetics of local beaches. Wind turbines do not emit greenhouse gases during operation, but small amounts are emitted by equipment during construction and manufacturing.[147]

9.5.2 Onshore

Onshore wind turbines are feasible at the residential and commercial scale. Residential wind turbines become cost effective at sites where there is a very strong wind resource. Since residential wind turbines have a lower height than industrial wind turbines they often are not as efficient because the strong high winds are not available. Large scale wind farms require large tracts of land with strong sustained winds. The Midwest northern Texas has the best wide spread wind resources in the country. Ridge lines in hilly and mountainous areas often have strong wind resources, however the ridge must be accessible to construction equipment to allow for a wind farm to be built.[159]

While large scale wind farms are spread out over a greater area of land, the actual land used is very minimal. Large wind farms and be integrated into crop fields with little to no impact. Bird deaths have been a environmental concern of wind farms however a extremely small amount of birds are killed by wind turbines and migratory birds learn to simply fly around them. Wind turbines emit do not greenhouse gases during operation, but small amounts are emitted by equipment during construction and manufacturing.[154]

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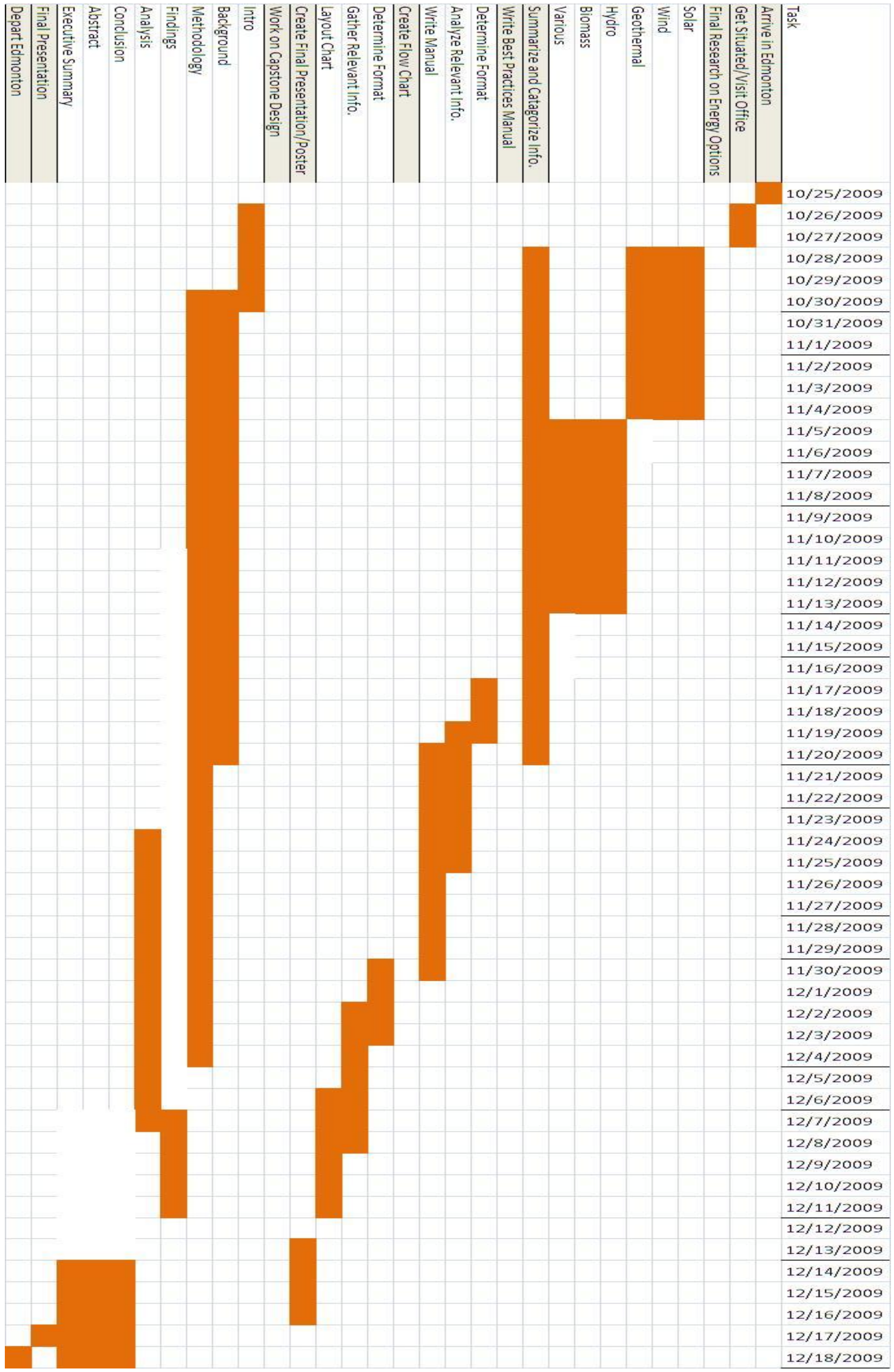
Appendix B: Timeline



Appendix C: Capstone Design

The capstone design for this project is designing a micro-hydropower system. Opposed to building a dam and completely altering the flow of a river, a run--the-river system was designed to lessen the environmental impact. Only a small portion of the river is going to be diverted into a pipe for use in the micro-hydropower system. Below outlines the steps required to design such a system.

Step One – System Determination

The site that was used for this aspect of the project was in Goffstown, New Hampshire. The "client" was interested in installing a renewable energy system that would generate electricity for their home. Based on the fact that electricity generation was the main energy need, a ground source heat pump was instantly removed as an option. From here it was determined that solar panels, a small wind turbine, or a micro-hydropower system could be installed.

The client's home is located in a river valley with a lot of trees. Due to this fact it was determine that a wind turbine wouldn't be realistic because there is not enough year-round winds to generate adequate power. It was also determined that solar panels wouldn't be a realistic option either because the amount of sunlight that reaches the site is not substantial to power the entire home.

With both solar and wind power not being adequate to generate power, it was determined that a micro-hydropower system would work the best. Based on this assumption the river flow and conditions needed to be analyzed in order to determine if the site would generate the proper power requirement.

Step Two – Computing River Flow

In order to design a micro-hydropower system the river conditions needed to be obtained. The United States Geological Survey's (USGS) website has a database of real-time water data for both current and past river/stream conditions. Using this database the data for river conditions, river flow and gage height were acquired.

The particular river that was used was USGS 01091500 Piscataquog River near Goffstown, New Hampshire. This river was adequate for design due to fact that there was river data for the last 3 years and that the average stream flow over this period of time was 14.067 m^3/s. Also based on topographical maps and general assumptions, it is determined that between the inflow and outflow of the system there is a total head of 10 feet available.

One of data points not used because it was an outlier. The stream flow for April 16, 2007 was 317.15 m^3/s and, if used in the stream calculations than the average stream flow would have been estimated at 34.27 m^3/s. This would have skewed the data making the average stream flow much greater than it should have been for the last 3 years. Due to the fact that there is a dam upstream of this site could be one reason for the extreme change in flow. The dam may have been drained because there was too much water in it or there could have been an extreme amount of runoff during the month of April.

Date	Stream Flow (ft^3/s)	Stream Flow (m^3/s)	Gage Height (ft)	Gage Height (m)
4/5/2006	1030	29.16635241	5.88	1.792224
5/17/2006	2650	75.03964455	7.65	2.33172
7/18/2006	188	5.323567236	4.28	1.304544
7/25/2006	158	4.474061826	4.06	1.237488
8/23/2006	248	7.022578056	4.38	1.335024
9/27/2006	31	0.877822257	3.26	0.993648
10/19/2006	338	9.571094286	4.55	1.38684
4/4/2007	697	19.73684236	5.39	1.642872
6/26/2007	108	3.058219476	3.79	1.155192
8/24/2007	31	0.877822257	3.16	0.963168
11/2/2007	158	4.474061826	4.01	1.222248
6/5/2008	88	2.491882536	3.65	1.11252
10/21/2008	150	4.24752705	3.97	1.210056
4/1/2009	1080	30.58219476	5.94	1.810512
Average:	496.7857143	14.06740506	4.569285714	1.392718286

Table 4: Piscataquog River Data

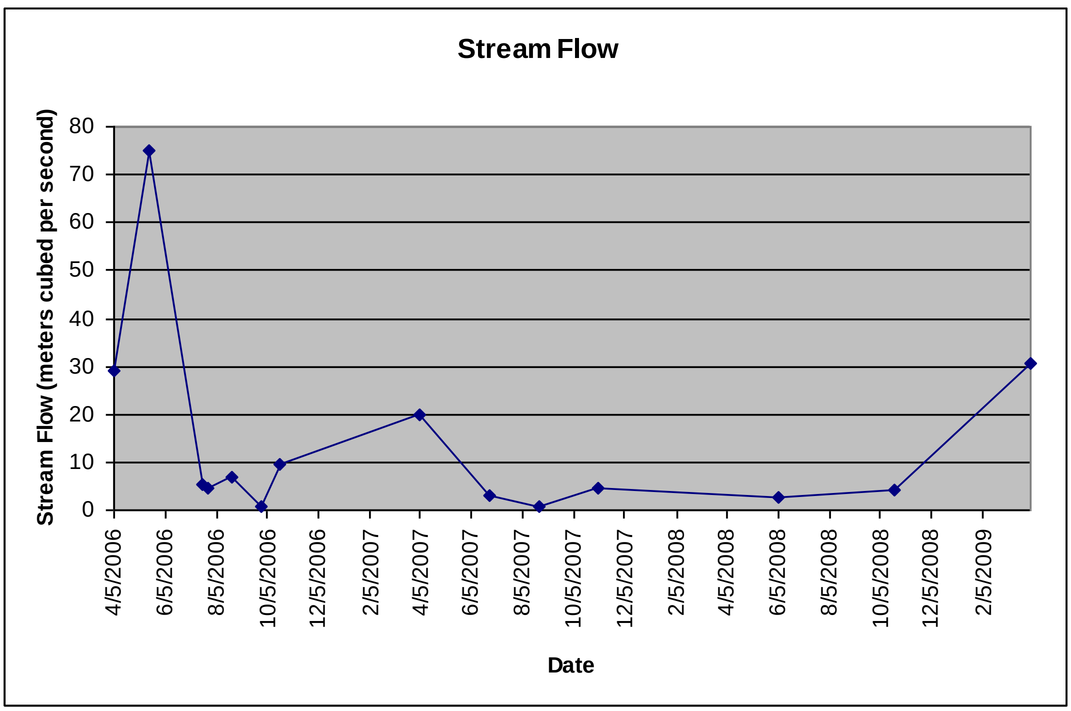


Figure 34: Graph of Piscataquog Stream Flow between 04/06 and 02/09

Step Three – Potential Power and Energy

After the site was chosen, the total potential power needed to be determined to ensure that the river would be adequate to generate enough power. The quantity of power that is available for use is directly proportional to the flow of the river, the force of gravity, and the system head. For this particular site the design was based on the minimum flow rate and the basis that a total of 1/3 of the flow was going to be diverted.

The first calculation that needs to be computed is the theoretical power. The equation is listed below. P_{th} represents the theoretical power, Q represents usable flow rate in m^3/s, H represents gross head in meters, and g represents the gravitational constant of 9.8 m/s^2. The values used to compute the theoretical power for the given site are listed below as well.

$$P_{th} = Q\ x\ H\ x\ g$$

Equation 1: Theoretical Power

$$Q = \left(0.877\frac{m^3}{s}\right) = \ 13{,}900\ gpm$$

$$H = 4.57\ m$$

$$P_{th} = \left(0.292\frac{m^3}{s}\right)(4.57m)(9.8\frac{m}{s^2})$$

$$P_{th} = 13.08\ kW$$

Theoretically the river can generate a total power of 13.08 kW if only 1/3 of the stream flow is used at the minimum flow time. This value is not correct however because 100% of the power won't be generated and distributed for use. A certain factor of power loss needs to be accounted for because no system will be 100% efficient. Smaller systems can have efficiencies as high as 70% or 80% and in this particular case, an efficiency of 70% is assumed. The equation and calculations to compute actual power output is listed below. This equation is the same as equation 1, however the efficiency factor (e) is accounted for.

$$P = Q\ x\ H\ x\ g\ x\ e$$

Equation 2: Actual Power Output

$$P = (13.08\ kW)(0.70)$$

$$P = 9.2\ kW$$

For this particular site, at any given time of the year, a minimum of 9.2 kW of power will be generated. This value was computed based on the fact that only 1/3 of the stream flow was used. If the usable stream flow is increased to ½ then the amount of power will be increased as well.

Step Four – Develop Flow Duration Curve

A flow duration curve (FDC) is a way for the homeowner to see how much power will be produced for the site throughout the year. Opposed to having to buy power from the local electricity supplier, the homeowner wants to be sure that all the power they need will be generated on site. The flow duration curve will show the probability for how many days a year (or period of years) a given flow will be exceeded. This curve will help to decide the usable design flow (Q) in a particular situation. In most scenarios you will want a design flow of 95% or higher especially if you want to have a system independent of an electric supplier.

For this particular case design, the design flow was based on the flow available 100% of the time. Designing the system based on the flow available 100% of the time will ensure that at any given moment there is a minimum flow of at least 0.877 m^3/s. See Figure 35 for flow duration curve.

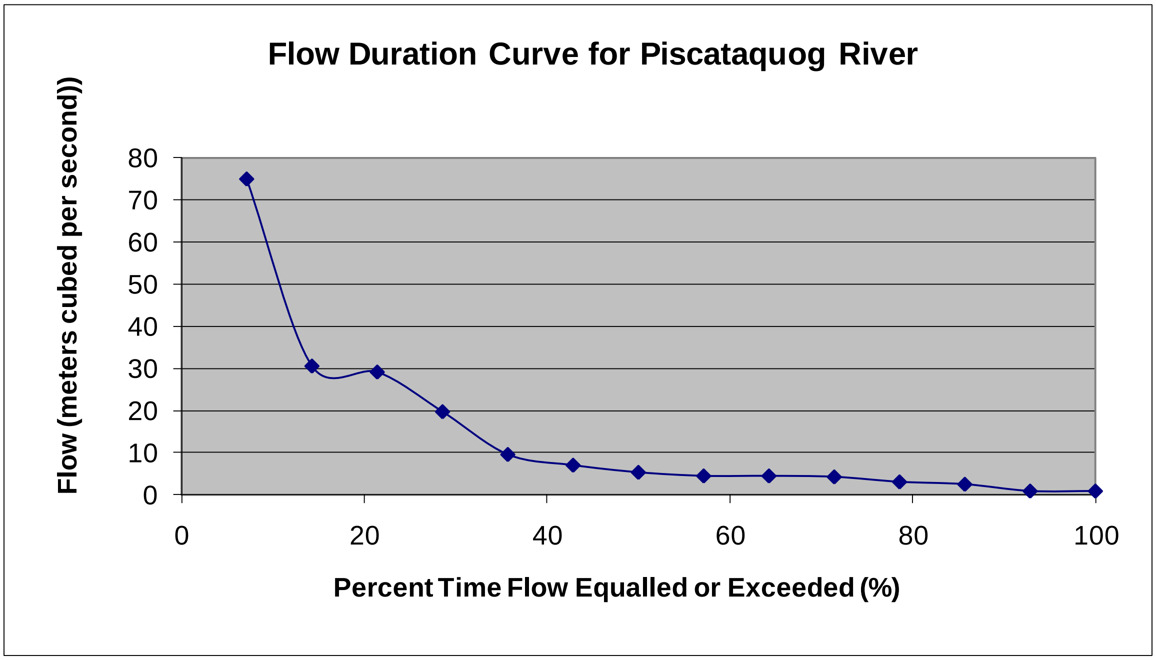


Figure 35: Flow Duration Curve for Piscataquog River

Step Five – Assess Energy and Power Requirements

In order to have an adequate system design it is important to look into the energy and power requirements of the household. In order to do this either an old electricity bill can be referenced or each appliance/light can be listed out and the amount of power consumed calculated. For this particular case, each of the appliances/lights was listed out and the amount of power consumed was calculated. One general rule of thumb is that the more appliances on at the same time, the higher the power requirement.

Table 5 represents the various appliances in a household and the amount of power they require. Although this table does not compile all possible appliances it is a good basis for all major appliances in a household. Note that there will be gas heating

Appliance	Power Rating (W)	Hours Per day	Hours Per Week	Weekly kWh	Annual kWh
Refrigerator (20 CF)	540	15	105	56.7	2948.4
TV	100	7	49	4.9	254.8
Computer	200	3	21	4.2	218.4
Printer	600	0.5	3.5	2.1	109.2
Water Pump for Well	1000	2	14	14	728
Microwave	1000	0.15	1.05	1.05	54.6
Washer	500		4	2	104
Dryer	4000		4	16	832
Dishwasher	1350	1	7	9.45	491.4
Toaster	1150	0.25	1.75	2.0125	104.65
Stereo	30	5	35	1.05	54.6
Lights (20 Total)	400	8	56	22.4	1164.8
Lamp (2 Total)	100	4	28	2.8	145.6
Hair Dryer	1000	0.15	1.05	1.05	54.6
Coffee Maker	900	0.3	2.1	1.89	98.28
Electric Stove and Oven	3500	2	14	49	2548
Phone/Answering Mach.	9	720	5040	45.36	2358.72
					12270.05

Table 5 : Conventional Appliance Power Usage

For the design household, many of the appliances are Energy Star/Efficient products. Table 6 includes the energy star values, which are denoted with an asterisk (*).

Appliance	Power Rating (W)	Hours Per day	Hours Per Week	Weekly kWh	Annual kWh
Refrigerator (20 CF) *				9.6	500
TV *				4.0	209
Computer	200	3	21	4.2	218.4
Printer	600	0.5	3.5	2.1	109.2
Water Pump for Well	1000	2	14	14.0	728
Microwave	1000	0.15	1.05	1.05	54.6
Washer	500		4	2.0	200
Dryer *				15.4	800
Dishwasher *				6.2	320
Toaster	1150	0.25	1.75	2.0	104.65
Stereo *	30	2	14	0.4	21.84
Lights (20 Total)	400	8	56	22.4	1164.8
Lamp (2 Total)	100	4	28	2.8	145.6
Hair Dryer	1000	0.15	1.05	1.1	54.6
Coffee Maker	900	0.3	2.1	1.9	98.28
Electric Stove and Oven	3500	2	14	49.0	2548
Phone/Answering Mach.	9	720	5040	45.4	2358.72
					9635.69

Table 6: Energy Star Appliance Power Usage

Step Six – Load Variation Chart

A load variation and management graph is typically developed to determine the maximum required power at any given time. This graph represents the typical power demands for the day and the time that the demand is the highest. Energy efficient appliances will help lessen the power load for the day, as well as reduce the cost of power. It has also been found that households that are “off-grid” will have an energy reduction of nearly 44% compared to houses that rely on a electric utility company. The main reason for this being that off-grid homes are typically more conservative with the amount of appliances they have and run at the same time.

A technique called “load management” can also be utilized to reduce the amount of electricity that is being consumed at any one given time. An overload on an electric system can be avoided by managing the time of use for appliances. An example would be not running the washer, dryer, and dishwasher at the exact same time. Figure 36 represents the “load management” technique for the design household.

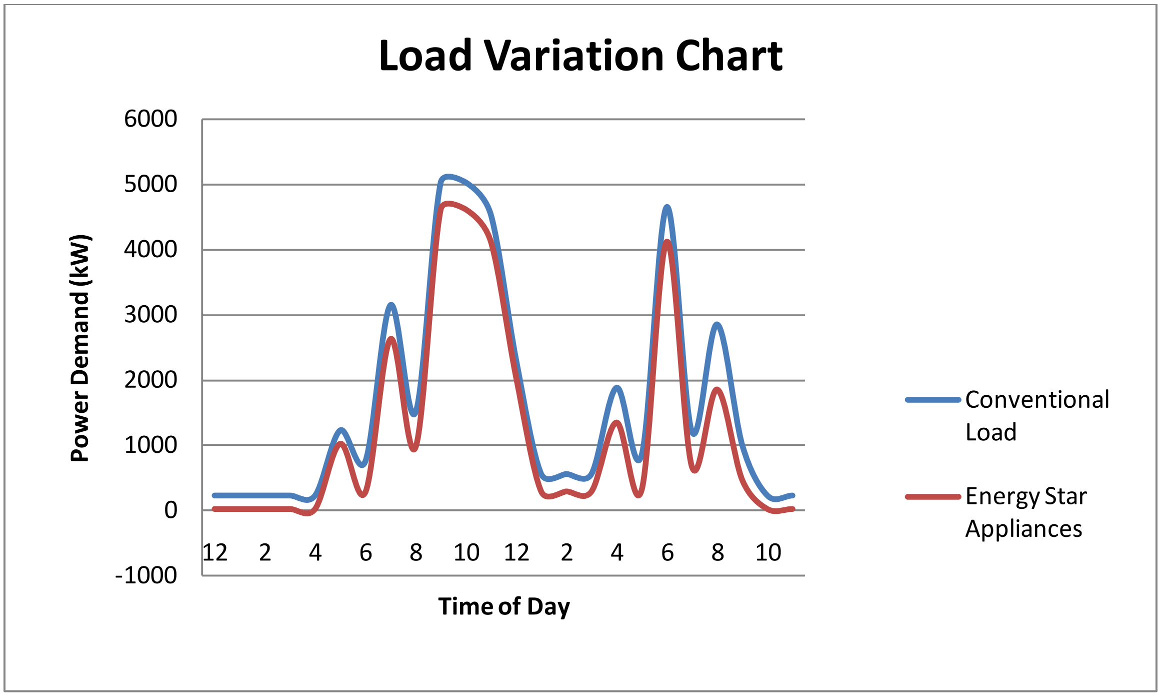


Figure 36: Load Variation Chart

Mechanisms called "load controllers" can also be installed on the micro-hydropower system and can double the load. By installing one of these controllers you can manage the peak demand by using energy available to its full potential. These controllers will use energy from non-essential loads when the system is becoming overloaded. The non-essential items will be automatically turned on and off by use of the controller and can make a 10 kW micro-hydropower system a 20 kW system with load controllers.

Step Seven – Feasibility Study

A basic feasibility study is performed to determine if the site is adequate for a micro-hydropower system. This study is system specific and is only used when analyzing a micro-hydropower system. An in-depth feasibility study will includes a site survey, an environmental assessment, the project design, a hydrological assessment, and a detailed cost estimate. The basic feasibility study presented in this report addresses the following questions:

- How much head is available?

  There is a total head available of 10 feet (3.048 meters).

- How long does the canal/pipeline have to be in order to reach the head?

  The pipe will have to be 100 foot long in order to reach the head from the forebay to the power house.

- What are the minimum and maximum flow rates, and when do these occur?

  A minimum flow rate is 0.877 m^3/s and occurred during the months September 2006 and August 2007. The maximum flow rate is 75.0 m^3/s and occurred in May 2006.

- How much power can be generated with the available flow rates?

  The minimum flow rate will generate a total of 13.1 kW of power at any given time, which is adequate for this household. The system will be designed assuming that the minimum flow rate is available 100% of the time.

- Who owns the land?

  The land is owned by the homeowner.

- Where are the nearest electricity power lines?

  The nearest power lines are located in the street in front of the house. The power from the micro-hydropower system will only be used for the house and not be fed back into the grid. The house is being treated as if it is "off the grid". There will be no power storage for this household since an AC power system will be installed.

• What would the environmental effects of installing a micro-hydropower system be?

The environmental effects of installing a micro-hydropower system would be minimal. A full environmental system should be performed, however it can be assumed that there will be a minimal impact on river aquatic life because of the dam located upstream of the site. As for the surrounding area, similar to all construction, there will be a period of time where the plants/trees are affected. After the construction is completed, grass and trees should be replanted and proper water runoff management techniques should be taken into consideration

• What is the approval process to install the micro-hydropower system?

The New Hampshire Department of Environmental Services should be contacted with the project description and site plans. The Army Corps of Engineers should also be contacted to see if there is any restriction on river diversion. The local building department needs to approve the plans for the micro-hydropower system prior to any work being done. Once the plans are approved then the system can be built.

• What financial incentives are available that encourage renewable energy, and how can you apply for them?

Currently the state of New Hampshire does not have any incentives available for building a micro-hydropower system. There are incentives however for installing energy efficient appliances. National Grid offers a maximum incentive of $4,000 for installing energy efficient refrigerators/freezers, lighting, duct/air sealing, and building insulation. See http://www.dsireusa.org/ for more information on tax credits and federal incentives.

• How much will it cost to develop the micro-hydropower system?

The cost for a 10 kW AC-Direct micro-hydropower system is around $26,000. The cost for the equipment is around $21,400 and the cost for the installation is around $4,600. This means that the cost per kW is around $ 2,600 (see step nine for exact system cost).

Step Eight– Determine Equipment and Material to be Used

The micro-hydropower system that is going to be used is a run-of-river system. This system is unlike a dam system because only the flow that is required is taken from the river and no "blockades" are constructed in the river. An intake pipe will be placed in the river to divert a portion of the flow to another area. A small canal will then be constructed to lead the water from the intake pipe into the forebay. The forebay is a tank that stores the water until time of delivery.

From the forebay, the water will be directed toward the power house (which has the turbine, controller units, and generator) via a penstock pipe. Due to the fact that the site is located in a severe frost area which receives a decent amount of annual snow fall, the penstock pipe is to be buried below the frost line. The penstock pipe will transport the water under pressure and rotate the turbine. After the water rotates the turbine it will be sent out of the power house and back into the stream. The power that is generated in the powerhouse will then be distributed to the main house for use. See Figure 37 for site schematic.

Figure 37: Micro-hydropower Schematic

Materials and turbine design are factors to consider to achieve the highest efficiency. The penstock pipe can either be made out of Mild Steel, HDPE, or uPVC. Due to the fact that the pipe is going to be buried, HDPE will be the best material to use because it does not corrode very easily.

A low reaction turbine was selected for this design. It reaction turbine will use the pressure change of the water to move the blades of the turbine. In essence the turbine is “taking” the waters power and the pressure is then reduced as it leaves the turbine. There are two different types of low head reaction turbines that can be used, a propeller or Kaplan. In this particular case a propeller turbine was selected because it is extremely efficient and can reach efficiencies as high as 95%.

The two types of micro-hydropower generators are synchronous and asynchronous. Asynchronous, also referred to as induction, generators are appropriate to use for smaller systems such as this one. These generators are cheaper than synchronous generators and are extremely rugged. They are also rated for systems that generate less than 10 kW to 15 kW.

Lastly the micro-hydropower system can generate enough power for the peak load and therefore an AC-direct system can be used. There will be no battery storage and the system will supply the power directly for use. These systems are known as “water-to-wire” installations and are extremely economical.

Step Nine – Compute System Cost

Due to the fact that an AC-direct system is going to be installed there will be no need for any battery installations which will greatly reduce the cost of the system. A majority of the costs associated with a micro-hydropower system are initial one time costs. These systems are also extremely low maintenance which reduces the system’s lifetime cost as well. Below is a list of the various components needed for the system and the cost associated with them.

Component	10 kW System
Chanel	$1,000
Forebay	$1,500
HDPE Penstock	$3,500
Turbine	$3,000
Generator	$4,000
Transmission Line	$3,500
Powerhouse	$3,000
Outlet	$1,500
Miscellaneous	$2,000
Total Equipment Cost	$23,000
Installation Cost	$6,000
Total Amount Cost $/kW	$29,000 $2,900

Table 7: Micro-Hydropower System Cost

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