WIND ENERGY

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ABSTRACT

The more fossil fuels are depleted, the more of a need there is to find new forms of energy. This report takes a look at several different kinds of renewable energy before narrowing down its focus to wind energy. A variety of principles are discussed on how wind power and wind turbines function proving how important wind velocity is in producing electrical power. There is a cost and benefit analysis of the feasibility of wind power. This analysis found the economic costs of setting up wind turbines to be smaller than the potential gain the turbines can produce over time. There are also some effects that wind turbines can have on society such as federal and state tax incentives and the creation of new jobs. Finally this paper's main focus is to look into vertical axis wind turbines and examine their advantages and disadvantages when compared to the standard horizontal axis wind turbines used today. There are indeed some areas in which vertical axis wind turbines can have an advantage over horizontal axis wind turbines.

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ALTERNATIVE ENERGY

Today, Energy is commonly produced through means that reduce environmental quality. Renewable or alternative energy is the desired method to create a cleaner more preferred environment. Alternative Energy can also help the economy by producing more jobs. There are many different types of renewable energy. Wind, Solar, Tidal, Hydroelectric, Biogas, and Geothermal Energy are all ways to create renewable energy.[1]

Figure 1 – Best Renewable Energy Sources below shows the areas with the best resources of renewable energy.

Figure 1 – Best Renewable Energy Sources

Each type of renewable energy comes from different aspects of nature making it a source that will be available for a long time to come. Countries are making substantial efforts to make a cleaner environment. Wind and Solar energy are arguably the most two notable forms of

[1] "Renewable Energy For America: Harvesting the Benefits of Homegrown, Renewable Energy." *What Is Renewable Energy, Types of Renewable Energy Sources*. Web. 02 Apr. 2012. <http://www.nrdc.org/energy/renewables/?gclid=CIWg-YfbhK8CFQ7sKgodV1vG6Q>.

renewable energy. Wind energy has no pollutants and has roughly the same electricity output of coal and gas fired power plants. Solar energy is readily available and with new technology the cost and size involved keeps getting cheaper and smaller. Tidal Energy uses the energy from tides and produces electricity. Hydroelectric Energy converts the pressure of flowing water into electricity. Biogas Energy involves burning of animal waste to produce and generate electricity, found mostly in use by farmers. Geothermal Energy is generated by the heated steam from the earth's core to the surface.

Sustainable Energy

Sustainable Energy is defined as "Effectively, the provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their own needs. ...Sustainable Energy has two key components: renewable energy and energy efficiency." – *Renewable Energy and Efficiency Partnership*.[2] Wind Energy is a contributor to sustainable energy, as wind is a sustainable resource for future generations. Solar Energy can also be a contributor to sustainable energy, as the sun will be giving off solar irradiance for years to come.[3]

Wind Energy

Possible loss of some species such as birds is an inevitable outcome with Wind Energy. Collisions of birds into wind turbines will happen and as time goes on, more deaths may arise because of the more installments of wind turbines. Other long term affects include a number of wind turbines taking up space and creating loud noises at these locations.

There are many difficulties involving wind energy. The transportation of wind turbines has high costs and can be cumbersome. Road, Rail, and Water transportation are the three distinct methods of transporting the wind turbines. Each has their advantages and disadvantages. Roads are easily and readily available to get to certain areas such as wind farms. Roads also have restrictions of weight and length capacity. Gas prices are higher than ever and present problems

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[2] Renewable Energy and Efficiency Partnership (August 2004). "Glossary of terms in sustainable energy regulation" (PDF). http://www.reeep.org/file_upload/296_tmpphpXkSxyj.pdf. Retrieved 2008-04-19.

[3] "Sustainable Energy." *Wikipedia*. Wikimedia Foundation, 04 Mar. 2012. Web. 04 Apr. 2012. <http://en.wikipedia.org/wiki/Sustainable_energy>.

for road transportation along with shortage of drivers. The rail systems are a much cheaper way for long distance travel, however are problematic with the specific areas in which the rail systems can have access to. Water is a good way of transportation for wind turbines that are installed on the coastlines. Barge travel is less expensive than road and rail transportation. This method is slow and is not accessible to many locations. Figure 2 - Water Transportation below shows two wind turbine masts being transported by a barge.

Figure 2 - Water Transportation

Figure 3 - Oversized Load of a Wind Turbine Blade shows a picture of a wind turbine blade being transported through a road system. Because these trucks are specifically made to transport wind turbines, it greatly decreases there value on the transportation of other components. Because of

this companies are not willing to invest in these trucks.[4]

Figure 3 - Oversized Load of a Wind Turbine Blade

Solar Energy

Difficulties involving solar energy vary from the initial cost, comparative production of electricity from other methods, and the non-constant solar rays making it through the earth's atmosphere. Solar panels, which harness the solar rays, from the sun are big and bulky causing a need of large areas for installation. The location of the sun determines how efficient the system can perform. The initial cost of solar energy is large compared to wind energy at this current time. Improvements in technology are consistently improving making solar energy more efficient. Figure 4 - Solar Map of the United States demonstrates the best areas for solar power: red being the best to light blue and purple being the worst.[5]

[4] "Transportation & Logistics." AWEA Educational Workshop Series. Http://www.awea.org/learnabout/publications/upload/Transportation_1Pager-2.pdf. Web. 1 Feb. 2012. <http://www.awea.org/events/fall_symposium_f2012.cfm>.

[5] "Solar Energy." Renewable Energy,. Alternative Energy. Web. 04 Apr. 2012. <http://www.altenergy.org/renewables/solar.html>.

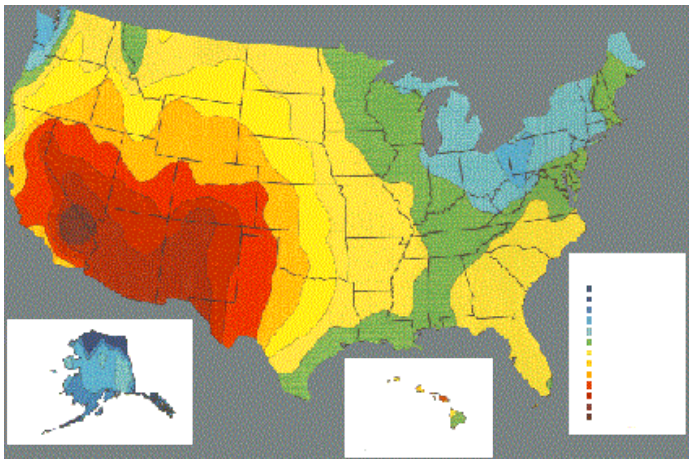

Figure 4 - Solar Map of the United States

There are advantages to having solar energy; however this paper will not go into detail about them. Just for an example, Desert Plants like the one shown below Figure 5 - 10 Square Mile Solar Farm can produce as much energy as the Hoover Dam. This is an incredible achievement that could become a large part of a nation's commercial electrical needs.[6]

Figure 5 - 10 Square Mile Solar Farm

6 "http://saferenvironment.wordpress.com/2009/02/02/solar-power-%E2%80%93-sustainable-green-energy-to-protect-our-economy-and-environment/"

Hydroelectric Energy

Hydroelectric Energy is yet another form of alternative energy. One-fifth of the world's electricity is generated by hydroelectric energy. A huge advantage of dams is that when electricity is in demand, the dam's gates open and the demand is supplied. It is a very convenient, efficient and inexpensive source of renewable energy. Almost 90% of the energy available can be converted into mechanical energy. 97% of renewable energy is generated by hydroelectric energy worldwide. This is a remarkable number when it comes to the amount of different technologies of renewable energy.

Figure 6 - Arial View of the Hoover Dam

The building of dam's can greatly affect people nearby. Because a dam needs a reservoir the river that a dam may be built on can alter the river an immense amount causing significant problems with animals. Figure 6 - Arial View of the Hoover Dam shows the reservoir created by the Hoover Dam. The construction of dams will require that river water be diverted to some other location which can have an effect on ecosystems that are reliant on that water. The reservoirs from dams typically hold back debris, nutrients and silt causing long-term environmental hazards. This will eventually make the dam either inoperable or will make future generations have to clean out the debris to keep proper functionality. It has been known to have catastrophic failures causing floods and other issues such as mud slides.[7]

[7] "Hydroelectric Power." *Renewable Energy,*. Alternative Energy. Web. 5 Feb. 2012. <http://www.altenergy.org/renewables/hydroelectric.html>.

Geothermal Energy

Heat from the core of the Earth can be harnessed and converted into electricity. There are different variations of geothermal energy that can be captured. "Some geothermal systems are formed when hot magma nears the surface (1,500 to 10,000 meters deep) directly heats groundwater."[8] These hot spots generate heat causing volcanos and other nature formed areas such as hot springs and geysers. Hot steam from these naturally occurring areas can be converted into mechanical energy and used to produce electricity. "Other geothermal systems are formed even when no magma is nearby as magma heats rocks which in turn heat deeply-circulating groundwater."[8] Water can be pumped to and from these hot rocks to heat up the water through convection and use the heated water to produce electricity.

Many difficulties arise through geothermal energy causing it to not be readily available at all times. The heat that is captured from geothermal areas need to be extremely hot to make electricity production a reality. Each geothermal area is unique to its area and each area needs to be very active. Within the country, the western United States has the most active regions; however there are other spots in the world that have greater active regions and would benefit more.[8]

Geothermal Energy is considered a renewable source of energy; but there have been instances in which the steam rising from the earth's core could not be naturally replaced due to the fact that it was extracted too quickly. At a site like this the steam was found not to be infinite causing the

[8] "Geothermal Energy." *Renewable Energy, Geothermal.* Alternative Energy. Web. 28 Jan. 2012. <http://www.altenergy.org/renewables/geothermal.html>.

site to have to shut down. Figure 7 - Geothermal Map of the United States shows the best areas to have a geothermal location. Currently the technology available for geothermal energy is nowhere near where it needs to be to take full advantage of this type of energy.[9]

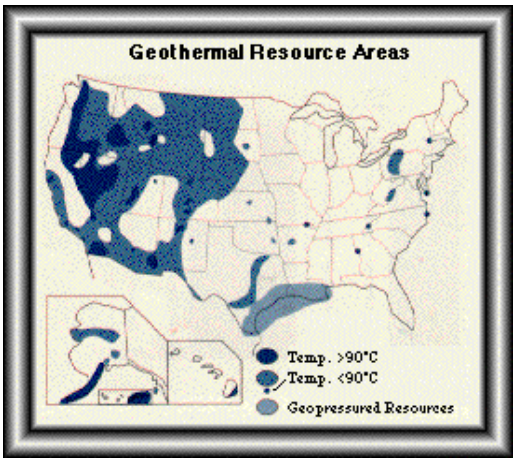

Figure 7 - Geothermal Map of the United States

Biomass Energy

Biomass Energy is the conversion from stored energy in organic matter from the process of photosynthesis. The existence of biomass comes from plants which are transferred to animals during the intake of these plants. The stored energy is taken from the animals waste through combustion. Combustion of the waste releases the stored carbon dioxide formed during photosynthesis. Biomass is second to hydroelectric in the production of electricity from renewable energy sources. The low cost of biomass energy enables it to become widely utilized and accounts for 15% of the world's total energy. This form of energy is also widely used in developing countries that cannot afford high costs prices for other forms of energy.

[9] "Geothermal Energy." *Renewable Energy, Geothermal.* Alternative Energy. Web. 28 Jan. 2012. <http://www.altenergy.org/renewables/geothermal.html>.

Biomass can be produced not only through animals waste, but combustion can occur through multiple materials such as timber, contaminated waste wood, urban sold waste and even tires. There are people that believe that the above materials can be used as a meaning of a biomass material. Because there is a very broad term of what exactly is biomass, the burning of some materials could prove to be harmful and not a source of clean energy. As it could be an economic and environmental benefit it is also a downfall that could ruin the environment with harmful pollutants from the burning of such materials. Biomass Energy, when performed correctly can become a great form of alternative energy and needs to be considered in the future as a way to produce electricity.[10]

Time will come when renewable energy will be the only method of energy generated. Because of this, the various types of renewable energy that are sustainable for future generations will need to become more efficient and cost effective. In order for renewable energy to become more efficient and cost effective, new technology will need to be developed annually to meet the increasing demands of the electricity needed.

[10] "Biomass Energy." *Renewable Energy,*. Alternative Energy. Web. 19 Jan. 2012. <http://www.altenergy.org/renewables/biomass.html>.

HISTORY

Ever since the invention of sails, mankind has been able to harness the power of wind energy to their benefit. Originally people used the power of wind for transportation purposes such as sailboats. This proved to be one of the most effective methods of travelling over bodies of water. As time progressed, man was able to do more with the power of wind. This came in the form of the windmill which was effective in grinding grain and pumping water to provide for communities. The first windmills were made in what is now Afghanistan, Iran, and Pakistan approximately during the ninth or as early as the seventh century[11]. These Panemone windmills were the first vertical axis wind turbines and although they were not as efficient as today's standards, they were some of the most reproduced and patented designs used for wind turbines.

The first windmill used for the production of electricity was built in Scotland in July 1887 by Prof James Blyth. This windmill was 33 feet high with cloth sails and was used to charge accumulators to power the lighting in Blyth's cottage, thus making it the first house in the world to have its electricity supplied by wind power. Blyth offered the surplus electricity to the people of Maykirk for lighting the main street; however, they turned down the offer as they thought electricity was "the work of the devil." Although he later built a wind machine to supply emergency power to the local buildings, the invention never really caught on as the technology was not considered to be economically viable.

[11] "Wind Power Overview" EM Ages. 22 May 2010 < windturbineins.com >.

Across the Atlantic, in Cleveland, Ohio a larger and heavily engineered machine was designed and constructed in 1887-1888 by Charles F. Brush. This was built by his engineering company at his home and operated from 1886 until 1900. The Brush wind turbine had a rotor 56 feet in diameter and was mounted on a 60 foot tower. Although large by today's standards, the machine was only rated at 12 kW; it turned relatively slowly since it had 144 blades. The connected dynamo was used either to charge a bank of batteries or to operate up to 100 incandescent light bulbs, three arc lamps, and various motors in Brush's laboratory. The machine fell into disuse after 1900 when electricity became available from Cleveland's central stations, and was abandoned in 1908.

Throughout the twentieth century, wind power made great strides in providing self-sufficient electricity in countries that acknowledged the economic benefits of wind energy. In the first quarter of the twentieth century, Denmark shined as the leading country in producing wind-driven electric generators. By 1908 there were 72 wind turbines that ranged from 5 to 25 kilowatts. In 1957 Johannes Juul installed a turbine similar to the ones used today with three blades and a horizontal axis facing upwind[12]. Then in 1978, the world's first multi-megawatt wind turbine was made capable of producing 2 megawatts of power. Several Danish manufacturers such as Kuriant, Vestas, Nordtank, and Bonus were able to provide a jump start to the modern wind power industry with their serial production of small turbines that could each produce around twenty to thirty kilowatts. With all of these accomplishments, Denmark was able to create quite a name for itself in the wind turbine producing community.

[12] "Wind Power Overview" EM Ages. 22 May 2010 < windturbineins.com >.

However, there were other places the made strides in the field of wind power aside from Denmark. For instance, the brothers Joe and Marcellus Jacobs launched a factory called Jacobs Wind in Minneapolis which created wind turbines to provide electrical power to farms and other remote areas which were too far away from big electric companies to effectively use their power. Jacobs Wind produced approximately 30,000 small wind turbines for people in these kinds of situations including areas in Africa and Antarctica. In 1931, a new kind of vertical axis wind turbine was invented which used aerofoils surrounding a tower such that the turbine could function from wind coming from any direction. During World War II, German U-boats used small wind turbines to recharge its submarine batteries.

In 1973, the oil-price crisis sparked an interest in people trying to find new alternative forms of fuel. This was great for the advancement of wind turbine technology. In the United States, NASA wind turbines were developed after careful research creating 13 different experimental wind turbines. They were able to pioneer many of the technologies used in making wind turbines today such as steel tube towers, variable-speed generators, composite blade materials, partial-span pitch control, as well as aerodynamic, structural, and acoustic engineering design capabilities. In the late 80's California offered tax rebates for anyone who used wind power which highly motivated locals to invest in using small scale wind turbines which could produce up to 1.8 kilowatts of power each. Also in the 80's all horizontal wind turbines were made to rotate clockwise as opposed to old mills which ran counter-clockwise.

By the time the twenty-first century arrived, wind power had already become a fairly well established form of producing energy. As the century began, fossil fuel prices were still relatively low; however there was still interest in wind power as people became concerned with energy security, global warming, and fossil fuel depletion. This led to the creation of commercial wind power which increased by 30 percent each year. However, in 2003 a large increase in oil prices frightened many people into supporting commercial wind power.

WIND TURBINE DESIGN

To put it simply wind energy is produced by wind blowing on blades, turning them, and producing power through the use of a turbine. However, it is much more complicated than that. In order to most efficiently harness the energy that is contained within wind power one must understand how wind works, how wind affects its surroundings, and how best to turn wind into energy.

Wind is the flow of gases on a large scale. Wind is created by differences in pressure where air flows from high to low pressure areas. Global wind is caused by both the uneven heating of air on Earth's surface and the rotation of Earth along its axis. Since dry land can heat up and cool down faster than the ocean, the difference in heat from the equator to the poles creates an atmospheric convection system which creates wind. Wind exists all around the world from the surface up to the stratosphere which can have wind speeds of over 99mph. Wind may be found in almost every crevice on the Earth, but that does not mean that wind turbines can be made everywhere on Earth. Wind can vary by location with varying strengths ranging from a gentle breeze to a gale force wind capable of demolishing buildings. This variability in wind intensity makes wind power less consistent in output as common fuel-fired power.

Global wind may be caused by changes in temperature and Earth's rotation, but the surface of the Earth can also have an effect on wind. The more obstacles in the way of wind, the more difficult it is for wind to flow. Obstacles on the Earth's surface such as buildings, hills, valleys, and bodies of water act as a roughness that creates shear in the wind. This wind shear is similar to friction

although only the air near the surface is affected. Wind is also affected by height and its velocity is proportional to how high the air is flowing. The higher up air flows, the less surface roughness can affect it. This explains why most wind turbines focus on having towers as tall as they can be in order to catch the fastest wind they could.

Wind energy is the kinetic energy caused by the motion of the air. The energy created by wind can be calculated using the formula $E = A * v * t * \rho * \frac{1}{2} * v^2$ where v is the wind velocity, ρ is the density of the air and A*v*t is the volume of the air passing through the area A during the time t.[13] This explains why the wind speed is so critical in the output of power from wind turbines. Also key in the production of electricity is the area through which the wind passes by. The power caused by wind can be found knowing that power is energy over time which leads to the equation $P = \frac{1}{2} A \rho v^3$. This explains why many wind turbines focus on having long blades and more surface area to catch the wind. Unfortunately not all of the energy flowing into turbines can be converted into useable power. While there is an input airflow to create power in the turbine, there is also a need for air to flow out of the turbine as well creating a loss potential electrical output power. According to Betz' Law there is a maximum amount of power that can be extracted from a wind turbine with only 59 percent of the total amount of theoretical wind power possible being capable of extraction.

As was previously discussed, the best way to turn wind energy into electrical power is to have a wind turbine. The wind turbines functioning today may seem like an obvious choice for

[13] Grogg, Kira S. "Harvesting the Wind: The Physics of Wind Turbines." Physics and Astronomy Department (2005). Carleton College. 13 April 2005.

performing this function, but what exactly makes wind turbines so effective? The short answer to this question is that wind turns blades on a wind turbine along its axis which in turn generates electricity from being rotated. Basically this is similar to a fan running in reverse since fans use electricity to generate wind and wind turbines use wind energy to generate electricity.

To go into more detail, there are two main types of turbines that exist. There are horizontal axis wind turbines (HAWT) which are the most common form of wind turbines used today and there are vertical axis wind turbines (VAWT), both of these are shown in Figure 8.

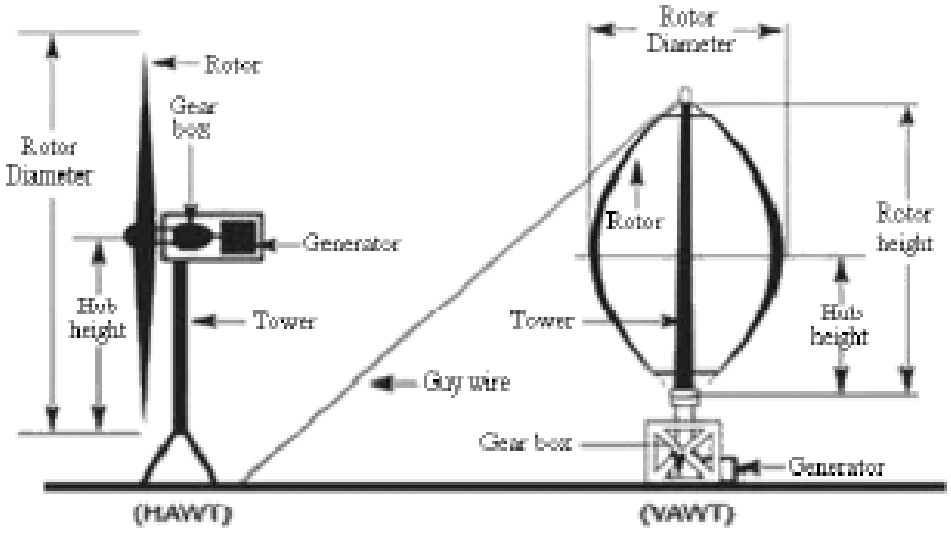

Figure 8: Horizontal Axis Wind Turbine (left), Vertical Axis Wind Turbine (right)

Wind turbines are made up of rotors which rotate due to the wind causing a generator to run. The rotors are supported by a tower and the generator is connected to the rotor's axis by a gearbox.

Choosing the correct kind of wind turbine to use and where to put it can prove to be one the most demanding tasks involved in producing power from wind. Since wind velocity is so crucial in

determining how much power a wind turbine can produce it is best to choose a location that has a relatively consistent supply of wind that has a minimum velocity for wind turbines to function which is approximately 5 to 6 meters per second.[14] In order to get an idea of what kind of wind speeds a location has, many wind turbine companies gather data directly from the candidate site first and create a wind speed distribution curve, similar to the one shown in Figure 9, in order to best analyze the data.

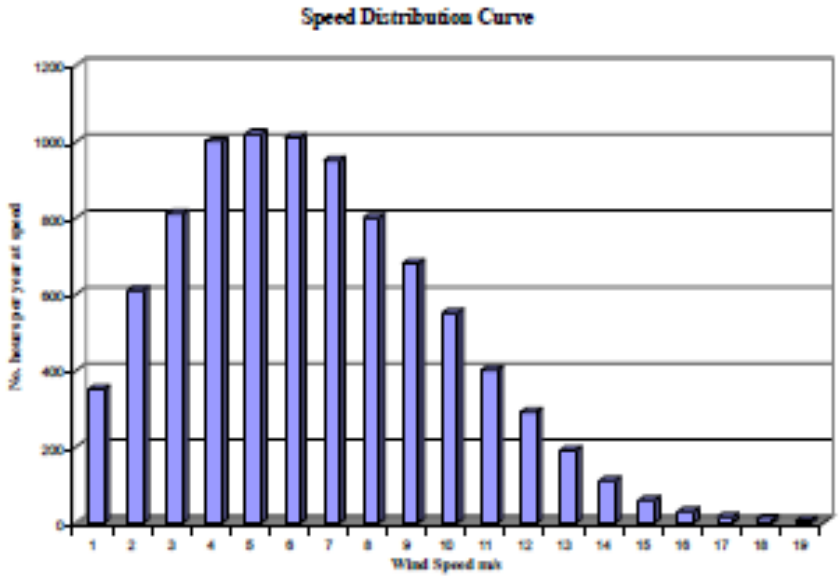

Figure 9: A Sample Speed Distribution Curve

When looking at the efficiency of a wind turbine it is very important to consider the types of rotor blades used. Most wind turbines used currently have three blades since it is relatively economical while still being rather symmetrical and balanced. Similar to airplane wings, wind turbines use rotors made of airfoils which focus on lift, perpendicular forces to the airflow, rather than drag,

[14] Grogg, Kira S. "Harvesting the Wind: The Physics of Wind Turbines." Physics and Astronomy Department (2005). Carleton College. 13 April 2005.

parallel forces. Lift works by having the edge of the airfoil angled slightly out of the direction of the wind. This causes the airflow on the upper part of the airfoil to move faster than the lower part creating a pressure difference which "lifts" the airfoil upward as Figure 10 depicts. The angle at which the airfoil is compared to the wind is called the angle of attack. As the angle of attack increase, the lift increases up to a certain point at which it decreases dramatically and the drag force increases sharply.

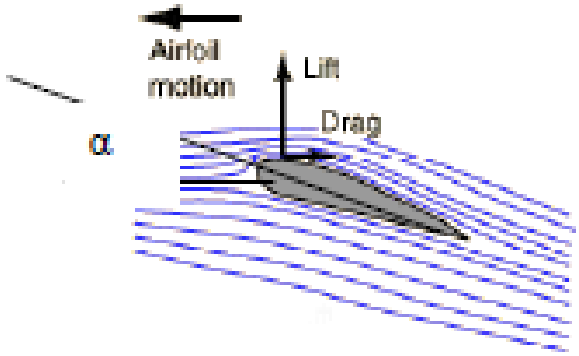

Figure 10: A Cross Section of an Airfoil and the Airflow around it

Another key factor in determining the effectiveness of a wind turbine is how the blades are shaped. Different shapes of blades can affect the lift and drag forces on the blades as wind flows over them. The thrust of a given section and the torque of the blades can be determined using information revealed in the blades' geometry. Using parameters such as length of blades, R and the desired tip speed ratio, λ, one can use a computer program to calculate the optimum blade shape for the ideal rotor. This does not mean that every rotor used today is perfect as most choose to make them with linear variations. However these ideal situations are not entirely consistent to actual circumstances since they do not account for turbulence, high winds, or misalignment of the rotor.

Blades have two different ways to control their positions in their sockets in order to maintain a constant speed despite fluctuating angles of attack due to inconsistent wind speed. Stall-controlled blades use a twist to create a drop in lift force as the wind speed becomes too high. This is called stall and at an angle of attack of around 10 to 16 degrees the wind begins to not flow smoothly until it reaches a full stall where it stops movement. The cut-out wind speeds (when the rotor shuts down) are in the range of 20-32 m/s, while the cut-in speed (to start a turbine) is about 5 m/s.[15] This design benefits from its lack reliance on electrical and mechanical controls, but it is more difficult to manufacture and design. The other form of controlling blades is called the pitch-controlled turbine. Pitch-controlled turbines rotate their blades to smaller angles of attack, to get less lift, as wind speed increases. At the cut-out wind speed the blades turn their edges into the wind creating an angle of attack of zero in order to eliminate lift and stop the rotor's motion. Unfortunately, the mechanical adjusting of the blade pitch occurs on a longer time scale than turbulent wind fluctuations, thus creating more power fluctuations. However, specially designed generators can correct for this problem.

[15] Grogg, Kira S. "Harvesting the Wind: The Physics of Wind Turbines." Physics and Astronomy Department (2005). Carleton College. 13 April 2005.

DIFFERENT TYPES OF WIND TURBINES

Advantages / Disadvantages

Wind is defined as the natural movement of the air, especially in the form of a current of air blowing from a particular direction. Being able to contain this natural phenomenon, wind can be essential into producing mechanical energy. Mechanical energy from wind turbines can be converted into electricity, enabling a user to power a device or much more. There is an array of vertical axis and horizontal axis wind turbines that can convert the kinetic energy from the wind into electricity for the human user. Along with the advantages of wind turbines, there are also disadvantages of using such technology.

Many modern wind turbines that can be visible seen from a far distance, are horizontal three bladed turbines used for commercial use. These turbines shown below in Figure 11 - Three Bladed Wind Turbine are very reliable and efficient; however, these turbines are very large and loud.[16] In past years, there has been much consideration to the vertical axis design, a much smaller design. These vertical axis turbines are more versatile then horizontal axis turbines because of the locations and applications that they can be used for.[17] However, with any device, an advantage typically means there is a disadvantage and both the horizontal and vertical axis turbines do not escape this realization.

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[16] "Wind Power on Land." *A Design and Technology Site*. Technology Student. Web. 04 Mar. 2012. <http://www.technologystudent.com/energy1/wind6.htm>.

[17] "Wind Turbine." *Wikipedia*. Wikimedia Foundation, 04 Jan. 2012. Web. 8 Feb. 2012. <http://en.wikipedia.org/wiki/Wind_turbine>.

Figure 11 - Three Bladed Wind Turbine

Advantages of wind energy, to name a few, include: no pollutants, small land area, alternative energy and multiple sizes. Converting wind to energy while simultaneously producing no pollutants is a huge advantage considering recent troubles with the environment. This is arguably one of the most important advantages when discussing wind turbines and why it will be one of the better alternative forms of energy in coming years. Once the initial cost of purchasing a wind turbine is complete, the energy generated can be sold and used to pay back the initial cost. This in itself can be very beneficial in saving money in the future. It can also be seen as an investment opportunity by selling the energy to make a profit. [18]

Third world countries can use the modern technology of wind turbines to help develop their country in a relatively cheap way. By efficiently utilizing the placement of wind turbines, third world countries can produce energy, letting them focus on other important means. Although

[18] "Wind Energy." *Renewable Energy,*. Alternative Energy. Web. 18 Feb. 2012. <http://www.altenergy.org/renewables/wind.html>.

most wind turbines are very tall the amount of area taken up on the ground is very slim. Long horizontal turbines can be placed on farms while simultaneously allowing farmers to keep their farmland with little interruption. Figure 12 - Scale of Horizontal Axis Wind Turbine shows just how tall a horizontal axis wind turbine is. Vertical Axis turbines can be used in a multitude of locations, such as: the sides of houses, tops of buildings, and many other not apparent places. The two types of turbines let users distinguish between which design is the best design for their particular use. New advances in the design of turbines are regularly being produced, which allows the user to be able to choose from a vast range of sizes and designs.[18]

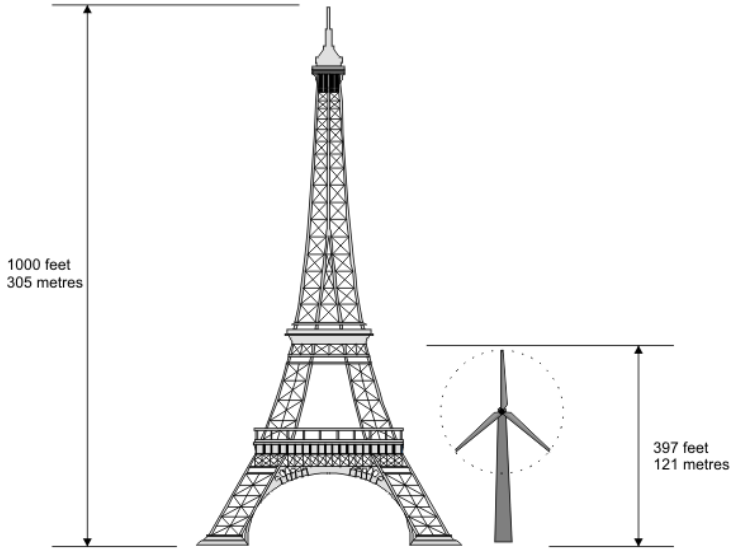

Figure 12 - Scale of Horizontal Axis Wind Turbine

Another advantage of turbines is the use of going off the grid. A household can create their own supply of energy to be used without paying electrical companies to get energy. The idea of going off the grid can be useful to a country as a whole. If anything ever happened and energy from

conventional methods disappeared, this could be the easiest and most reliable way to get and store energy.

Although there are many advantages to wind energy, there are also disadvantages that need to be understood. Disadvantages of wind energy include: not a constant supply, community scenery along with noise, and household capacity. Because wind is not constant, it often varies between nothing and too much. Wind is not always readily available causing times when wind energy is not being produced. This is typically bad because there then needs to be alternative ways to produce energy, which costs more money. Storms are a typical example of when winds may exceed the maximum force that a wind turbine can withstand. This in itself can cause turbine failure which ultimately causes more money to fix or replace.[19]

The countryside is often viewed as a place that should be untouched and left to its natural surroundings. This can be achieved by not building wind turbines on that type of land; however, with no turbines built, no energy is being produced through this method causing alternative methods to create energy a necessity. Building wind turbines on the countryside often industrializes the look and feel of the nearby surroundings. This typically ugly look sways people from wanting these structures on their lands.[20]

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[19] "Disadvantages of Wind Energy." - *Don't Get Blown Away by All The Positives of Wind*. SBI. Web. 26 Feb. 2012. <http://www.alternative-energy-resources.net/disadvantages-of-wind-energy.html>.

[20] "Solar Panel Wind Turbine.com." *Wind Energy Disadvantages*. Web. 9 Feb. 2012. <http://www.solarpanelwindturbine.com/wind-turbine-and-wind-energy/wind-energy-disadvantages/>.

One of the advantages mentioned earlier was that wind turbines do not create pollutants. When in use, this statement is true; however, when these devices are being built, it is often the case that through the manufacturing process, pollutants are produced. According to Anguil Environment Systems, an experienced wind turbine manufacturer, "The potential to emit Volatile Organic Compounds (VOCs) and Hazardous Air Pollutants (HAPs) such as Xylene, Ethyl Benzene, Styrene and Phenol into the atmosphere is a major concern for communities and regulatory agencies."[21] Companies are continuously trying to improve the manufacture process to truly keep wind turbines a clean source of energy.

So far, advantages and disadvantages have been shown for wind turbines in general, however because there are a vast array of wind turbines, advantages and disadvantages will be considered for the specific wind turbines. Vertical and Horizontal Axis turbines are the two main types and will be analyzed in more depth.

Horizontal Axis turbines are the most common and easily noticeable type of wind turbine. The components involved are all stationed on the top of vertical tower. The horizontal axis is able to rotate 360 degrees enabling production with whatever way the wind wants to travel at that moment. The wind hits the blades of the turbine causing a motor to automatically turn toward the incoming wind. The components inside the turbine cause the generator to produce electricity

[21] "Wind Turbine Manufacturer Implements Clean Air Initiative." *Anguil*. Wind Turbine Manufacture. Web. 04 Apr. 2012. <http://www.anguil.com/case-studies/composites-fiberglass-carbon-fiber/wind-turbine-manufacturer-implements-clean-air-initiative.aspx>.

which is then sent to the power grid. Because the wind can at times be very strong from storms, the turbine has a built in break enabling it to slow the rotation of the blades to not cause damage. The components, being at the top of the vertical shaft must also have a center of gravity through that axis allowing stability.

Horizontal Axis turbines are very difficult to transport and install. Large trucks accompanied by multiple police officers are needed in the transportation of the wind turbine blades because of the oversized load. Installation requires multiple cranes to accurately piece together the turbines at the high altitude. The maintenance is very difficult, needing highly trained personal to fix damaged or failed parts. [22]

Vertical Axis turbines are not as common as horizontal axis but can be just as effective. Most if not all components can be placed at the bottom near the ground causing the center of gravity to be at a low position. Because the blades are positioned on the vertical axis, the ability of 360 degrees movement still exists. This is important because the turbine can produce energy with whatever direction the wind is blowing. The amounts of transportation and installation costs are much less than horizontal axis. They are also easier to maintain and service should something go wrong. Because blades are rotating on the vertical axis the constant spinning, half of the time, causes drag on the turbine blades face is in the opposite direction of the wind which lowers the efficiency of the device. Higher wind velocties are often needed for the turbine to start turning

[22] "Advantages & Disadvantages Of Wind Energy." *Natural & Renewable Energy Sources*. Web. 28 Jan. 2012. <http://www.clean-energy-ideas.com/articles/advantages_and_disadvantages_of_wind_energy.html>.

which is not always readily available so, initial energy may be needed to start the turning of the turbine.[23]

Cost

As mentioned in the advantages and disadvantages section above, it is known that the wind is not a reliable source which can greatly affect the overall cost of buying a wind turbine. There are different cost analyses that must be analyzed for the specific environment before determining if buying a wind turbine is a viable option. Because different environments change dramatically it is important to analyze the average wind speeds. First and foremost, if there is little to no wind in the area that a wind turbine is going to be installed, a different form of alternative energy would be a more viable option.

Cost analysis must be done on the following: connection to the grid, any associated permits, shipping, installation, and tax incentives or refunds. Many states allow households to connect to the grid for free and actually receive a tax refund for energy sold to the utility company. Checking the local town's rules and regulations for wind energy will protect the user from any fees that may be charged for having a wind turbine. There are many state incentives for clean energy. Looking into these incentives could help extremely with cost benefits. [24]

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[23] "PDFCLOUD.NET." *Vertical Axis Wind Turbines*. Conserve Energy. Web. 1 Mar. 2012. <http://www.conserve-energy-future.com/VerticalAxisWindTurbines.php>.

[24] "Babeled." Cost Analysis of Wind Turbines to Power Your Home. Web. 25 Jan. 2012. <http://www.babeled.com/2010/02/04/cost-analysis-of-wind-turbines-to-power-your-home/>.

State incentives can be very useful in the purchasing of a wind turbine. Performing specific research beforehand can save the buyer money. There are currently fourteen states in the United States that promote the idea of clean energy refunds. These fourteen states include Arizona, California, Connecticut, Illinois, Massachusetts, Minnesota, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Washington, and Wisconsin. Sales taxes are exempt in these fourteen states, and many other states have tax incentives for properties with wind energy.[25]

Figure 13 - Windspire Vertical Axis Turbine

In order to get an understanding of the cost that it would take to use wind energy, the Windspire vertical-axis wind turbine shown above in Figure 13 - Windspire Vertical Axis Turbine will be analyzed. This specific wind turbine is a good example of typical costs that would be involved with vertical axis turbines. The Windspire has an initial cost of $4,995, which is much less than the average horizontal wind turbines. The Windspire produces on average 166kW/hr per month with an optimization speed of 11 mph. A 30% federal tax refund is available for the Windspire

[25] "Menu." *State Incentives for Wind Energy*. Wind Energy. Web. 7 Feb. 2012. <http://energybible.com/wind_energy/state_incentives.html>.

with local rebates of up to $4,800 are also available depending on location.[26] A list is available of the cost and amount of energy produced for multiple types of horizontal and vertical axis wind turbines in Appendix A.

Efficiency

No matter what type of wind turbine is being analyzed, there is a limiting factor of how much wind can theoretically be converted into energy. That percentage of efficiency of a wind turbine is 59.3%. This is called the Betz Limit. Consider all the energy from the wind being converted into energy, if this were the case, there would be no wind coming out of the wind turbine. If the wind speed out of the turbine were zero at the exit, no new wind would be able to enter. Wind Turbines need some energy at the leaving point of the turbine to keep the full system cycle in movement creating energy. In order to get a perfectly efficient wind turbine that is at 59.3% efficiency there are many assumptions that need to be considered. These assumptions are considering an ideal world with constant horizontal wind flow, no drag from the rotor or blades, the rotor produces no heat transfer, and a massless rotor.

These assumptions can be considered and an equation using conservation of mass can be analyzed to get the efficiency of Betz Limit. However, the reader may be considering that the assumptions made in the derivation of Betz Limit, are unrealistic. In a realistic case, the true efficiency of a wind turbine will be much less than the limit mentioned above. Considering the

[26] "The Windspire." *Windspire Wind Turbines by Windspire Energy*. Windspire. Web. 17 Mar. 2012. <http://www.windspireenergy.com/windspire/>.

efficiencies of the components within the turbine such as the generator and blades, the overall efficiency of a wind turbine is likely to be around 20% to 35%.[27]

The efficiency of a wind turbine may not be the overall deciding factor for the user to buy such a device. After all, the user or buyer cares most about the amount of electricity output per cost of the device. Cost efficiency is most likely the governing factor in the decision of a wind turbine. Considering the factors mentioned earlier in the Cost section, it can be determined how cost-efficient a wind turbine will be.[28]

Locations

As mentioned earlier, the placement and location of a wind turbine can be a huge factor on how effective it may be. There are many locations in the United States that an installation of a wind turbine would not be a good idea. However, there are also many places that are considered to be a smart location for an installation of a wind turbine. Figure 14 - Electricity Production in the United States below shows a map of the United States with the electricity production of small wind turbines. Analyzing Figure 14 - Electricity Production in the United States, the reader can see where the most output of electricity comes from. These values may change for a specific location. Consider an area in the white section of the figure, it is possible that a specific spot may produce wind at a constant rate and generate electricity at a high efficiency. Checking average wind

[27] "Betz' Law." *Wikipedia*. Wikimedia Foundation, 29 Mar. 2012. Web. 1 Apr. 2012. <http://en.wikipedia.org/wiki/Betz'_law>.

[28] "Wind Turbines and the Wind Energy - How Much Power Is in the Wind?" *Science and Technology Education from Flying Turtle Exploring*. FT- Exploring. Web. 04 Apr. 2012. <http://www.ftexploring.com/energy/wind-enrgy.html>.

speeds for that specific spot is generally the best way to determine if a wind turbine is right for an area.

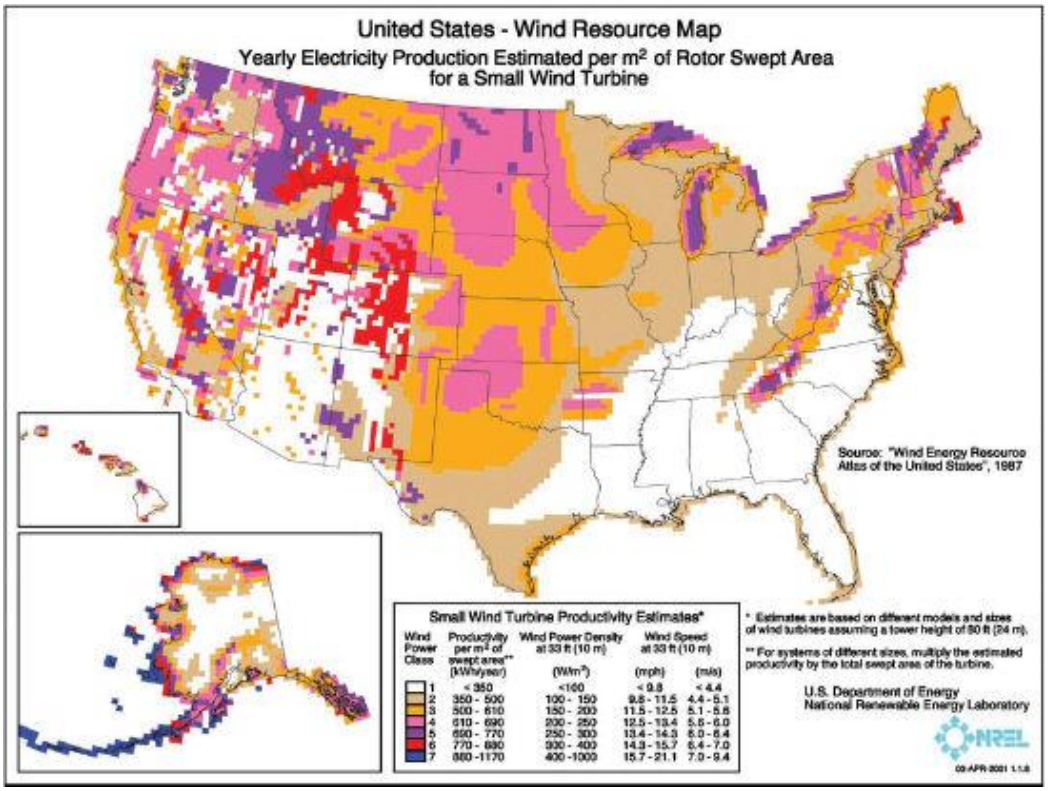

Figure 14 - Electricity Production in the United States

The higher the wind turbine is, the better the efficiency will be. Eliminating obstacles in the way of the turbine will also improve generation of electricity. Figure 15 - Height vs. Efficiency below shows the increase of wind power efficiency relative to the height of the turbine. Figure 16 - Effects of Obstacles shows how certain obstructions in a typical environment may affect the efficiency of generating wind energy.[29]

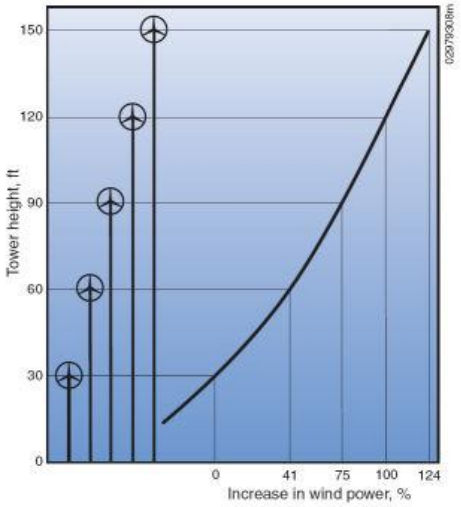

Figure 15 - Height vs. Efficiency

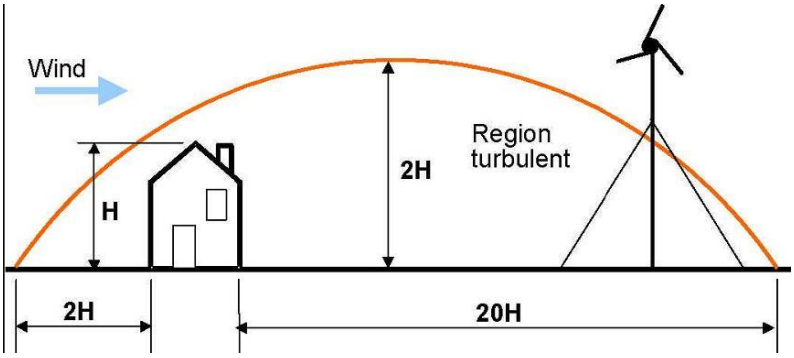

Figure 16 - Effects of Obstacles

[29] "Map of Best Locations for Wind Power | Wind Power | Solar Power |." *WindSolarEnergy.ORG*. Web. 26 Feb. 2012. <http://www.windsolarenergy.org/map-of-best-locations-for-wind-power.htm>.

SOCIETAL IMPACT

The most important aspect of an alternative energy source is how it affects society. Efficiency and large scale environmental effects play a major role as well but if the energy source is not accepted by society, than it will fail to grow. Societal impacts are extremely important and at the same time very controversial. Whether or not the benefits outweigh the consequences are often debated between governments. Compared to all other forms of alternative energy, wind energy seems to have the least amount of consequences to the environment and society. Wind energy has been coined as the fastest growing form of alternative energy in the world. There are many different reasons why wind energy is beginning to take off, especially in the US. The first way in which wind energy benefits society is how it can affect an economy. The economy is presently a major matter of discussion and wind energy has the potential to continue to improve the devastated economy. If wind energy continues to grow like it has, it will continue to provide sound investment opportunities for citizens and tens of thousands of jobs nationwide therefore improving the economy.

E c o n o m y

The most enticing attribute to wind power is that it is free. It requires no harvesting or mining. Once the initial costs have been paid out and costs accounted for maintenance, wind power pays for itself. People have begun to realize this and economies all over the world are beginning to improve. Wind energy, while being environmentally friendly, requires many fields of expertise to come together in order to work. The three phase system, which will be explained later, required to produce a fully functioning wind turbine has the ability to create thousands of jobs nationwide. This is especially true for rural communities. Wind turbines and wind farms require many square miles of land. Rural communities rich with farmland are beginning to take advantage of what wind energy is able to provide to their community. Wind projects stimulate development, manufacturing, and maintenance sectors from all over. Rural communities can thrive off this kind of economic growth. Wind energy can do even more than stimulate a community's economy but can be very beneficial for the individuals as well. Wind energy keeps local dollars more local instead of going to large electrical utilities. It also provides financial investment opportunities as well. Between the economy improving, jobs being created, and investment opportunities, it becomes clear how wind energy can be economically beneficial.[30]

Risks

No matter what kind of financial investment is being examined, there is always a certain amount of risk that is associated with an investment. These risks are accompanied by different levels of

[30] "Know Your Economics." n.d. Windustry. March 2012 <http://www.windustry.org/wind-basics/learn-about-wind-energy/wind-basics-know-your-economics/know-your-economics>.

reward. A financial investment provides a greater amount of return for taking a larger risk. This idea of Risk vs. Reward hold true for wind energy. There are three different ways to invest in wind energy and all three have different Risk vs. Reward relationships. Figure 17 portrays the three different investment types and what is involved with each type.

Figure 17 - Risk vs. Reward[31]

The financial opportunity that carries the least amount of risk is when a land owner leases his/her land to a third party. The third party provides the capital for the wind turbines and is in charge of developing, construction, and operation and maintenance of the turbines. The land owner will receive payment for the use of his/her land. This investment has a low risk factor because the investor is only risking his/her land and no capital. The land owner will not be able to use the portion of land that houses the wind turbines but the small payments paid by the third party

[31] "Know Your Economics." n.d. Windustry. March 2012 <http://www.windustry.org/wind-basics/learn-about-wind-energy/wind-basics-know-your-economics/know-your-economics>.

typically make up for any unusable land that is normally used as farm land. The investor is not risking any money that he/she could possibly lose towards the wind turbine. The reward factor for this investment is quite low since the risk is low. The land owner will only receive payments for the use of his/her land and reap no other benefits that the wind turbines may be able to offer. Because wind turbines do not significantly affect crop growth, the investor only makes small profits from the third party and does not receive any electricity generated from the wind turbines unless it is part of the agreement between the investor and third party.[32]

The second way to invest in wind power carries an intermediate risk. This is a cooperative investment that requires multiple parties to come together and pool their money. By investing with multiple people, the costs of owning wind turbines and responsibilities, including construction and maintenance, are divided between everyone making it less expensive for the individual. There is an intermediate risk carried with this type of investment because each individual is jeopardizing a portion of their money but is not assuming all of the financial responsibility. If something were to go wrong with the turbine then the amount of financial damage experienced by each individual would be reduced by the amount of people involved in the investment. The benefits of wind power will be divided similarly between the investing partners. Tax benefits and other incentives along with the electricity generated from the shared turbine would be equally divided or distributed according to the agreed upon joint contract.[33]

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[32] "Know Your Economics." n.d. Windustry. March 2012 <http://www.windustry.org/wind-basics/learn-about-wind-energy/wind-basics-know-your-economics/know-your-economics>.

[33] "Know Your Economics." n.d. Windustry. March 2012 <http://www.windustry.org/wind-basics/learn-about-wind-energy/wind-basics-know-your-economics/know-your-economics>.

The highest risk investment in wind power is investing individually. By investing individually, the investor solely assumes all of the responsibilities and costs associated with wind power. This includes the cost of developing, manufacturing, constructing and maintaining the project. If something were to go wrong then the only person who would suffer losses would be the initial investor. The major benefit to this type of investment is that the investor will acquire all of the profits provided by the wind turbine. Large corporations are more likely to invest in wind power using this method because they are able to withstand a large loss if a project fails. This type of investment is rarely used by farmers or other low paying occupations due to such high risks and costs. The lease and joint investments are typically used by the farming populations and those who cannot afford to suffer large losses.[34]

Costs

Unless an investor is leasing his/her own land to a separate wind power party, the most important part to an investment is the cost of the project. Costs involved in a wind power project are the development, maintenance, repair, metering equipment, fees, and consulting services if they are needed, and the turbine itself. Knowing these costs before entering an investment is vital to the investor's success. Often times consulting firms are hired to perform feasibility studies to help estimate all of these costs before the investment is made. Many projects fail half way through the projects lifespan because funds run out. Like any investment, there is a lot that goes into wind

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[34] "Know Your Economics." n.d. Windustry. March 2012 <http://www.windustry.org/wind-basics/learn-about-wind-energy/wind-basics-know-your-economics/know-your-economics>.

power and many factors must be factored in if the project is going to be profitable for the investor.[35]

Because wind power is a clean and renewable power source, federal and states government are now offering investors with incentives for being involved in wind power. The U.S. Department of Agriculture offers several types of grants for eligible wind power projects to help with high costs. The Clean Renewable Energy Bond (CREB) program is a newer federal incentive. CREBs are tax credit bonds with interest-free finance rates available to utilities and electric companies for wind power projects. The federal government currently offers 1.9 cent/kWh tax credit for energy generated by wind turbines. Another example of incentives offered to wind energy investors is reduced or eliminated sales tax on their equipment. Low interest loans are also offered. Although the federal government has not fully committed itself to wind energy and therefore do not offer many incentives for owners of wind energy systems, state governments vary in this area. Many states around the US have very high renewable energy goals and reward owners of renewable energy systems for helping them achieve its goal. Refer to Table 1 and Table 2 for a list of federal incentives and state incentives currently offered:

Federal Incentives for Wind Energy Systems	
Federal Production Tax Credit	The Wind Energy Production Tax Credit (PTC) is a tax credit based on the production of power generated from wind

[35] "Know Your Economics." n.d. Windustry. March 2012 <http://www.windustry.org/wind-basics/learn-about-wind-energy/wind-basics-know-your-economics/know-your-economics>.

	energy. The PTC provides 1.9 cents per kWh produced during the first 10 years of operation. The credit is adjusted for inflation annually.
Public Utilities Regulatory Policy Act (PURPA)	This law coincides with the National Energy Act of 1978. The law states that the utilities must purchase electricity from non-utility generators or renewable power producers that can produce electricity at a lower cost than that what it would cost for the utility to produce the power. Utilities often purchase electricity from wind energy plants due to the large difference in production costs. As fossil fuel prices continue to increase, PURPA will become more and more valuable to renewable energy facility owners.
Clean Renewable Energy Bonds (CREBs)	These tax credit bonds benefit the bondholder by providing them with a tax credit that they can use against their federal income tax. CREBs have an interest free finance rate. The bondholder may transfer the tax credit to another party or hold onto unused credits for future use for up to three years.
The New Markets Tax Credit Program	By making equity investments in certain Community Development Entities (CDEs) this program provides a credit against federal income tax. The CDE may then invest in the renewable energy project owned by the investor therefore

	reducing costs.

Table 1- Federal Incentive for Wind Power[36]

State Incentives for Wind Energy Systems	
Sales Tax	Fourteen states currently eliminate the sales tax on wind energy equipment. There are also states that do not completely eliminate the tax but have similar sales tax reductions for wind energy equipment.
Investment Tax Credits	Only several states including HI, MA, MO, NC, OR, and UT provide this incentive. The incentive provides anyone with certain tax benefits that vary by state for investing in renewable energy. The incentives differ frequently but even an investor who leases land will be compensated for that investment.
Property Tax Reduction	This incentive helps lower the property tax burden of owning a wind energy facility. This tax is much higher than the similar tax provided to those who own a fossil fuel energy facility due to the amount of land necessary for wind energy production. Many sates provide this incentive. MI state governments provide tax reduction that lower costs by 1.0

[36] "Wind Energy Incentives ." n.d. Energy Bible. March 2012 <http://energybible.com/wind_energy/federal_incentives.html>.

	cent per kWh.
Accelerated Depreciation	The modified accelerated cost recovery system (MACRS) states that wind property has a depreciation life of five years. This depreciation lifetime is much shorter than the fifteen to twenty years given to non-renewable energy facilities. This short depreciation life results in beneficial taxes in the project's early years. The value of a dollar is essentially worth more after taxes today than later on in the life of the wind facility.
Direct Production	The direct production incentive is similar to production tax credits but provides direct cash income. The Renewable Energy Production Incentive (REPI) provides 1.5 cents per kWh to wind power facilities owned by non-profit organizations.
Direct Investment	These grants allow for state money to be used to conduct wind energy assessments and feasibility studies for potential wind energy investors. Potential wind energy investors must apply to receive these state funded grants.
Government Subsidized Loans	Wind energy owners typically have higher debt interest rates by one to two percent. Some states offer subsidized loans with lower interest rates for wind energy facility owners.

	These lower interest rates reduce loan payments and initial project costs. A few states like MN have federal government subsidized loans even though no subsidized loan program exists yet at the federal government level.
Net Metering	This system guarantees a market for the power produced by a wind energy facility. By being accepted into this program, wind energy facility owners are permitted to use a reversible meter. When the turbine produces less energy than what is being used on site then the wind turbine owner pays the utility company for the additional required electricity at the standard retail costs. When the wind power plant generates more electricity than what it requires, the utility is obligated to buy the additional electricity generated from the wind facility. The price at which the utility purchases the extra electricity varies by state. Some states do not allow net metering above a certain size of wind facility.
Site Prospecting, Review and Permitting	Certain state programs and some at the federal government levels have been created to conduct site assessments, evaluate transmission issues, study nearby bird populations, settle zoning issues, and aid with the permitting process. These are only some of the requirements that must be met

	before building a wind energy facility and these programs help lessen the burden. These programs must be applied for and have very strict guidelines.
Renewable Portfolio Standard (RPS)	These standards change from state to state but the general standard states that retail energy providers must provide a certain percentage of renewable power from certain renewable sources for a given time. Contracts can be made between a wind energy plant and a utility guaranteeing that the utility must provide customers with a certain percentage of renewable energy from that wind energy plants. An RPS works in sync with credit trading so wind energy suppliers sell credits for extra renewable power they generate.
Renewable Setasides	Certain states, CA for example, provide 0.7 percent surcharge on electric bills to support renewables during the four year transition to a competitive market. CA is expected to set a side seventy million dollars for wind energy alone.
Auctioned Contracts	Some electric utilities provide renewable energy by issuing request for proposals (RFPs). Wind turbine owners bid on these RFPs guaranteeing to generate a certain amount of electricity for the utility to provide under the specification of the RFP and contract price. These RFPs puts owners and

	utilities under contract to provide for each other.
Green Marketing/Pricing	This is a voluntary program in which utility customers can pay a premium to purchase only green power, power produced from renewable energy sources, instead of a mix or just power produced from a non-renewable energy source. This program creates a demand for renewable energy sources like wind energy facilities. Response to this program has been limited but is expected to increase once people begin to learn the advantages of renewable energy. The premium for this program changes from state to state.
State Mandates	These mandates differ from state to state. Certain states require power companies to purchase a certain amount of their generation from renewable sources for storing unwanted matter such as nuclear waste on site

Table 2 - State Incentives for Wind Power[37]

As it can be seen state governments are much more involved in the push for renewable energy sources. It is clear how beneficial wind power can be to the United States economy. As of right now however, renewable energy is not a high priority to the federal government. Wind energy has the potential to be among the largest source of manufacturing jobs worldwide during the 21st century. The federal government needs to make a long term policy to using more renewable

[37] "Wind Energy Incentives ." n.d. Energy Bible. March 2012 <http://energybible.com/wind_energy/state_incentives.html>.

energy. Nonrenewable energy will continue to pollute the atmosphere until this occurs. Once the US federal government realizes how beneficial renewable power source like wind power can be, the economy may start to turn around and the country may return to the top of the world economy

Benefits

The economic rewards associated with wind power falls into three categories: the electricity one does not have to pay for, revenue received for energy production, and state and federal incentives. Depending on the size of an investors wind power project, he/she may not be able to benefit from all of the rewards. Small turbines often do not produce more power than needed to power a house so there would be no revenue from electricity sales and no federal or state tax benefits due to this. Producing enough electricity to power a home may be enough to please the investor however, making it a sound investment.

Larger wind farm-sized turbines often produce enough electricity to supply power on site and then any other electricity can be fed into the grid. This system is called net metering and when any excess power from a wind turbine reaches the grid, the investor's meter will run backwards. At the end of a billing period, the electrical companies will pay the investor the difference if the wind turbine has provided more power to the grid than what it used on site.

There is also what is called renewable-energy credits. Due to the increased awareness of renewable energy, many states now required power companies to meet a renewable energy quota. This means that in order for the state to allow the power companies to continue business, the power companies must purchase a certain amount of their electricity from renewable sources. Under this

green credit program wind turbine owners receive credits for each megawatt-hour of wind energy produced per year. These credits can then be sold to the power companies looking to meet their state or federal renewable energy quota for the year. The price of the credits vary considering that the power companies need them in order to stay in business so the wind turbine owners can make hefty profits off of these credits.

The tax credits for wind turbines can be quite beneficial depending on where the turbines are located. The federal government of 1.9 cent/kWh applies to everyone but local state governments have their own set of tax incentives for setting up green renewable energy systems.

J o b s

One of the most appealing factors of wind turbines is that they bring economic development to communities that host them. Since turbines are relatively scarce around the world compared to other energy resources such as coal power plants, they create a demand for jobs. Wind turbines are typically large in stature and it makes sense that it would take a lot of people to create a functioning wind turbine. A wind turbine generally goes through three phases from the time that the idea is conceived to operating. These three phases are the research and development phase, the manufacturing phase, and the maintenance and operational phase. It may take years before completing all three tasks and hundreds of people depending on the size of the project. With wind power becoming better known around the country and people interested in investing in it, more and more people are being needed in the wind power industry. Refer to Table 3 for an idea of what kinds of jobs are associated with each phase of wind turbine lifespan.

Development Phase	Manufacturing Phase	Operational Phase
Project Developers	Construction Positions	Project Managers
Field Engineers	Transportation Managers	Project Coordinators
Environmental Consultants	Contract Managers	Production Managers
Legal Support	Project Control Managers	Wind Turbine Technicians
Document Control	QA/QC Technicians	Wind Turbine Maintenance
Administrative Support	Safety Technicians	Office Support

Table 3 - Wind Energy Project Phases[38]

These are only some of the jobs stimulated by wind power. Table 3Figure 3 is placed in order of importance. If something goes wrong during the development phase then the project is in danger of not even continuing on into the manufacturing phase. Each phase is dependent on each other in order for the life span of a wind turbine to be profitable for the owner. Figure 18 displays the typical supply chain for a wind turbine.

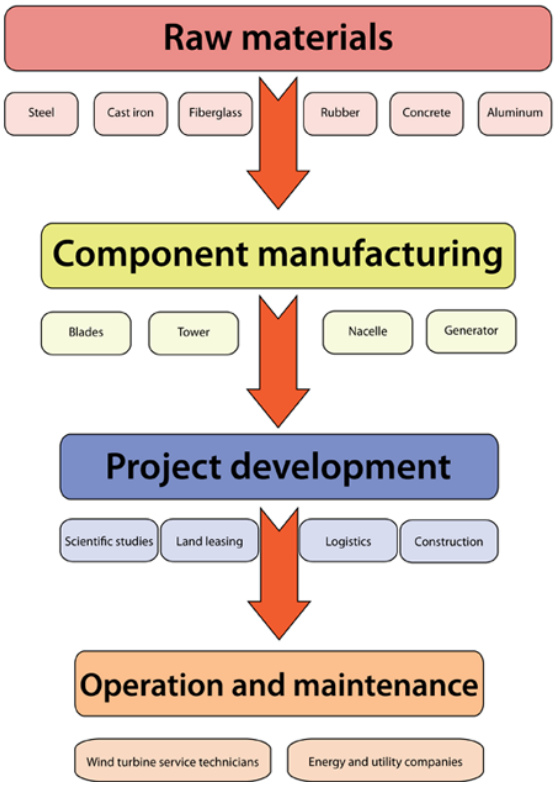

Figure 18 - Wind Power Supply Chain

[38] n.d. Wind Energy Jobs. March 2012 <http://www.windenergyjobsinfo.com/>.

Figure 18 is a little different than Table 3. Raw materials typically fall under the manufacturing phases because it is the manufacturer's job to make sure that all of the materials arrive on time and are of the right specifications. The manufacturing and development phases are sometimes referred to as the same phases. In order to make sure that the project goes smoothly the manufactures and developers work very close to each other to ensure that everyone is on the same page. If the developer specifies something that the manufacture misses than the project may be in danger. Workers involved in the operation and maintenance field are brought up to speed during construction since the developers and manufactures are not so much involved in the project once the turbine is built. It will be up to the operation and maintenance worker to keep the turbine running smoothly.[39]

Research and Development Phase

The research and development stage is the most important phase in the life of a wind turbine. This stage is where all the planning takes place. A major part of the period is how the financials will work out and if the project will be a viable investment. Another part included in this phase is all of the legal documents must be in order. Wind turbines are large pieces of equipment and there are many permits and licenses that need to be accounted for. Because so much takes place during this phase, it takes the most time as well.[40]

The initial step in this multi-year process is the site selection. There are many factors that are taken into consideration when choosing an ideal turbine site. The land must be able to support a turbine

[39] James, Hamilton and Drew Liming. "Careers in Wind Energy." n.d. Burea of Labor Statistics. February 2012 <http://www.bls.gov/green/wind_energy/>.

[40] "How Wind Power Works." n.d. How Stuff Works. March 2012 <http://science.howstuffworks.com/environmental/green-science/wind-power8.htm>.

that is often times in excess of 1000 tons, the site must be easily accessible for delivery of the large turbine components, and the site must experience wind speeds without excess variability to make it feasible for wind turbines. There are also many environmental concerns that must be taken into consideration. Local bird populations are often a concern as well as other ecosystems. Just any other large structure they can kill birds if located in migratory bird flyways. Along with the local animal populations that will be affected, the local communities must support the wind project. Wind turbines are often large structures that may not be appealing to the eye. They also make noise and people are often concerned about how they affect property values. Many property-owners adjacent to land hosting wind turbines believe that the turbines negatively affect their property value. Recent studies have shown however, that wind turbines and wind farms are actually increasing property values. They open new investment opportunities and show potential homebuyers that the community is well knit and believe in the betterment of earth's environment. If local communities are not on board with the project, lots of complaints could be made and jeopardize the project. Developers must inform the community how beneficial the project could be for them.[41]

Once the right site has been chosen and all necessary permits obtained and financing secured, the developers work closely with the manufactures to get the right turbine components to the site. Because of the complexity, size, and cost of turbines these two parties must be on the same page to ensure a successful project. Before the turbine components arrive on site, the developers must

[41] James, Hamilton and Drew Liming. "Careers in Wind Energy." n.d. Burea of Labor Statistics. February 2012 <http://www.bls.gov/green/wind_energy/>.

have the steel reinforced concrete foundations and access roads completed. Once the turbine components arrive on site, many developer firms have their own construction crews that will install the turbine. Often times the local contractors will be hired to aid and assist the construction effort. This will prove as valuable experience for the local contractors since they will more than likely be involved with the operation and maintenance phase.[42]

Research and Development Jobs

Research and development is vital to the success of a manufacturer. Because wind energy is relatively new to the energy industry, there is still much competition between companies dealing with how much they actually know about turbines. Firms all over are trying to find innovative ways to get more power and efficiency out of their wind turbines. This need for advanced and innovative minds creates a major demand for scientists and engineers in the wind energy industry. Whether is wind farm development, overseeing manufacturing processes, or turbine installation, scientists and engineers are proven to be very useful in the wind energy industry. Because wind turbines are comprised of numerous types of machinery and complex ideas, the nature of any scientist or engineer work depends on their specialties. The following is a list of engineering divisions that are in most demand by the wind industry: civil engineers, computer engineers, environmental engineers, mechanical engineers, aerospace engineers and industrial engineers. This is a limited list but covers the most requested fields of engineering that a research and developer or a manufacture would be interested in hiring. Engineers of this field will earn a salary of $75,000 - $95,000.

[42] American Wind Energy Association. "Resources." n.d. AWEA. March 2012 <http://archive.awea.org/faq/wwt_economy.html>.

Type of Engineers	Median Annual Wages
Aerospace Engineers	$94,780
Civil Engineers	$76,590
Electrical Engineers	$83,110
Electronics Engineers, except Computer	$89,310
Environmental Engineers	$77,040
Health and Safety Engineers, except Inspectors	$74,080
Industrial Engineers	$75,110
Materials Engineers	$83,190
Mechanical Engineers	$77,020
Engineers, All Other	$89,560
Engineering Technicians, except Drafters	$50,130

Figure 19 - Engineering Yearly Salaries[43]

Type of Scientists	Median Annual Wages
Atmospheric and Space Scientists	$84,710
Zoologist and Wildlife Biologists	$56,500
Geoscientists, except Hydrologists and Geographers	$81,220
Environmental Scientists and Specialists, including Health	$61,010

Figure 20 - Scientist Yearly Salaries[44]

[43] James, Hamilton and Drew Liming. "Careers in Wind Energy." n.d. Burea of Labor Statistics. February 2012 <http://www.bls.gov/green/wind_energy/>.

Manufacturing Phase

Large and complex wind turbines are designed and produced by companies called original equipment manufacturers (OEMs). OEMs are large multinational companies that are also involved in business elsewhere of the wind industry. Wind turbines are typically a small part of their business plan. Other companies are solely involved in the wind industry and partner with various other smaller companies to manufacture individual components and systems that make up a wind turbine. For years, OEMs that partake in the wind industry were primarily based oversees and the domestic OEMs typically manufactured turbine components overseas. As the United States wind energy market has grown however, OEMs are beginning to localize their production in the US. By doing this OEMs are taking advantage of the market growth and reduce their transportation costs and import/export costs. By manufacturing in the US, OEMs can take advantage of all the small businesses involved in the wind industry and have them aid with assembly and even certain parts of the turbine such as blade epoxies and gears. Because of the scale of most wind turbines, the blades, towers, and nacellas are built separately at different places across the country. This activates the country's economy by demanding more jobs in more places. If the wind industry continues to grow and turbine manufactures continue to reduce the amount of imported turbine components, then the demand for domestic jobs will continue to grow within the wind industry. Turbines require numerous engineered components therefore stimulate the manufacturing economy in the nearby areas. With the manufacturing of these turbines and their components, the demand for the installation of these turbine mechanisms rises. Once the turbines are installed there

[44] "How Wind Power Works." n.d. How Stuff Works. March 2012 <http://science.howstuffworks.com/environmental/green-science/wind-power8.htm>.

becomes a demand to maintain these machines to insure that they continue to operate efficiently for the span of their lifetime. [45]

Manufacturing Jobs

Do to the sheer size of certain turbine parts like their tower sections and blades, it is economically inefficient to import these parts from overseas or ship them across long distances of land. Manufacturing plants nearby prospective wind turbine land becomes ideal for anyone interested in building turbines. Although wind turbine technology is not all that advanced, one turbine still consists of thousands of various component. A manufacturing plant that can generate these various parts in a centralized location can be a major cost saver. The jobs produced from a single plant can produce upwards of 200 manufacturing jobs. These include but are not limited to: machinists, computer-controlled machine tool operators, assemblers, welders, quality-control inspectors, and production managers. These workers must produce wind turbine components that match the design specifications created during the development phase. As the OEMs keep moving their production over to domestic land the amount of manufacturing jobs will only increase to keep up with the demand caused by the uprising wind industry.

Occupation	**Median Annual Wages**
Machinists	$41,480
Computer-Controlled Machine Tool Operators, Metal and Plastic	$34,790
Team Assemblers	$29,320

[45] James, Hamilton and Drew Liming. "Careers in Wind Energy." n.d. Burea of Labor Statistics. February 2012 <http://www.bls.gov/green/wind_energy/>.

Welders, Cutter, Solderers, and Brazers	$35,920
Inspectors, Testers, Sorters, Samplers, and Weighers	$37,500
Industrial Production Managers	$87,120

Figure 21 - Manufacturing Yearly Salaries[46]

Operation and Maintenance Phase

The maintenance phases compared to the manufacturing and development phase is much less involved. Once wind turbines are completed they required little human supervision. Different types of sensors are installed in the turbine that inform energy companies and owners the current states of efficiencies and power output. If a sensor shows a less than adequate reading, then a local worker is sent to identify the problem. These wind service technicians must be well trained and be able to diagnose problems quickly because for every second that the turbine is turned off the owner of the turbine loses money. It is these maintenance workers that make all of the work performed in the previous phases worth it to the project.[47]

Operation and Maintenance Jobs

There are typically three types of operation and maintenance personnel. There are those employed by the OEMs , those who work for companies specializing in wind turbine maintenance, and those who are independent and work as contractors. OEMs usually offer warranties on their wind turbines for two to five years. If any problems arise during the warranty period they will send their wind turbine technicians (wind techs) to fix the problem. Once the warranties are over and

[46] James, Hamilton and Drew Liming. "Careers in Wind Energy." n.d. Burea of Labor Statistics. February 2012 <http://www.bls.gov/green/wind_energy/>.

[47] n.d. Wind Energy Jobs. March 2012 <http://www.windenergyjobsinfo.com/>.

problems arise. Owners either hire a firm specialized in wind turbine maintenance or an independent contractor. If cost is an issue then contractors are typically hired because their wages are less than a wind tech working for a company. Wind tech salaries range from company to company but usually have a starting salary between $35,000 and $40,000. Experience plays a major role in becoming a wind tech. OEMs will only hire wind techs with many years of experience in order to stand by their warranties.

Occupation	**Median Annual Wages**
Construction Laborers	$29,110
Operating Engineers and other Construction Equipment Operators	$39,530
Crane and Tower Operators	$47,170
Electricians	$49,800

Figure 22 - Laborer Yearly Salaries[48]

[48] James, Hamilton and Drew Liming. "Careers in Wind Energy." n.d. Burea of Labor Statistics. February 2012 <http://www.bls.gov/green/wind_energy/>.

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SUMMARY

The purpose of this paper is to understand how wind energy is made, how it compares to other forms of energy, and how it impacts humanity with close attention to the different ways in which wind energy can be generated such as using a vertical axis turbine or a horizontal axis turbine. Wind, Solar, Tidal, Hydroelectric, Biogas, and Geothermal Energy are all forms of renewable energy that were discussed in this paper before narrowing down its focus to wind energy. Wind power is understood to its fullest ability with research done on its vast history and different ways in which people have sought to achieve maximum efficiency with wind turbines. A variety of principles are discussed on how wind power and wind turbines function proving how important wind velocity is in producing electrical power. Wind power is assessed by understanding its advantages and disadvantages as well as performing a cost and benefit analysis of wind energy. This paper found the economic costs of setting up wind turbines to be smaller than the potential gain the turbines can produce over time. Advantages of wind energy, to name a few, include: no pollutants, small land area, alternative and renewable energy and multiple sizes. There are also some effects that wind turbines can have on society such as the creation of new jobs and federal and state tax incentives like the Clean Renewable Energy Bond which offers 1.9 cent/kWh tax credit for energy generated by wind turbines. Finally this paper's main focus is to look into vertical axis wind turbines and examine their advantages and disadvantages when compared to the standard horizontal axis wind turbines used today. Horizontal axis wind turbines have the benefit of being the most common form of harnessing wind power as they can collect wind efficiently from nearly any direction and they can have an automatic break on the speed at which their blades rotate should the surrounding wind ever become dangerously fast. However, there are some

problems with horizontal axis turbines such as their difficulty being transported, installed, and maintained. Vertical axis wind turbines however, are more stable than horizontal axis turbines since they have a lower center of gravity and they are cheaper and easier to transport and maintain. Unfortunately, vertical axis turbines have more drag than horizontal axis turbines which lowers the efficiency of the device and occasionally initial energy may be needed to start the turning of the turbine. Despite these differences, both vertical and horizontal axis wind turbines make up sound investments through their financial risks and rewards to create a sustainable and clean form of energy that could have a major impact on future generations.

APPENDIX A

WEPOWER (FORMALLY PACWIND)

1.2 kW Rated Power	1051-4000 kWh Annual Capture
DC Battery Charger Off Grid	5 Year Warranty
5'10" Rotor Diameter	Engineered for 20 Years
6'7" Blade Length	5.5 kW is about $30,000[49]
350 lbs (Excluding Tower)	Website: 1.2 kW WePower
Output Voltage (DC) 48 V DC (Off-Grid)	
Output Voltage (DC) 150-400V DC (Grid Connected)	

[49] http://green.tulane.edu/PDFs/WindEnergy.pdf

HELIX WIND

2.0 kW Rated Power	Up to 1500 kWh Annual Capture
10.8’ High	5 Year Warranty
4’ x 8.66’ Rotor Dimensions	Engineered for 30 Years
Grid Connection- 110-240 VAC	$10,500 Retail Price
295 lbs (Excluding Tower)	Website: Helix Wind
Cut in Speed 11.1 MPH	

QUIET REVOLUTION QR5

	9600 kWh Annually at 13 MPH
16.4’ High	2 Year Warranty
10.2’ Diameter	Engineered for 25 Years
$37,000 Retail Price	Website(s): Specification Sheet Quiet Revolution
990 lbs.	

INDSPIRE

1.2 kW Rated Power	2000 kWh Annually
30’ High	2 Year Warranty
20’ Diameter	8.5 MPH Cut in Speed
$12,000 Retail Price	Website(s): Windspire Energy
624 lbs.	

1.0 kW Rated Power	
8.2’ Blades (4 blades)	
5’ Rotor Dimensions	
	Website: Wind Smile
Cut in Speed 5.6 MPH	

WIND SMILE

FOUR SEASONS WIND

1.0 kW Rated Power	2000 kWh Annually
6’7” Blades (5)	On or Off Grid Option
5’10” Rotor Diameter	6.0 MPH Cut in Speed
$7,590 Retail Price	Website(s): Four Seasons Wind Power
352 lbs.	5 Year Warranty

SHANGHAI AEOLUS WINDPOWER TECHNOLOGY

1.0 kW Rated Power	
6’5” Blades (5)	On or Off Grid Option
5’9” Rotor Diameter	
	Website(s): SAWT
440 lbs.	

URBAN GREEN ENERGY

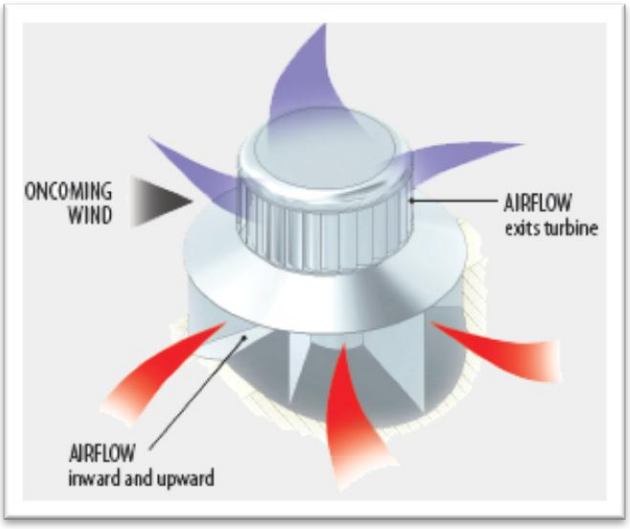
1.0 kW Rated Power	1750 kWh/year (5.5 m/s)
8’85” Blades (5)	On or Off Grid Option
5’9” Rotor Diameter	7 MPH Cut in Speed
$7,000 Retail Price	Website(s): Urban Green Energy
386 lbs.	

GALE WIND TURBINE

1.0 kW Rated Power	
3.23 square feet area	Off Grid, 12 V Charger
	4.25 MPH Cut in Speed
$7,000 Retail Price	Website(s): GALE- Tangarie Wind Turbines
85 lbs.	

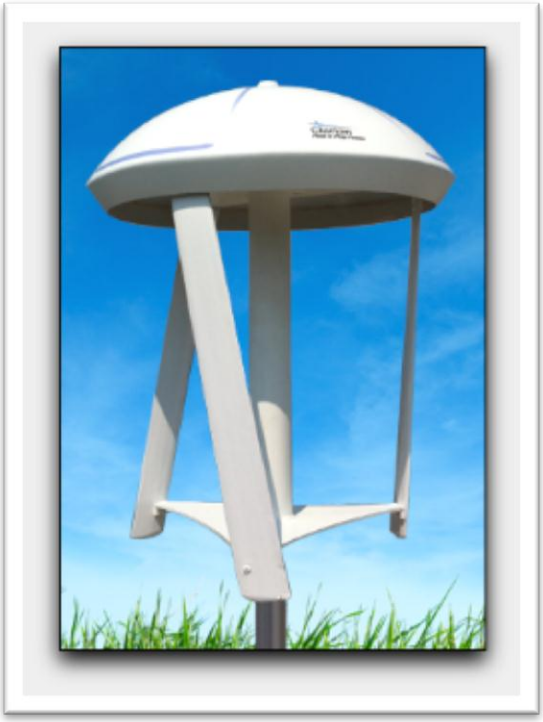
LIBERTY ENERGY

1.8 kW Rated Power	
	Website(s): Liberty Wind Energy



CALRIAN WIND

0.40 kW Rated Power	40 kWh/ month
4’ Tall	120 V AC
3’ Wide	4.25 MPH Cut in Speed
$800 Retail Price	Website(s): Clarian Wind
30 lbs.	USA



Z POWER

1.0 kW Rated Power	
	On or Off Grid Option
6’6” Rotor Diameter	Less than 1 MPH Cut in Speed
	Website(s): Vindz Power
	India

WINDTERRA SYSTEMS

1.0 kW Rated Power	$5,900 Retail
7’4” Tall	On or Off Grid Option
8’75” Rotor Diameter	Less than 12 MPH Cut in Speed
644 lbs.	Website(s): Windterra
3 Blades	USA

URWIND

1.7 kW Rated Power	$5,900 Retail
8’9” Tall	On or Off Grid Option
8’9” Rotor Diameter	Less than 8.7 MPH Cut in Speed
297 lbs	Website(s): UrWind
2000-4000 kWh/Year	North America
20 Year Life	3 Year Warranty

TURBY

2.5 kW Rated Power	$15,000 Retail
9’5” Tall	9 MPH cut in speed; 31 MPH cut out
6’6” Diameter	220-240 V Output AC-DC-AC
3500 kWh Annually	Website(s): Turby: Turbine Specifications
40% Efficiency	Netherlands
300 lbs.	

FLEXIENERGY

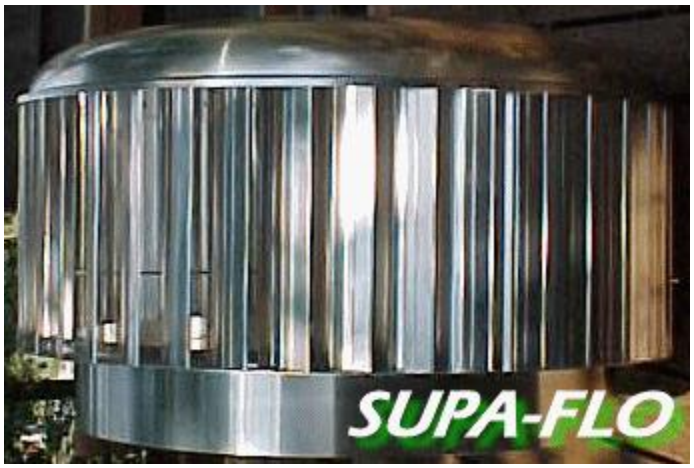
1.0 kW Rated Power	$2,000 Retail Price
77 lbs	5..5 MPH cut in speed
8’2” Diameter	Grid
Rome	Website(s): FlexiEnergy

SILENT WIND TURBINE

500W	Luethi Enterprises Limited
Start up wind speed: 8.1mph	Wind speed 10mph=130W
Wind Speed19 mph= 260W	Wind Speed 30mph=360W
Wind Speed 50-80mph=500W	3ft wide and 3ft tall
143lbs	Produces dc power only
Price: TBD by owner	Website: http://www.silentwindturbine.com/index.htm

SUPA-FLO

500 W Rated Power	88 lbs Weight
643mm Height	Price $3,500
1096mm Width	Website: Rooftop Wind
Power Output Range 5-50 MPH	Engineered for 20 years +



NANO ZÜS

300W Rated Power	Global Wind Group Inc.
3ft Wide by 3ft High	60lbs
Scalable up to a 5MW version	Price: TBD
Website: http://www.globalwindgroup.com/products/nano-zus	

URBANITE

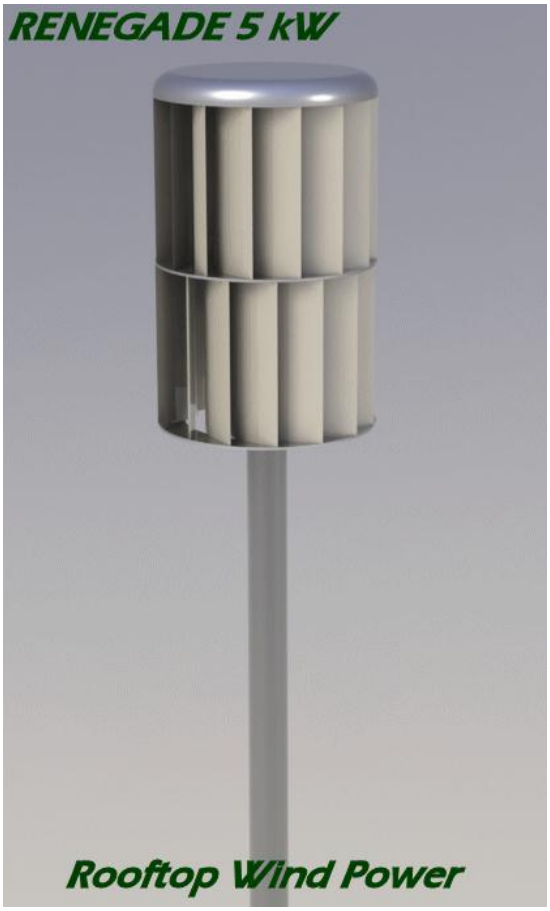
1000 W Rated Power	220 lbs Weight
1443mm Height	Price $5,500
1096mm Width	Website: Rooftop Wind
Power Output Range 5-50 MPH	Engineered for 20 years +

PATRIOT

2.5 KW Rated Power	300 lbs Weight
8” Height	Price $TBD
6” Width	Website: Rooftop Wind
Power Output at 24 MPH = 2500 W	Engineered for 20 years +

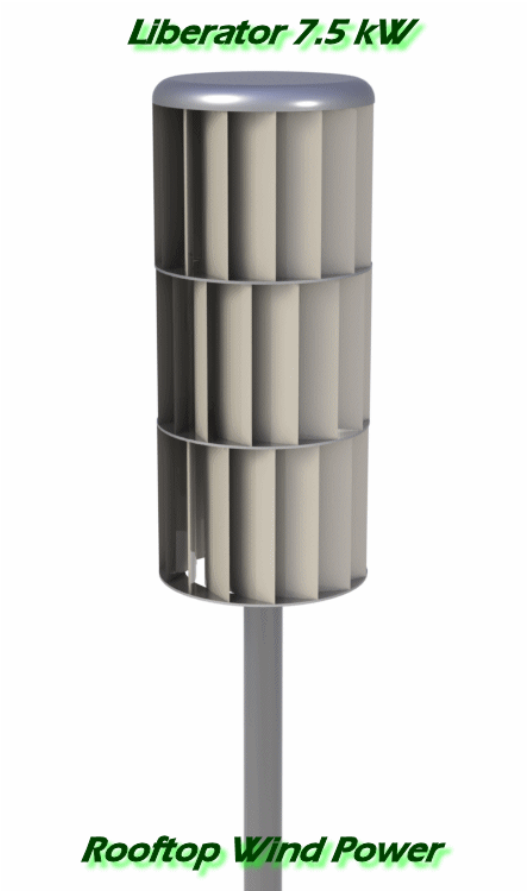
RENEGADE

5.0-7.5 KW Rated Power	400 lbs Weight
12” Height	Price $TBD
8” Width	Website: Rooftop Wind
Power Output at 24 MPH = 5000 W (Will continue to produce power about 24 MPH up to 7500 W)	Engineered for 20 years +



LIBERATOR

7.5-12.5 KW Rated Power	500 lbs Weight
16” Height	Price $TBD
8” Width	Website: Rooftop Wind
Power Output at 24 MPH = 7500 W (Will continue to produce power above 24 MPH up to 12500 W)	Engineered for 20 years +



S322 WIND TURBINE

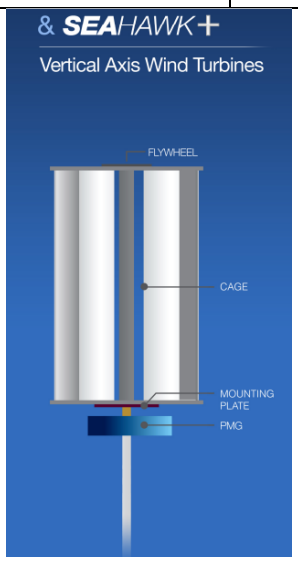
2.0 KW Rated Power	295 lbs Weight
10.8’ Height	Price $10,500
4’ Width	Website: Helix Wind
5 Year Warranty	Engineered for 30 years +

S594 WIND TURBINE

4.5 KW Rated Power	1330 lbs Weight
19.8’ Height	Price $17,500
4’ Width	Website: Helix Wind1
5 Year Warranty	Engineered for 30 years +

SEAHAWK +

3.4” Cage Diameter	1.5kW Max Power Output
6.0” Total Length	120 MPH Max Windspeed
28 MPH Rated Windspeed	8 MPH Cut-in Windspeed
180 lbs	3 MPH Start Up Windspeed
608 RPM Rater Rotor Speed	Website(s): WePower
Price TBD	



SEAHAWK

2.5” Cage Diameter	600W Max Power Output
4.0” Total Length	120 MPH Max Windspeed
28 MPH Rated Windspeed	8 MPH Cut-in Windspeed
160 lbs	3 MPH Start Up Windspeed
608 RPM Rater Rotor Speed	Website(s): WePower
Price TBD	

THE ZOETROPE

approximately 150-200 watts	Amount for Supplies Price TBD
45-3/4” Tall	Run at top speeds of 60 MPH
23-3/4” Diameter	200 lbs.
Efficiency Determined by how well turbine was put together	Website(s): Applied Sciences

MAG WIND

2.5” Cage Diameter	1110kWh/month in a 13MPH avg Wind
4.0” Total Length	>100 MPH Max Windspeed
5kW rated output in 28 MPH Wind	<5 MPH Cut-in Windspeed
Price $10,800	Website(s): Mag-Wind

HONEYWELL

1.0 kW Rated Power	$6,500 Retail Price
6’ Tall	1500 kWh produced
185 lbs.	Grid or Off Grid
	Website(s): Northern Tool

SOUTHWEST WINDPOWER SKYSTREAM

2.4 kW Rated Power	$5,399 Retail Price
8 MPH Cut in Speed	400/month kWh produced
12’ Rotor Diameter	Utility connected or battery charging
205 lbs	Website(s): Southwest Windpower

PROVEN ENERGY PROVEN 7

2.5 kW Rated Power	$14,000 Retail Price
11.4’ Rotor Diameter	4,700 kWh produced
24’ Tower Height	Utility connected or battery charging
8 MPH Cut in speed	Website(s): Proven Energy

ENFLO WIND

0.5 kW Rated Power	$3,000 Retail Price
5.6’ Rotor Diameter	1,700 kWh produced
	Utility connected or battery charging
Swiss	Website(s): Enflo Technology

AMPAIR 600 WIND TURBINE

0.6 kW Rated Power	$15,000 Retail Price
	Utility connected or battery charging
UK	Website(s): Ampair

BERGEY XL1

1.3 kW Rated Power	$6,300 Retail Price
8.2 ft Diameter	24 VDC Battery Charging
5.6 MPH Cut in Speed	Website(s): Bergey

SUNFORCE

0.6 kW Rated Power	$707 Retail Price
2.1 ft Diameter	Battery Banks
4 MPH Cut in Speed	Website(s): Sunforce

Based on the cost analysis and research the ideal turbine is one that generates a reasonable amount of wind power without extensive up-front costs. In comparison the UrWind VAWT and the Southwest HAWT would be ideal to generate electricity to power residential areas in ideal conditions.