Wind Power

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As the demand for alternative, sustainable forms of energy increases, more companies, homeowners, and industries are considering the use of wind power. Wind can be captured as energy in many ways, with electricity-generating-turbines as the major form. Many applications and configurations of wind energy systems can be seen. Wind energy has many advantages, with very few disadvantages. Recently, interest in wind power has greatly increased. According to the AWEA, in 2007, "45% growth of wind power was seen, 5,200 MW installed, generating 16 billion kWh. Wind projects accounted for about 30% of all new power generating capacity added in the US. Global wind capacity increased over 20,000 MW". The statistics say it all. Since there are other forms of sustainable energy out there, it is imperative that the issues regarding wind energy be realized.

Wind energy systems can use wind to convert the kinetic energy to either mechanical energy or electrical. Typically, the transformation of energy is to electrical. This transformation is done by the use of a turbine. Harnessing the winds energy is not a new technology. Ancient Egyptians used the wind to sail ships on the Nile, and build windmills to grind grains into cereal. "American colonists used windmills do grind wheat and corn, to pump water, and to cut wood at sawmills." (Energy Information Association, 2008). Only since the 1970's have people been sincerely considering alternative energy, specifically wind power.

One may wonder, with all the alternative forms of energy out there, what makes wind power a good choice? First off, carbon dioxide, a greenhouse gas that contributes to climate change, is not emitted through the use of wind turbines. Obviously, wind is free, unlike other "fuels" such as oil and natural gas. Contrary to other traditional forms of energy and the equipment that is needed to produce this energy, wind turbines have very few moving parts which make them last longer and need little maintenance. Wind power uses no water, which is a great advantage with water being a precious commodity. "In addition, operations of wind turbines do not leave behind to dangerous residues like nuclear plants. Also, decommissioning costs of wind turbines are much smaller than those of many other types of wind power plants, especially compared with those of nuclear generators. Land occupied by wind farms can find other uses such as agriculture" (Rosa, 2005) Below, in Table 1, wind energy is compared with nuclear, coal, and natural gas, which are all popular sources of energy. The table clearly shows the advantages wind power has over its competitors.

Environmental Impacts of Electricity Sources

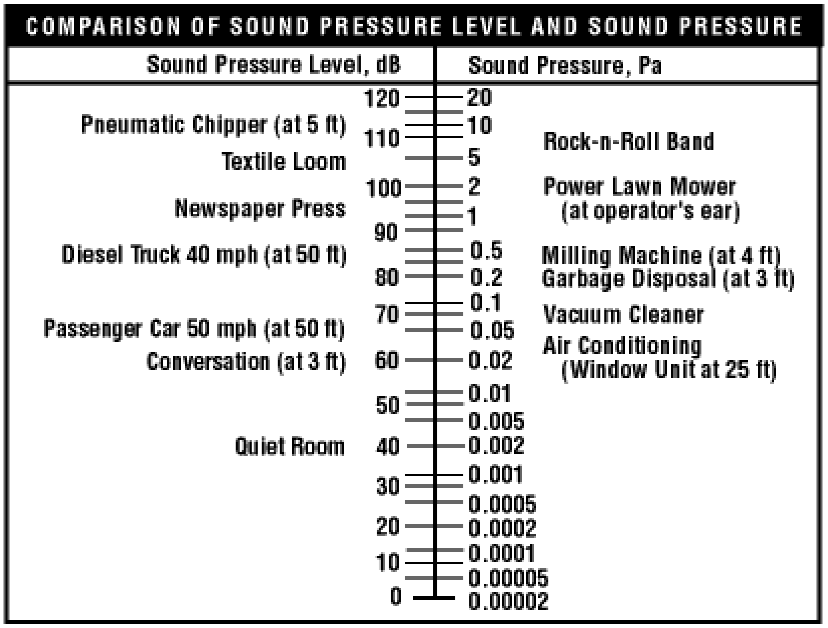
	Wind	Nuclear	Coal	Natural Gas
Global Warming Pollution	None	None	Yes	Yes
Air Pollution	None	None	Yes	Limited
Mercury	None	None	Yes	None
Mining/Extraction	None	Yes	Yes	Yes
Waste	None	Yes	Yes	None
Water Use	None	Yes	Yes	Yes
Habitat Impacts	Yes	Yes	Yes	Yes

Table 1: Environmental Impacts of Electricity Sources Source: (AWEA)

As with any good energy source, there are disadvantages. Wind power's disadvantages include noise, siting issues, variability of wind, and unsightly looks according to some. Wind turbines produce broadband noise when their rotor blades revolve and experience turbulence. This is a type of aerodynamic noise. Broadband noise is characterized as a "swishing or whooshing sound" (Gray, 2005). Older wind turbines create tonal sounds, like a "hum or whine at steady pitch". These sounds are a result of mechanical components or unusual wind currents. Tonal sound is no longer a problem in newer turbine designs. Looking at Figure 1 below, the sound of objects that are heard daily can be compared.

Figure 1: Comparison of Sound Pressure Level and Sound Pressure

(Canadian Centre for Occupational Health and Safety, 2006)



Wind turbines sound pressure can vary, depending on the wind speed and size of the turbine. Below, in Table 2, different sound pressure levels can be seen for different sized turbines:

Make and Model	Turbine Size	Wind Speed (m/s)	Estimated Sound Power (dB(A))
Southwest Windpower Whisper H400	900 W	5 10	83.8 91
Bergey Excel BW03	10kW	5 7 10	87.2 96.1 105.4

Table 2: Sound Power of Small Wind Turbines (Alberts, 2005)

An average wind turbine is as loud as a diesel truck or a newspaper press. However, one must consider what else is in the vicinity of the wind turbine. For example, in one study, it was found that "turbine noise was more noticeable and annoying at the cut-in wind speed of 4m/s than at higher wind speeds. At this speed, the wind was strong enough to turn the blades, but not strong enough to creates its own noise. At higher speeds, the noise from the wind itself masked the turbine noise". *(Alberts, 2005)* Much controversy is made over whether wind turbines are noisy; however, it is dependent on the ambient conditions, wind speed, and turbine speed. Therefore, not all wind turbines are "noisy" as many people argue.

Another issue which spawns controversy is the siting of the wind turbines. There are many issues which prevent wind farms from being build in a particular area. Required permits, regulatory approvals, and licenses must be obtained first. When siting the possible building of a wind turbine in an area, one must take careful consideration to make sure that threatened or endangered species do not live in the area, the location is not on protected land or wetlands, and the location is not of known historical resources. Also, community facilities and services cannot be in the vicinity. Land development constraints include "noise limits, setback requirements, floodplain issues, height requirements, and zoning constraints." *(Committee, 2008)* Additional considerations include telecommunication interferences, aviation, and aesthetic. These aspects, some obvious, must be taken into consideration when siting wind turbines.

One particular problem that ignites arguably the most conflict is wind turbines killing wildlife, specifically birds. Avian studies have shown that "bird kills per megawatt average one to six per year or less, which the exception of a single 3-turbine plant in Tennessee that has a recorded 11 per MW per year."*(AWEA)* Apparently, this even includes sites with heavy bird traffic, (i.e. migrating birds). The National Academy of Sciences has estimated that in 2006, wind energy was responsible for less than .003% of bird deaths caused by human/feline activities. This minuscule percentage can be compared to other causes. Cats cause "1 billion bird deaths a year, and buildings cause 100 million to 1 billion deaths per year.." *(Erickson, 2007)* With this comparison in mind, the role that wind turbines play in bird deaths is rather insignificant.

Perhaps the most important issue effecting wind power availability in a certain area is the variability of wind. It is imperative to be able to quantify the relationship of power output as a function of speed, and variations of speed as a function of time. The power output as a function of wind speed going through the rotor can be seen in a power curve. Figure 2 below shows an idealized power curve for a wind turbine.

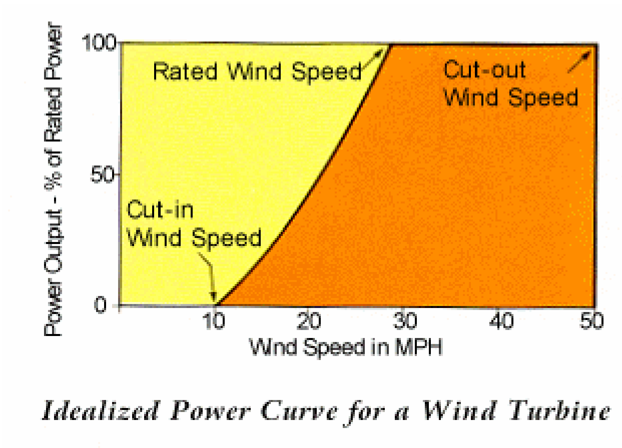


Figure 2: (AWEA)

It is also important to be able to read a power curve. The rated power is the "maximum power it can deliver under steady conditions." (Rosa, 2005) The rated wind speed is the wind speed at which the rated power is achieved. In Figure 2, the cut-in speed is at 10 mph, which means, at this speed, the turbine can start to rotate and produce power. From 10 mph to about 28 mph, the rather sharp increase is due to the fact that the power available from wind increases eight times for every doubling of wind speed. From about 28 mph to 50 mph, the power output is constant. At 50 mph, the turbine is no longer operating at a safe speed and will not work. The wind speed distribution is the percentage of hours per year that the wind is blowing as a function of the speed of the wind. The wind speed distribution is a useful way to determine the variability of wind speed. In wind turbine applications, a constant speed is needed. Wind turbine performance is best in an environment with smooth, prevailing winds. If there is much variability then other sources of energy will have to be used as backup. Figure 3 is an example of wind speed distribution graph.

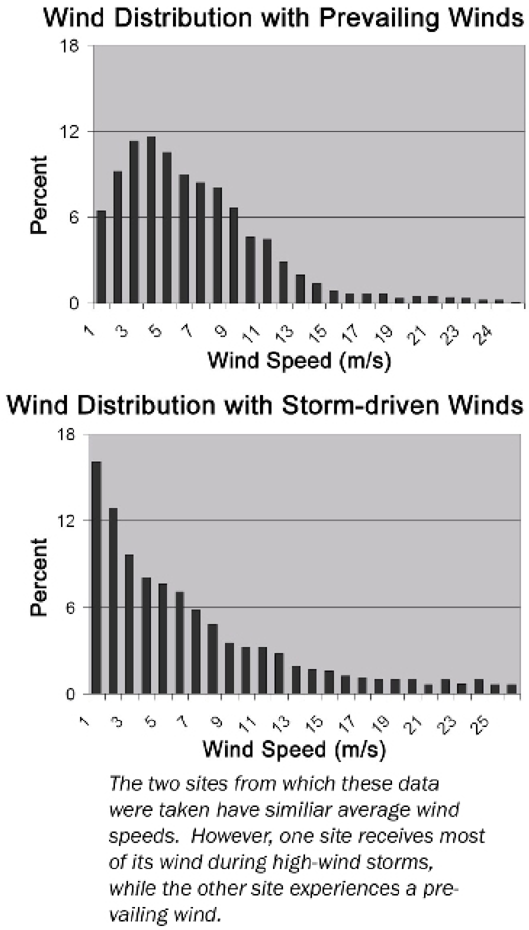


Figure 3 (Resource Assessment and Siting)

In addition to wind speed distribution and the wind turbine power curve, the capacity factor is another way to quantify energy production in general. The capacity factor is "the ratio of the actual or estimated energy produced to the energy production that would result from operation at full-rated power for every hour of the year." (NWCC, Wind Performance Characteristics, 1997) An oil refinery, for example, would have a relatively high capacity factor since the plant runs almost all the time (except for turnaround periods). Since wind power is variable in most cases, the capacity factor is not as high.

To determine whether wind power is feasible in a specific area, a wind resource map can be the major deciding factor. The map utilizes the wind power density (measured in Watts per meter squared) and the classes of wind power density for two standard measurement heights to show how much energy is available via wind. Below (Figure 4) is a wind resource map of the United States. More detailed maps for each state are available using GIS (Geographic Information Systems).

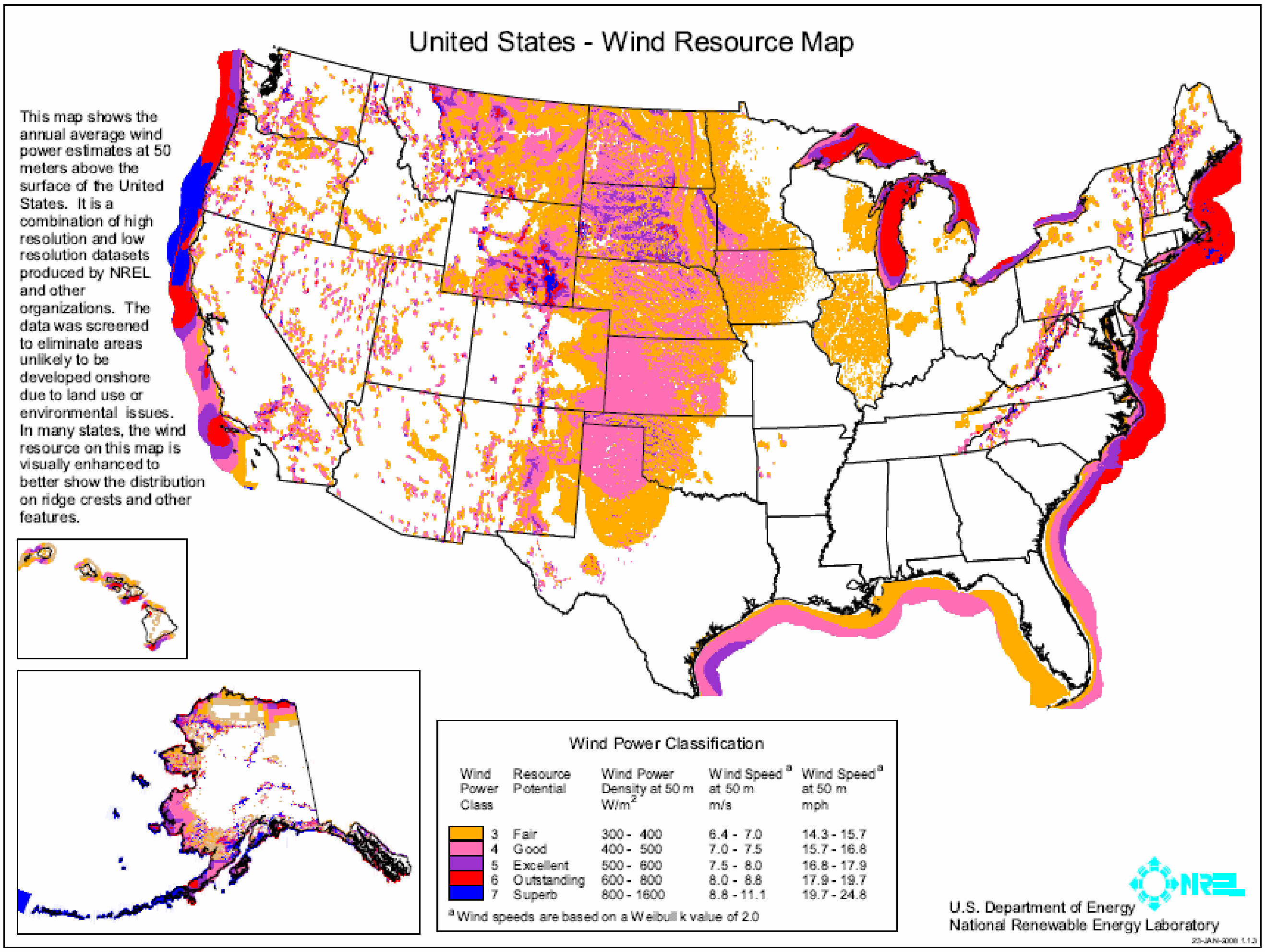
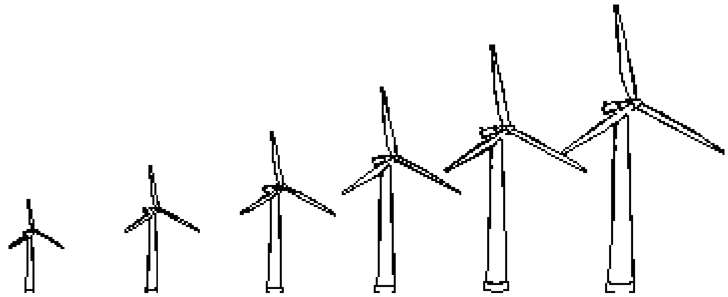


Figure 4 (NREL, 2008)

Why is it necessary to know how power output is a function of wind speed, and time? If this power is connected to an electrical grid, it needs to be reliable and constant. Electricity must be generated, so what is done when it is not constant? When the wind energy output falls, "reliable electrical service is maintained by turning up the output of other generators on the electric power systems. Electric utility companies serve as system operators .Reliable electrical service can be maintained by system operators dispatching generators up and down in response to variation in load and wind generation." (White, 2008) Even with the variability of wind speed, electricity will still be generated, thereby making wind power reliable.

With any feasibility analysis of an energy system, economics is typically the driving force. If the energy system in question is too expensive or not cost effective, even if it is the most novel design, its not going to get implemented. To determine the "real" cost of energy generated from wind turbines, one must take into consideration a variety of factors, and even then, the amount is only approximate. When measuring the cost of energy in any system, typically the units "kWh" is employed (kilowatt hours). The first factor that must be looked at is the cost of investment. For wind plants "$1000/kW in 1997" was the average. (Rosa, 2005) Apparently, these investment costs are "comparable with those of fossil-fueled and hydroelectric plants. However, since wind plants have such low capacity factors (reasons described previously), for one-on-one comparison, the cost of wind power plants should be multiplied by (.5/.2=2.5). This is because fossil-fuel power plants usually have a capacity factor of "at least 50%" and wind power plants only have around "20%." (Rosa, 2005) In addition, fuel costs must be considered. Wind obviously takes no fuel to produce energy. Operating, maintenance, decommissioning, and land costs must also be evaluated when determining the cost of energy. "In general, winds exceeding 5 m/s are required for cost-effective application of small grid-connected wind machines, while wind farms require wind speeds of 6 m/s." (AWEA, American Wind Energy Association). Cost is also dependent upon financing method and ownership. These two components greatly complicate the cost analysis of wind energy. The size of the turbine also plays an important role in the cost. Intuitively, a larger turbine will cost more because it takes more material, hence more money to produce. All of these factors decide how cheap or expensive wind power is. As in any energy system, this may be the most important component.

The sizing of a wind turbine is a function of the energy needed and the amount of wind energy available. Obviously, a wind turbine being used in a residence will be a lot smaller than a wind farm's turbine that is connecting to a grid. The general relationship is the larger the turbine, the larger the power output available. To show this relationship, see Figure 5 below:



	1981	1985	1990	1996	1999	2000
Rotor (meters)	10	17	27	40	50	71
Rating (KW)	25	100	225	550	750	1,650
Annual MWh	45	220	550	1,480	2,200	5,600

Figure 5: (AWEA, Wind Energy Basics, 2008)

In order to discuss the different configurations or designs of wind turbines, it is necessary to understand the parts of a wind turbine and how they work. Fortunately, wind turbines comprise of very few components. The three main parts are the rotor, the nacelle, and the tower. The rotor consists of a number of blades (usually 2-3). “The rotor is mounted to a drive shaft within the nacelle to operate the upwind of the tower. The rotor attaches to the drive train emerging from the front of the nacelle” (Committee, 2008). The nacelle is the housing that sits on top of the tower, behind the rotor. This houses the gearbox, drive train, transformer, and generator. Most nacelles have an anemometer which measures the wind speed. The anemometer and wind vane signals information to an electronic controller. The tower is the structure that supports both the rotor and nacelle. The towers are typically made of steel while the blades are fiberglass-reinforced polyester or wood epoxy. (AWEA, Wind Energy Basics, 2008)

Equipped with the knowledge of the components of wind turbines, a discussion of the different configurations can be explained. The three main types include the “drag-type, lift-type, and Magnus effect wind plants   In a drag type turbine, the wind exerts a force in the direction it is blowing.” (Rosa, 2005) An example of a drag-type turbine is a Savonius turbine. Figure five is a schematic of Savonius turbine:

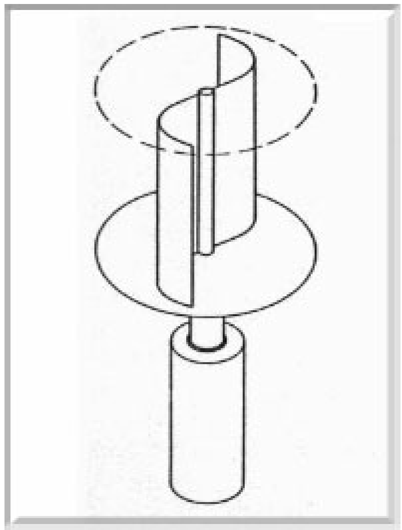
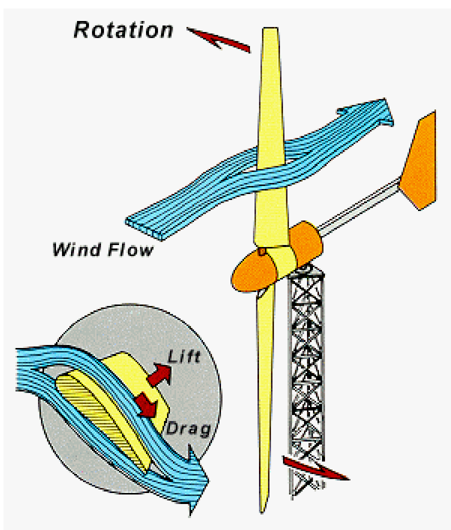


Figure 6: Savonius Wind Turbine

The Savonius rotor uses some lift in addition to drag. "Essentially all present day wind turbines are of the lift type and, over 90% of these are of the horizontal type. The horizontal-axis wind turbines are those where the axis of the rotor's rotation is parallel to the wind flow. Figure six is a good illustration of how the lift force works to propel the blade.



Principles of Wind Turbine Aerodynamic Lift

Figure 7: (Darling, 2008)

The vertical-axis wind turbines axis of rotation is perpendicular to the wind stream. Figure seven shows how this works in comparison to a horizontal-axis turbine.

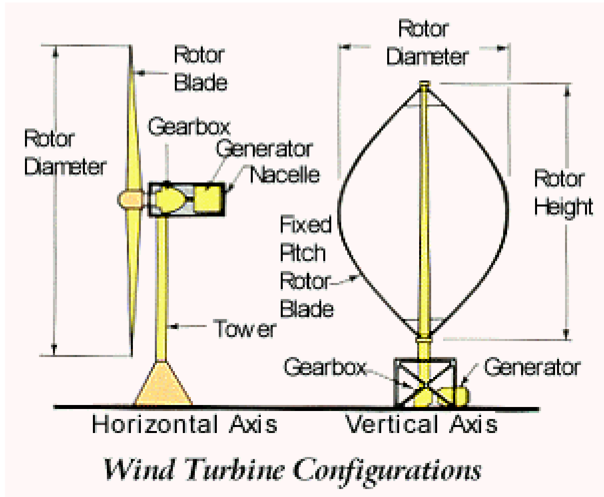


Figure 8: (Darling, 2008)

The third type of turbine is the Magnus effect wind machine. This machine apparently is "unpromising". (Rosa, 2005) A good analogy of how this works it "when a pitchers throws a curve, he causes the ball to spin creating an asymmetry: one side of the ball moves faster with respect to the air than the other, and consequently, generates the 'lift' that modifies the trajectory of the ball. The resulting force, normal to the wind direction, is the one which generates the energy. Figure eight is an illustration of a Magnus effect.

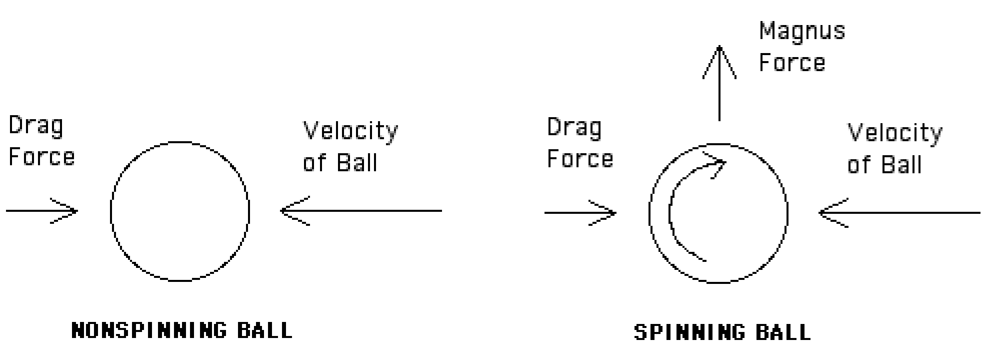


Figure 5: Magnus Effect (Teresi)

Now that the important wind turbine configurations are realized, application of wind energy can be evaluated for residential uses. Who should invest in wind turbines? According to the AWEA, "the best candidates for these systems are rural homes and businesses with at least an acre of property, a class 2 or better wind resources, and utility bills averaging $150 per month of more. A 10-kw grid connected residential scale system generally costs around $55,000 to install. The average U.S home requires around 10,655 kWh per year." (AWEA, American Wind Energy Association). Homeowners must also consider zoning restrictions and look into economic incentives to make the investment cheaper. Small turbines are classified from 20W to 100kW. They typically have a 20-40 year design life. A typical home would expect to pay 12 cents / kWh with 10mph wind speed, with a payback period of around 8-16 years. Since turbines have very few parts, they do not need much maintenance, thus making them reliable. According to the AWEA, "A 3 kW turbine, including 60-80 foot tower, utility-tie inverter, batteries for back-up system, utility switch box, battery system box, hardware and installation components, costs about $15,000. A homeowner using $60-100 per month of electricity can save 10-20% off the electric bill with a 1 kW turbine, given strong wind resources."

Even though there is great hope for wind power, the publics' opinions must be taken into account. In one survey, people were filling to accept "a lower standard of living if it meant a cleaner environment (63% majority). According to Farhar, "approximately 56% to 80% of respondents to recent national surveys say they would pay a premium for environmental protection or renewable electricity."(Farhar, 1994)

According to the AWEA, public opinion in support of wind usually shifts to become even more strongly in favor once the wind turbines are installed and operating. When questioned about wind turbines, most people have the general consensus that "they look cool" and "I don't mind as long as we don't have to depend on oil as much". Some are concerned with the aesthetics and think that turbines are ugly, while others are concerned about the turbines killing birds.

The public's opinion is especially important when discussing whether wind turbines should be installed on a community scale. Community wind energy is best executed via a "co-op". This means that the turbines are owned partly by local homeowners and possibly by a local energy company. By creating a co-op a number, a number of results are seen. Energy independence, rural economic development, and community ownership are established. By having a co-op, the residents of the community receive some of the revenue generated through the production of energy from the wind turbines. This is great for rural towns that depend substantially on local commerce. A fine example of a wind coop is based in Toronto. The turbine is located on the Lake Ontario waterfront, standing 308 feet high, and has a 750 kW capacity. The $1.6 million turbine produces enough electricity per year to power about 250 homes. This project, termed, WindShare, is a partnership with Toronto Hydro, and the residents, each owning 50%. The partners share equal responsibility for the capital costs, maintenance, and capital costs. According to the former WindShare vice president, “It’s really brought a lot of people together, and I don’t think the project would have had the same support without the co-op; we would have been just another commercial entity building something on the lakeshore.” (WindShare, 2008) Many communities world-wide have the potential to have such a co-op in their community.

Wind energy has the potential to change the way in which the world obtains their energy. While there are many significant advantages, minor disadvantages can be seen. The disadvantages mostly are dependent on the public’s opinion (i.e. noise, aesthetics of the turbines). If the public can be taught the basics of wind power and the rewards that they will get utilizing it, they may be more willing to accept it. Siting wind turbines remains to be one of the most important aspects when determining whether to install in a particular area. The economics of the installation is a also a key factor. All of these factors show that wind energy is going to be one of our key ways to obtain energy.

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