

## INTRODUCTION

Imagining a world with no electricity is almost impossible. Electricity plays an important role in people's everyday lives. From being able to cook breakfast to powering a car, electricity is virtually everywhere, and without it human-kind would be greatly affected. Every day activities, from the minutest to the most important, would come to a halt. The only thing more important than electricity is the energy that produces it.

Energy can be divided into either renewable or non-renewable. Non-renewable energy is an energy source that, once used up, cannot be recreated in a short period of time. It is the most common energy source. Some examples of non-renewable energy sources include the fossil fuels -- oil, natural gas, uranium, and coal ([www.eia.doe.gov](http://www.eia.doe.gov)).

Renewable energy is an energy source that can be replenished in a short period of time. Such sources include solar energy, wind energy, geothermal energy, biomass, and hydropower and ocean energy. Renewable and nonrenewable energy sources can be used to produce secondary energy sources including electricity and hydrogen ([www.eia.doe.gov](http://www.eia.doe.gov)).

Because the most common way of generating energy is through non-renewable energy sources, many have become concerned with what will be done when these non-renewable sources are exhausted. Those who are concerned with the production of the energy necessary to survive, encourage the development of renewable energy sources for the future of a dependant ecosystem. A renewable energy source that is increasing in popularity is wind energy conversion.

## HISTORY

Wind energy has been around for many years. At one time, wind was the major source of power for pumping water, grinding grain and transporting goods by sailing ships. Throughout these years, it has been reinvented numerous times. Present day applications of wind power include water pumping and the generation of electricity.

The earliest known use of wind power is the sail boat, which helped ancient sailors understand lift, and they used it every day, even though they did not have the physics to explain how or why it worked ([www.telosnet.com](http://www.telosnet.com)). The first windmills were used to automate the tasks of grain-grinding and water-pumping and the earliest-known design is the vertical axis system developed in Persia about 500-900 A.D. ([www.telosnet.com](http://www.telosnet.com)). The first use was apparently water pumping, but the exact method of water transport is not known because no drawings or designs are available.

The first known documented design is also of a Persian windmill, which was vertical sails made of bundles of reeds or wood which were attached to the central vertical shaft by horizontal struts ([www.telosnet.com](http://www.telosnet.com)). Grain grinding was the first documented wind mill application and was very straightforward. The grinding stone was affixed to the same vertical shaft. The mill machinery was commonly enclosed in a building, which also featured a wall or shield to block the incoming wind from slowing the side of the drag-type rotor that advanced toward the wind ([www.telosnet.com](http://www.telosnet.com)).

The first windmill used for electricity production was built in Cleveland, Ohio by Charles F. Brush in 1888 ([wikipedia.org](http://wikipedia.org)). By 1908, there were 72 wind-driven electric generators from 5kW to 25kW. The largest machines were on 79 ft. towers with four-bladed 75 ft. diameter rotors ([wikipedia.org](http://wikipedia.org)). By the 1930s, windmills were mainly used to generate electricity on

farms, mostly in the U.S. where distribution systems had not yet been installed. “In this period, high-tensile steel was cheap, and windmills were placed atop prefabricated open steel lattice towers” (wikipedia.org).

### **How it works?**

Wind energy works as a result of the sun unevenly heating the atmosphere. Some parts of the atmosphere are warmer than others, and as these rise, other air blows in to replace it; this creates wind.

The energy stored in the wind can be used by building wind turbines. Wind turbines are machines used for converting the kinetic energy in wind into mechanical energy through the use of a tall tower, with a large propeller on the top (wikipedia.com).

Wind turbines in groups are called wind farms which allow for larger electricity production when all the right elements, wind, large propellers, and numerous turbines, are present. In order to have a successful project, wind farms should be built in places with strong, steady winds. Some optimal places are in “coastal areas, at the tops of rounded hills, open plains and gaps in mountains” (home.clara.net).

In order for a wind turbine to work efficiently, wind speeds usually must be above 12 to 14 miles per hour. Wind has to be this speed to turn the turbines fast enough to generate electricity. The turbines usually produce about 50 to 300 kilowatts of electricity each. A kilowatt is 1,000 watts. Once electricity is made by the turbine, the electricity from the entire wind farm is collected together and sent through a transformer. There the voltage is increase to send it long distances over high power lines

Wind speeds vary from year to year and with other affecting variables. The best wind speed to build wind turbines is, on average, 15 mph, which contain “nearly 60 percent more energy than a site with an average wind speed of 13 mph” (windustry.com).

To have a better idea of where to place the turbines, wind maps and the use of anemometers can help in this decision. Anemometers are “placed on a tower at the location and height [one] plans to install [the] wind turbine(s)” (windustry.com). The energy produced by these turbines can be stored for later use in grids, for example when the wind is not very strong and additional energy cannot be produced.

## **VERTICAL VS. HORIZONTAL TURBINES**

There are two types of wind turbines based on the axis about which the turbine rotates. The turbines can either turn on a horizontal or vertical axis.

### **Horizontal Axis Turbines**

Horizontal axis turbines are the most popular types. The main rotor shaft and electrical generator are located at the top of a tower and must be pointed into the wind (wikipedia.com). The turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds, and they are placed at a great distance in front of the tower and are, at times, tilted up a small amount (wikipedia.com).

### Advantages

The following are advantages and disadvantages according to the website wikipedia.com:

- Blades are to the side of the turbine’s center of gravity, helping stability.
- Ability to wing warp, which gives the turbine blades the best angel of attack. Allowing the angel of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season.

- Ability to pitch the rotor blades in a storm, to minimize damage.
- Tall tower allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.
- Tall towers allow placement on uneven land or in offshore locations.
- Can be sited in forests above tree lines.
- Most are self-starting
- Can be cheaper because of higher production volume, larger sizes and, in general higher capacity factors and efficiencies.

#### Disadvantages

- Horizontal wind turbines have difficulty operating in near ground, turbulent winds because their yaw and blade bearing need smoother, more laminar wind flows.
- The tall towers and long blades (up to 180ft. long) are difficult to transport on the sea and on land. Transportation can now cost 20% of equipment costs.
- Tall horizontal wind turbines are difficult to install needing very tall and expensive cranes and skilled operators.
- Supply of Horizontal turbines is less than demand and between 2004-2006, turbine prices increased up to 60%. At the end of 2006, all major manufacturers were booked up with order through 2008.
- The FAA has raised concerns about tall horizontal turbines' effects on radars in proximity to air force bases.
- Height can be a safety hazard for low-altitude aircrafts.
- Offshore tower can be a navigation problem.

- Downwind variants suffer from fatigue and structural failure caused by turbulence.

## **Vertical Axis Turbines**

Vertical axis turbines have the main rotor shaft running vertically. The generator and/or gearbox can be placed at the bottom, near the ground, so the tower does not need to support it (wikipedia.com). It is difficult to mount vertical-axis turbines on towers, which means that they operate in slower, more turbulent air flow near the ground, with resulting lower energy extraction efficiency (wikipedia.com).

### Advantages

The following are advantages and disadvantages according to the website wikipedia.com:

- Easier to maintain because most of their moving parts are located near the ground.  
This is due to the vertical wind turbine's shape. The airfoils or rotor blades are connected to a gearbox.
- As the rotor blades are vertical, a yaw device is not needed, reducing the need for this bearing and its cost.
- Vertical wind turbines have a higher airflow pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures. Mesas, hilltops, ridgelines and passes can have higher and more powerful winds near the ground than up high because of the speed up effect of winds moving up a slope or funneling into a pass combining with the winds moving directly into the site.
- Low height is useful where laws do not permit structures to be placed high.

### Disadvantages

- There may be a height limitation to how tall a vertical wind turbine can be built and how much swept area it can have.

- Most vertical turbines need to be installed on a relatively flat piece of land and some sites could be too steep for them while available to horizontal turbines.
- Vertical turbines that use guy wires to hold it in place create serious problems for the bottom bearing as all the weight of the rotor is on it and the guy wires increase downward thrust in wind gusts.
- Most Vertical turbines produce energy at only 50% of the efficiency of horizontal turbines in large part because of the additional drag that they have as their blades rotate into the wind.

The group believes that horizontal axis turbines will be more effective because this type of turbine produces more energy and less drag than the vertical axis turbine.

### **LOCATION**

The most important factor to consider is the speed of the wind because it varies from year to year, season to season, the time of day and the height above the ground.

([www.windustry.com](http://www.windustry.com)) Wind power is characterized according to power class 1 – 5. The higher the number indicates higher winds. Locations in where the land is flat or hilltops experience desirable wind speeds ([www.infinitepower.org](http://www.infinitepower.org)). Wind distribution is also a factor to consider because the wind does not blow at the same speed all the time. The ideal wind is one that maintains stable high speeds. Daily and seasonal wind cycles must be observed since these are factors that determine the strength of the wind when electricity is most needed such as during the daytime and during the coldest and hottest months. It is also imperative to consider the directions of the best winds for electricity production. Wind turbines must be placed in areas free of obstacles such as buildings and other structures in the landscape, thus these obstacles may slow down wind speed. Likewise, the smoother the land and free of vegetation the better the

land ([www.windustry.com](http://www.windustry.com)). Consequently, turbines will not be affected by the roughness of the land. As with any location throughout the state, areas determined for appropriate development must consider environmental, social, and technical capability ([www.infinitepower.org](http://www.infinitepower.org)).

The Texas Panhandle has the best quality winds in the state. South of Galveston and the Texas coast experience strong sea breezes that could be suitable for commercial development. The Trans-Pecos and mountain passes possess the highest average wind speeds in Texas. Locations in West Texas must be site specific due to the wind in the mountainous terrains that can rapidly change over short distances. The Great Plains in Texas to North Dakota contain the greatest potential for the nation’s wind power potential. ([www.infinitepower.org](http://www.infinitepower.org))

As mentioned earlier, the Great Plains, the Gulf Coast and certain areas of the Trans-Pecos are three major areas with good wind power potential in Texas. All of these areas are classified to have a wind speed of class 4 or better. That is, these three locations in Texas have the capacity of producing all of the energy consumption in the state. ([www.infinitepower.org](http://www.infinitepower.org))

**Potential Electricity Production on Windy Lands in Texas**

<b>WIND POWER CLASS</b>	<b>AREA (km2)</b>	<b>PERCENT OF STATE LAND</b>	<b>POTENTIAL CAPACITY (MW)</b>	<b>POTENTIAL PRODUCTION (Billion kWh)</b>	<b>% OF TEXAS ELECTRIC CONSUMPTION</b>
3	143,400	21.13%	396,000	860	371%
4	29,700	4.38%	101,600	231	100%
5	5,000	0.74%	21,600	48	21%
6	300	0.04%	1,600	4	2%
Total	178,400	26.29%	524,800	1,143	493%

(graph provided by [www.infinitepower.org](http://www.infinitepower.org))

## Proposed Wind Projects in Texas

Project	Utility/Developer	Location	Status	MW Cap	On Line By / Turbines
Wildorado	Xcel Energy/Tierra Energy	Oldham & Potter Counties	NA	160	NA
JD Wind IV	John Deere Credit/Distributed Wind Systems	panhandle	under construction	79.8	Suzlon 2.1-MW (38)
JD Wind VI	John Deere Credit/community wind	Sherman County	under construction	10	Suzlon 1.25 MW (8)
Buffalo Gap, phase II	AES/Direct Energy	near Abilene	under construction	232.5	GE Energy 1.5 MW (155)
Lone Star	Horizon Wind Energy		under construction	200	
Sweetwater Phase IVa	CPS San Antonio/Babcock & Brown and Catamount Energy Corp.	near Sweetwater	under construction	135	Mitsubishi 1 MW (135)
Sweetwater Phase IVb	CPS San Antonio/Babcock & Brown and Catamount Energy Corp.	near Sweetwater	under construction	105.8	Siemens 2.3 MW (46)
Sand Bluff	Airtricity	near Big spring	under construction	90	

(graph provided by [www.awea.org/projects/texas.html](http://www.awea.org/projects/texas.html))

### ISSUES

Issues identified through windustry.com include:

- Cost to consumers – Energy will be sold to electric companies and the sellers will have little influence on how much these will charge consumers for electricity consumed.
- A variable resource - Turbines produce energy only when the wind blows.
- Aesthetics – People do not accept wind turbines because of the visual impact of these.
- Noise – Wind turbines are big and produce noise.
- Biological Resource Impacts – Wind energy can impact plants and animals due to direct collision and electrocutions with wind turbines.
- Construction – Areas where turbines are constructed may be temporarily disrupted due to the transportation of large and heavy equipment.

- Zoning Laws – Some places do not allow high towers, so a special construction permit must be obtained.
- Radars – interference with electro-magnetic telecommunications.

### **CHALLENGES WITH THE BUSINESS MODEL**

One of the challenges of the business model is information overload. Many websites have information regarding wind energy including methods for owning wind turbines through individual ownership, forming a joint venture, or leasing your own land for the erection of wind turbine as well as the advantages and disadvantages of each. Much information is also available on the motivation for owning a wind turbine such as for private use, supplemental energy or sale of the utility and advantages and disadvantages of each as well. ([www.windustry.com](http://www.windustry.com))

Since the wind industry is not a very common industry in this area, many people are not eager to invest in it because they do not know much about it. Only those who are interested in creating alternative sources of energy are the ones who do research on the industry. Thus, this results in most of the available funds to come from government grants rather than by investors who can reap the benefits from the wind industry. Not much information was obtained in relation to how much funding would be necessary to cover all of the costs incurred when building wind turbines. Only vague estimates were given.

Another challenge is to understand exactly how the wind turbines work and generate electricity. There has to be a real understanding of the types of wind turbines and components of the wind turbine such as the propeller blades, tower, gearbox and generator ([www.home.clara.net](http://www.home.clara.net)) to know where to erect a wind turbine in relation to the direction of the wind. It is difficult to understand wind turbines and the generation of electricity as a whole when an individual is not exposed to such industry.

## **COST**

There are several factors that influence the cost of a wind project. These include the turbine itself, construction costs, interconnection fees, metering equipment, maintenance and repair, and consulting fees. Financing arrangements, the size of the project, and the taxes also influence the cost of a wind project. Additional costs include operational costs such as warranties, administrative fees, insurance, property taxes, land-lease payments, and contingency fund for unexpected issues, which usually cost 2%-3% of the initial system costs. Proper maintenance will increase the turbines' lifetime as well as increase the return on investment.

According to [windustry.com](http://windustry.com), a popular machine in the U.S. today is a "state-of-the art 2 MW turbine that stands as tall as a 30-story building and costs roughly \$3.5 million installed...with a good wind resource, this size turbine can produce 6 million kWh of electricity each year, or enough energy to run 600 average American households" ([windustry.com](http://windustry.com)). In the event that a grid is attached to the turbine, the costs range from \$1000-\$2000 per kW for a large-scale system bigger than 100kW ([energy.iastate.edu](http://energy.iastate.edu)). In general, cost rates decrease as machine capacity increases.

Another alternative is to install a battery to the turbine. The battery serves to keep the turbine working when wind is not at its potential. Wind turbines with an operating battery installed cost from \$4000-\$5000 per kW; a single battery costs at least \$2000 ([energy.iastate.edu](http://energy.iastate.edu)).

## **WIND ENERGY COMPARED TO OIL**

Like oil, wind turbines have the potential to contribute to communities' economic environments by adding to the tax base and providing new types of income. For example, each 100 MW of wind development in "southwest Minnesota has generated about \$1 million per year

in property tax revenue and about \$250,000 per year in direct lease payments to landowners” (windustry.com). In 1999, Bill Richardson, who is now New Mexico’s Governor, predicted that thanks to wind energy, in 20 years 80,000 jobs would be created and support by the WTC (windturbinecompany.com). Because building wind turbines has the potential to benefit the communities where these are located, they provide a good alternative to non-renewable energy sources, such as oil, and at the same time, provide the opportunity for new jobs.

Although every type of energy source is funded, compared to oil and other fossil fuels, wind energy “receives considerably less than other forms of energy” (windustry.com). For example, in the 2005 energy bill, of the \$14.5 billion tax funds, “all types of renewable energy and energy efficacy combined received only \$4.5 billion while fossil fuels received \$5.6 billion” (windustry.com). The group believes this to be the case because non-renewable energy sources, such as the oil, usually require larger upfront investments, have to be constantly monitored, and human labor is involved (ex. to pump oil rigs), compared to wind turbines which do not require most of those things. Wind turbines, once set up, work on their own and probably only require maintenance time and maintenance costs. The disparity in funding also hints that renewable sources may not be getting the funding because people have yet to realize the importance and benefits of further developing alternative energy sources.

Another issue with wind turbines compared to oil is that oil is not subject to the time of year or time of day, or anything of the sort, as are wind turbines. Oil can be pumped, where it is abundantly available, and at any time. On the other hand, in order to get the best out of wind turbines, certain wind conditions must be met. At the same time, because oil pumping is restricted to availability, wind turbines work anywhere there is wind, which, as long as the sun

continues to warm the earth and wind continues to blow, they can relatively be placed anywhere, even in places where there is low wind currents.

Fuel is usually sent to a processing plant to convert into energy, in wind turbines, the generating station is installed at the source of the fuel. “Wind is a native fuel that does not need to be mined or transported, taking two expensive aspects out of long-term energy costs” (windustry.com).

Wind turbines can also be owned by local landowners and small businesses. This creates the opportunity to import less fuel from other countries, which also helps energy dollars to return to the local economy.

Wind turbines do not generate contaminating particles that could damage the environment, including water. An oil spill near lakes or streams could have serious affects on the environment, animals, and society.

Both energy sources have landscape aesthetics issues. People may be concerned because turbines are tall and may “take away” from the scenery, the same way they may be concerned with oil rigs. Turbine owners try to minimize the visual affects from wind turbines by painting them a neutral color or designing each turbine uniformly.

## **RECOMMENDATIONS**

The project team would like to build commercial-scale wind farms throughout the state of Texas due to the magnitude of the growth potential in this state. The state of Texas is second after California, in wind power installation, with 1,995 MW, and this number is predicted to continue growing. Turbines as high as a 30-story building are recommended because “with a good wind resource, this size turbine can produce 6 million kWh of electricity each year, or enough energy to run 600 average American households” (windustry.com). The cost for such

turbines is roughly \$3.5 million installed. The team recommends installing the first turbines in the Great Plains of Texas due to that location's high wind power potential and then expanding to other regions in the state.

Horizontal turbines would be used due to their height advantage over vertical turbines. Their taller structure allows them to access to stronger wind power in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%. The turbines would also include a grid to serve as an alternative when the wind is not blowing at capacity. The costs range from \$1000-\$2000 per kW for a large-scale system bigger than 100kW (energy.iastate.edu)

The project team recommends that the potential investors seriously consider this project because the benefits are not only environmental and economical, but it also has high profitability benefits. The U.S. has potential to meet 20% of the electricity needs with wind energy, and currently (2007) only .2% of the U.S. energy supply is provided by wind, so there is great market share potential (windustry.com).

Investors would also (1) not pay for electricity since they will be provided by the electricity produced (2) revenues would be generated from the sales to electricity companies and (3) there are several tax savings and federal and state incentives (windustry.com).

The project could also be funded, not only through investors, but also through grant applications and state incentives and rewards. The joint venture would be a limited liability company (LLC) which would provide legal protection to the investors in case of financial problems or accidents at the wind farms.

## **PURPA of 1978**

The Public Utility Regulatory Policies Act's primary objective is to "back out foreign oil" and to "stimulate use of domestic renewables" (windustry.com). Under this act, "qualifying facilities" or a new class of non-utility power producer such as wind, solar, biomass, hydropower and waste resources, are exempt from being treated as a traditional electric utility company. Since QF's do not provide direct service to consumers and are not retail providers, they "are exempt from financial, rate and organizational regulation at the federal and state levels" but not from environmental, site permitting, building, electrical, zoning or any licensing laws at any level of government (windustry.com).

Additional benefits from being considered a QF is that the avoided costs to the utility companies are rewarded back to the QF, in this case, a wind turbine farm, for that avoided cost. Because the QF is producing that energy, "the utility's ratepayers would be unaffected and the QF would have the opportunity to receive payments based on money the utility would have spent anyway" (windustry.com). The website gives the example: if a utility was planning a new 200 MW power plant that would generate power at 7¢/kWh, the first 200 MW of QF's production would get 7¢/kWh. Conversely, for a utility with surplus power, the only costs avoided would be the costs of fuel and variable operations and maintenance costs. (windustry.com)

## **CONCLUSION**

### **IS IT TIME FOR IT?**

Yes, it is time for wind energy. As evidence has shown, wind power has proven to be the most cost effective source of electrical power. The utilization of fossil fuels as a source of energy has shown to increase costs and those costs are passed to consumers. Costs come from mining and extraction, transportation, technology, environmental impact to political costs. Depletion of these sources will also increase prices that are escalating everyday ([www.telosnet.com](http://www.telosnet.com)).

Technological advancements for the commercialization of wind power are already in place and continue to improve over time. Many companies and financial organizations are ready to reap the profits of wind power and take advantage from the public interest, political and environmental climate and emotional and marketing factors ([www.telosnet.com](http://www.telosnet.com)).

## SOURCES

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