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Wind Power A Viable Resource

This is the first of a series of essays on alternative energy sources which we as a nation can use to eliminate our dependence on fossil fuels. Wind power is a viable resource that we must harvest if we are to survive the depletion of non-renewable resources. This essay will go through the history of wind power, the electrical characteristics of wind power, its efficiency, an example of an existing wind plant, hit on the advantages and disadvantages of wind power, and finally the future of this resource.

Wind Power - A Brief History

Since early history the wind has been used to move ships, grind grain and pump water. Wind propelled boats along the Nile as early as 5,000 BC. New ways of using the energy of the wind spread around the world. By the 11th century people in the Middle East were using windmills extensively for food production. The crusaders carried this idea back to Europe. The Dutch refined the windmill and adapted it for draining lakes and marshes in the Rhine river delta. During the 18th century the Zaan region northwest of Amsterdam became the Netherlands' powerhouse. There Dutch millers constructed what must have been an amazing assembly of more than 700 industrial windmills along the Zaan river. These windmills drove Dutch industry at a time when England was struggling to figure out what to do with coal. Only by tapping the power of multiple windmills could the engineers drain the polders and make the Netherlands what it is today. The Dutch called these early wind farms gangs of windmills and a group can still be seen southeast of Rotterdam at Kinderdijk. This water pumping plant was in use until the 1950's.

Figure 1. Windmills at Kinderdijk in the Netherlands

In the late 19th century windmills were used to pump water for farms and cattle stations, and later to generate electricity for homes and industry. As time passed the steam engine replaced water-pumping windmills. However, industrialisation also sparked the development of larger windmills to generate electricity. Commonly called wind turbines these machines first appeared in Denmark in 1890. The popularity of using the energy in the wind has always fluctuated with the price of fossil fuels. When fuel prices fell after World War 2 interest in wind turbines waned. Nevertheless, when the price of oil skyrocketed in the 1970's interest in wind turbine generators increased dramatically. Modern wind farms generate electricity and lots of it. This electricity is used to pump water, power a hairdryer or cool the average house in the warmer months. The 28,000 wind turbines worldwide generate more than 7.8 Terawatt hours of electricity annually. Wind farms now scan the globe from a fjord in Denmark to the deserts of Southern California and from the moors of England to the shores of Albany Western Australia.

How Is The Wind Converted Into Electricity?

Wind is a form of solar energy. The uneven heating of the atmosphere by the sun causes wind as does the irregularities of the Earth's surface and the Earth's rotation. Any object that moves has kinetic energy therefore; the wind has kinetic energy that we can harvest. Kinetic energy is calculated by determining the mass of air that passes through each square metre of space and it is measured in Joules. Wind power is the process by which the wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. Wind turbines use the kinetic force to turn large blades (as shown in figure 2) that turn gears.

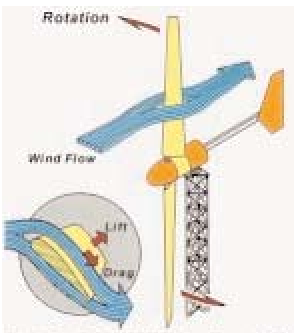

Figure 2. This shows that as the wind blows over the blades of a wind turbine; their aerofoil shape makes them turn.

This is achieved when air passes over the aerofoil section of the blade it travels faster over the top of the blade than it does below. This makes the air pressure above the blade lower than it is below. Due to the unequal pressure the blade experiences a lifting force. Wind turbine designers use these forces generated by the wind to make the rotor blades rotate. This rotational energy is transmitted either to an electrical generator or to a machine for mechanical work (such as a water pump). With electricity generating turbines a gearbox is used to speed up rotation which is typically about 30 times. Energy is extracted from the wind as it moves through the sweep area of the turbine's blades. There is a limit to the amount of kinetic energy that can be harnessed. A wind turbine could not extract 100% of the kinetic energy, simply because to do so the blades would have to stop the wind completely, this would require the sweep area to be a solid like a disk. Then the wind would simply blow around the turbine and the blades would not turn at all.

Types of Wind Turbines

There are two major types of wind turbines these being horizontal axis turbines and vertical axis turbines. Both types will be explained below.

Horizontal Axis Turbines

The horizontal axis turbine is the design most common in today's wind farms. They follow the traditional windmill design. The basic principle of the horizontal axis turbine is to position the blades so they are parallel with the wind. The advantages of this model compared to the vertical axis turbine is that it can handle stronger wind speeds at higher altitudes, has a higher efficiency, the rotor blades can use the wind to initiate movement without human intervention and wildlife on the ground are not affected. Most of the turbines have three blades. The foundation of these turbines is solid concrete 7 to 10 metres in diameter and they can be land or shore based. The tower is constructed of either steel lattice, tubular steel, or tubular concrete. The towers can stand as tall as 70 metres high and each blade can measure up to 35 metres in length. The blades are either made of plastic, fiberglass or epoxy and there is a housing for the gears that sits on top of the tower called a nacelle.

Vertical Axis Turbines

The other type of turbine is the vertical axis turbine and there is only one commercially manufactured model which is the Darrieus machine. This was named after its inventor French engineer Georges Darrieus who patented the design in 1931. As shown in figure 4 it looks very much like an eggbeater. These turbines have two or three blades and are made of similar components to the vertical axis turbines. Some of the advantages of this turbine is that the generator is located on the ground (which is a major advantage when performing maintenance), and a yaw mechanism is not required to turn the rotor against the wind. The disadvantages of this design are that wind speeds are very low close to ground level, so although it may save a tower, the wind speeds will be very low on the lower part of your rotor. The overall efficiency of the vertical axis machines is not impressive. The Darrieus machine needs a push before it starts. This is only a minor inconvenience for a grid connected turbine, since current can be drawn from the grid to start the machine. The machine may need wires to hold it up, but wires are impractical in heavily farmed areas. Replacing the main bearing for the rotor necessitates removing the rotor which means tearing the whole machine down.

Figure 4. The Darrieus Machine.

Electrical Characteristics Of Wind Power

The amount of electricity produced by wind energy can be estimated by the following equation - Electricity Produced = B×0.3×8760 (Where B is the rated capacity of the turbine in kW and the constants 0.3 and 8760 are related to wind speed). This is only a rough estimation since many places have higher wind speeds that lead to a greater production of electricity per turbine. However, a typical turbine rated at 660kW will produce approximately 1.7GW hours per year. A better measure of the amount of electricity that a turbine produces is to calculate how many homes it can supply. Since the average household's energy consumption is approximately 4345kW hours the above equation is divided by that amount. So one 660kW turbine will meet the needs for approximately 400 homes. Pay back time is the time needed to generate the equivalent amount of energy used in manufacturing the wind turbine. The average wind farm will pay back the energy used in its manufacture within three to five months, and over its lifetime a wind turbine will produce greater than 30 times more energy than what was used in its manufacture. This compares very favourably with a coal power station, which delivers only one third of the total energy used in its construction and fuel supply. Therefore, if fuel is included in the calculation coal stations never achieve an energy payback. Wind energy not only achieves payback within a few months of installation but also does so from a source that is free and inexhaustible. The major drawback of wind power is variability. However, in large electrical grids, consumer demand also varies and electricity generating companies have to keep spare capacity running idle in case a major generating unit breaks down. If a power company can handle varying consumer demand, it can also handle the negative electricity consumption from wind turbines. The more wind turbines that are on the grid the more short-term fluctuations from one turbine will cancel out the fluctuations from another. Therefore, wind power integrates well into the existing electrical grid.

Efficiency Of Wind Power

The maximum energy that a wind turbine can extract from the wind imposing on it is around 60%. However, the meaning of efficiency is different with wind power since its fuel is free. The major concern is not pure efficiency but rather how to improve productivity to bring the price of wind energy down. The output of a wind turbine depends on where it is located. In an average location the average capacity of a turbine is around 30%. This means that over the course of a year the turbine would produce 30% of the amount it would have produced if it were going flat out for the entire year. Turbines rotate and therefore produce electricity for about 85% of the time depending on location. Technical advances in aerodynamics and structural dynamics have contributed to a 5% annual increase in the energy yield per square metre wind turbine rotor area. New technology is constantly being introduced into new wind turbines. As such the energy output per turbine has increased 100 fold in the last 15 years. The factors that influence energy output are -

* Cut-in speed or the wind speed at which a turbine begins to produce power;
* The power a turbine produces at moderate wind speeds, this is determined largely by blade aerofoil shape and geometry;
* The wind speed at which the turbine may be shut down to protect the rotor and drive train machinery from damage;
* Operating characteristics such as low speed on-off cycling, shut down behaviour, and reliabil-

ity. Together these determine the turbine's availability to produce power when wind speeds are in its operating range;

* The efficiency of drive train components, such as the generator and the gearbox.

Although wind conditions near the coastline tend to be ideal for wind farms it is possible to find economical inland areas for wind turbines. The use of tall wind turbine towers is a way of increasing the energy yield of a wind turbine. This is because wind speed increases significantly with height above ground level. In low wind areas manufacturers supply special wind turbines with large rotors compared to the size of the generator. Such a turbine would reach peak production at lower wind speeds although it would waste some of the energy potential of high winds. Nevertheless, manufacturers are constantly optimizing their machines to local wind conditions. As for cost wind power has become the least expensive renewable energy source in existence. The energy cost to society per kilowatt-hour of electricity from wind power is the same as for a new coal-fired power station fitted with smoke scrubbing equipment. This equates to about 10 cents per kWh for an average site.

Albany Wind Farm Western Australia

Albany is a city of around 30,000 people on the south coast of Western Australia about 400 kilometres south of Perth. The city is adjacent to the ocean and sits in a large sheltered harbour. It was originally settled as a whaling station but in more recent times its major industries have been farming, fisheries and tourism.

Figure 5. Albany Wind Farm.

Why Was Albany Selected As A Site For A Wind Farm?

Albany is well known as a windy city since it gets plenty of cold wind gusts from the Southern Ocean. Having been to Albany myself on a number of occasions I can verify that from personal experience. In 1989, the State Energy Commission of Western Australia (now called Western Power) examined a number of sites on the main Western Australian electrical grid for the possibility of a large wind farm development. Albany was considered to offer the best prospects within environmental, technical and community constraints. The site of the wind farm is 12 kilometres south-west from the city centre. The site is 80 metres above sea level, this height and its proximity to the coastline and small distance to the main power grid make it an outstanding wind farm site.

Construction Of The Wind Farm

Before construction of the wind farm could take place a feasibility study was conducted in 1998. This study included the following areas -

* Environmental including noise, flora and fauna;
* Archaeological studies;
* Native title claims;

* Community consultation.

Following completion of the feasibility study, it was found that a wind farm could be built which met all of the constraints required. The final placement of the turbines was a combination of community opinion, environmental, financial and technical constraints. Development approval was sought and then received from the City of Albany Council and final approval for the project was received in July 2000 from the Western Australian Minister for Energy. Project construction commenced in August 2000 and was completed in July 2001.

Figure 6. The installation of the blades and hub on one of the 12 turbines.

Power Output Of The Wind Farm

The Albany wind farm was officially opened in October 2001. The wind farm consists of twelve 1800kW wind turbines connected to the Albany electrical system and Western Power's control network. The specifications of the turbines are listed below in Table 1.

Turbine rating	1800kW
Turbine make	ENERCON E66
Turbine type	Three bladed, upwind, horizontal axis, variable speed inverter coupled
Turbine tower height	65m
Turbine rotor diameter	70m (blade length 35m)
Start-up wind speed	2 m/s (7 km/hr or 4 knots)
Wind speed at which maximum output reached	14 m/s (58 km/hr or 31 knots)
Wind speed at which turbine stops due to high winds	36 m/s (130 km/hr or 70 knots)
Survivable wind speed	Greater than 60 m/s (220 km/hr or 115 knots)
Blade rotational speed	10 to 22 RPM
Turbine blade material	Glass fiber reinforced epoxy
Tower material	Steel

Table 1. Specifications of the Albany wind farm turbines.

The turbines installed do not have gearboxes and this keeps maintenance down to a minimum. The blades move slowly reaching a top speed of 22rpm in the strongest winds. In an average year the wind farm produces approximately 56.8GW hours per year. This amount supplies 75% of the city's electricity requirements and is enough to supply approximately 15,000 homes. The wind farm will also result in a lowering of Greenhouse Gas Emissions by about 77,000 tonnes per year as less coal and gas will need to be burnt to keep up with the demand for electricity.

Advantages Of Using Wind Power

The benefits of using wind power are many. The most important of these is wind power is a renewable resource. There is no fear of depletion because wind will always be present on the Earth. We can use every possible gust of wind today and there will still be wind tomorrow. Unlike solar power wind can blow during the day or night. Therefore, it has the potential to provide energy at any time of the day.

The most attractive thing about wind power is that its resource the wind is absolutely free. This means power companies do not have to spend millions of dollars recovering fossil fuels and storing waste. This way power companies can focus spending more money on building more power generating turbines.

Wind energy is a non-polluting source. When wind is used to generate electricity no harmful emissions are sent into the atmosphere as is the case with Carbon Dioxide when fossil fuels are burned. Another important advantage of wind farms is they require minimal space to operate. A typical wind farm of 20 turbines might extend over an area of 1 square kilometer but only 1% of the land area would be taken out of use. The remainder can be used for other purposes such as farming or as natural habitat. Wind turbines are also economically feasible to mass produce. Even though a single turbine does not generate a massive amount of electricity, when there are hundreds the numbers begin to add up compared to other sources of power generation.

Disadvantages Of Using Wind Power

While it seems that wind power is the perfect solution for the future there are some disadvantages to it that need to be addressed. One of the biggest complaints about wind power is that in comparison to other forms of power generation the amount of energy generated per turbine is considerably less than other sources. This means that there must be many turbines manufactured and assembled to provide useful amounts of electricity. Further to that if many turbines are required large amounts of land are need to support the turbines. This is because the turbines must be spaced to scientific calculations so one turbine does not interfere with the flow of wind that is to be the source for the next turbine. In addition, because wind is not a tangible resource it does not blow all the time. This creates problems because there is a constant need for electricity in today's society.

Wind turbines can be expensive to maintain especially the earlier models and because the entire model is mechanical equipment the working life of a turbine is only about 20 years. When wind turbines originally appeared the noise of the blades rotating was a major issue for people living close to them. However, newer technology has developed blades that carry less noise than the average home. There are also some safety issues involved with the blades rotating as there have been cases in colder climates of large chunks of ice being thrown from the blades as far as 200 metres from the turbine. The largest negative impact of wind turbines is the problem of birds flying directly into the path of the moving blades, which results in death.

The Future Of Wind Power

As fossil fuel usage becomes more and more controversial, and with global warming becoming a reality, alternative resources and technologies will have to replace the energy generation systems we currently use. In addition, fossil fuels are non-renewable resources, which means eventually there will come a day in the next few hundred years when most if not all resources will be depleted. At this point alternative forms of energy generation must be ready to produce what is no longer being generated by forms of the past. Wind power is on the verge of creating many new technologies for better efficiency. Estimates of a 5% annual increase in yield per square metre of the rotor blade are extremely encouraging. In addition, the weight of turbines has been tipped to decrease by a half every five years. The blades are becoming lighter but at the same time more sturdy which means they will be able to work in stronger winds.

One technology that is being researched at present is the solar tower. This technology sucks in warm air through the tower to drive turbines. This produces power 24 hours a day.

However, the drawback of this technology is that the tower has to be gigantic. A plant under investigation by EnviroMission would need to be 5 kilometres across and 1 kilometre high to provide enough power for 200,000 homes. This plant would cover 20 square kilometers and would be the world's largest engineered structure. As can be imagined this would take a considerable outlay of funds to create but it is one of the options open to us in the future.

I envisage more and more homes in the future will have a wind turbine in the backyard or on the roof as their main source of power with rechargeable batteries taking up the slack when there is no wind blowing. Together with solar cells and indeed the solar tower, I see wind power being the energy resource of the not too distant future.