Wind Power Guide

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Introduction

We have an ever-increasing thirst for energy. In the past fossil fuels - coal, oil, gas, wood and peat have in the main provided this energy. However, fossil fuels have two major problems, escalating costs and pollution. Alternatives to fossil fuels have been sought in two areas nuclear energy and renewable energy. The problems associated with nuclear energy are now well known and both economic and safety aspects may prevent the further expansion of nuclear power in most counties.

There are many renewable forms of energy including, solar, wind, water and biomass. This document explores all four but focuses on small-scale wind power.

Wind energy can be described as second hand solar energy or stored solar energy. This is because wind is made from the energy falling on the earth from the sun. Some of the sun's energy in the form of solar radiation is absorbed by the earth's atmosphere and the air is heated up. Hot air is less dense than cold air and is consequently lighter. It has a lower pressure than cold air, which means that as the air is heated cold air is drawn in. This heating is uneven leading to the air circulating around the earth producing vast movements of energy. The energy can be harnessed by large wind turbines and equally by small units supplying electricity to single houses, farms, workshops, boats, caravans, etc.

Small wind chargers with rotor sizes of less than 3 metres are available from several manufacturers as are plans for DIY units. Typical applications for the electrical energy generated by wind power include:

1. Charging batteries for low energy devices like lighting, radio, hi-fi, TV, etc.
2. Supplying power to remote locations such as caravans, boats and yachts, out houses and workshops.
3. Maintaining electricity for animal fencing, fish farming, irrigation, chicken layers, meteorological recording stations, radio repeater units and many more.

Generating your own power from the wind, however small that amount is, can be very satisfying and in addition help solve the problem of supplying power to remote locations without pollution.

History

The wind has been used to power machines capable of grinding corn, pumping water and producing electricity for hundreds years. There are records of Persian and Japanese wind machines as long ago as 200 BC. Wind power probably has its origin in the ancient civilisations of China, Tibet, India, Afghanistan, and Persia. The first written evidence of the use of wind turbines is that of Hero of Alexandria, who in the third or second century BC described a simple horizontal-axis wind turbine. From contemporary sources

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we also know that windmills have been used in the 11th & 12th century in England. Also from a contemporary eyewitness (1190) we know that German crusaders brought the skills of building windmills to Syria. From this, we may assume that this technology was generally known all over Europe since the Middle Ages.

The two most familiar types of wind machines are the traditional windmill used for grinding corn, once common place in Europe and the water pumping windmills that provided water to farms and towns in the U.S.A. and seen on many Western films. It is estimated that in the 1930s there were 6 million of these fan type mills in use in America.

Pitstone Windmill stands in the north east corner of a large field near the parish boundary of Ivinghoe and Pitstone in Buckinghamshire. It is thought to have been first built circa 1627 as this date is carved on part of the framework. This is the earliest date to be found on any windmill in the British Isles. It should be remembered that such a structure would have had to have frequent repairs made to it, so it is quite possible the mill predates 1627.



The design of the mill is what is known as a post-mill. This means the whole superstructure of the mill rests on one main post. This post arises from ground level through brick and a foundation chamber; the post then acts as a pivot for the timber built structure above with the sails. Consequently, the upper section of the mill and sails can be turned towards the direction of the wind. The mill machinery in the upper rotating section was reached by a long flight of external steps.

For many hundreds of years corn grown in the two adjoining villages was ground at the mill into flour. In 1874 the mill was bought by Adelbert Wellington Brownlow Cust, 3rd Earl Brownlow who owned the nearby Ashridge Estate. He subsequently let it to a local farmer, who ran a successful milling business from the mill.
In 1902 the mill was seriously damaged during a furious gale, damaging it beyond the price of economic repair. Circa 1922 the now derelict ruined mill was bought from the Ashridge Estate by a farmer whose land was close to the mill. In 1937 he donated it to the National Trust. However, it was not until 1963 that a band of volunteers began to carry out renovations at their own expense. After seven years of hard work in 1970 after an interlude of 68 years the mill once again ground corn. Today owned by the National Trust the windmill is open to the public on Summer Sunday afternoons.

The development of the water-pumping type windmill in the USA was the major factor in allowing the farming of vast areas of North America, which was otherwise devoid of readily accessible water, and also allowed the extension of rail transport systems, throughout the world, into areas where water could be pumped up from underground to supply the needs of the steam locomotives of those early times. They are still used today for the same purpose in some areas of the world where grid electricity is not a realistic option.

The many-bladed wind turbine atop a lattice tower made of wood or steel was, for many years, a fixture of the rural landscape throughout rural America. These mills, made by a variety of manufacturers, featured a large number of blades so that they

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would turn slowly but with considerable torque. A tower-top gearbox and crankshaft converted the rotary motion into reciprocating strokes carried downward through a pole or rod to the wellhead below.



In areas not prone to freezing weather, a pump jack (or standard) was mounted at the top of the well below. This was the connection between the windmill and the pump rod, which generally went through the drop pipe to the cylinder below. The pump jack provided a means for manual operation of the pump when the wind was not blowing. Some pump jacks provided a sealed connection, allowing water to be forced out under pressure, but many had a simple spout allowing water to flow away in a trough by gravity.

The drop pipe and pump rod continued down deep into the well, terminating at the pump cylinder below the lowest likely groundwater level. A suction tube usually continued a short distance more. This arrangement allowed wells as deep as 400 feet to be constructed, though most were much more shallow. The number of moving parts led to the whole arrangement to be rather trouble prone, and "well men", as they were called in the early days, had a profitable business in repair and maintenance work.

The wind turbines and related equipment are still manufactured and installed today in remote parts of the western United States where electric power is not readily available. The arrival of electricity in rural areas, brought by the REA in the 1930s through 1950s, made these windmills obsolete in the Midwest and other more built-up areas. The mills and towers remained for a time. Today, most are gone, victims of storms, rust, and progress.

As the use of fossil fuels developed and the use of electricity generated from coal and oil became widespread in the early 20th Century, renewables began to contribute less and less to the world's energy needs. Research continued in many counties with advances being made in both the theoretical and practical use of wind energy. Hence, the revival of the wider interest in wind power after the 1970s did not start from scratch, but could build on a solid foundation of theories and practical experiences. When the new era of wind energy was initiated in the 1970s new materials and technologies were available. Composite materials such as fibreglass showed to be very suitable for the blades, and electronics were developed to control the wind turbine. In the 1980s investment was once again made in Europe and America into the production of electricity from very large windmills (often known as wind turbine or wind turbines). Wind parks consisting of groups of wind turbine were built in California, Sardinia, Orkney, Ilfracombe in Devon, Carmarthan Bay and Richborough in Kent. These experimental sites were funded by public and private money. By the end of 1996 a total of 6200 MW grid connected wind turbine capacity was installed around the world. In 1996 1200 MW were added.

An up to date map of wind farms in the UK can be found at

http://www.bwea.com/map/uk.html

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The main application for mechanical farm wind pumps is drinking water supply. The markets for this type of machines include USA, Argentina, South Africa and New Zealand.

Cumulative global wind energy generating capacity topped 31,000 megawatts (MW) in 2002. Some 6,868 MW of new capacity were installed worldwide during the year, an increase of 28%, according to preliminary estimates by the American Wind Energy Association and the European Wind Energy Association. Wind plants now power the equivalent of 7.5 million average American homes or 16 million average European homes, worldwide. Global wind power generating capacity has quadrupled over the past five years, growing from 7,600 MW at the end of 1997 to an estimated 31,128 MW at the end of 2002 - an increase of over 23,000 MW. Wind is now the world's fastest-growing energy source on a percentage basis, with installed generating capacity increasing by an average 32% annually for the last five years (1998-2002). The slightly slower rate of 28% in 2002 was primarily due to a lull in the U.S. market.

	2001	2002	Capacity installed in 2002	Growth in %
Germany	8 754	12 001	3 247	37.1%
Spain	3 337	4 830	1 493	44.7%
Denmark	2 417	2 889	472	19.5%
Italy	697	785	88	12.6%
The Netherlands	493	688	195	39.6%
United Kingdom	474	552	78	16.5%
Sweden	293	328	35	11.9%
Greece	272	276	4	1.5%
Portugal	125	179	54	43.2%
France	94	153	59	62.8%
Ireland	125	138	13	10.4%
Austria	83	139	56	67.5%
Finland	39	41	2	5.1%
Belgium	32	44	12	37.5%
Luxemburg	15	16	1	6.7%
Total U.E.	17 250	23 059	5 809	33.7%

The case for wind power

Wind has been assessed as one of the most promising renewable energy sources for electricity generation in many countries including the UK. As energy use in colder climates is proportional to both temperature and available daylight, the greatest proportion of energy use is in the winter months. (In hotter climates energy use is often greater in the summer due to cooling and air conditioning requirements). This is favourably met by wind energy with three-quarters of the potential energy wind can supply is available between November and April.

Originally wind generators were built right next to where their power was needed. With the availability of long distance electric power transmission, wind generators are now often on wind farms in windy locations and huge ones are being built offshore. Since they're a renewable means of generating electricity, they are being widely deployed, but their cost is often subsidised by governments, either directly or through renewable energy credits. Much depends on the cost of alternative sources of electricity.

The wide spread use of large wind turbines is limited by two factors.

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1 - The relative generating cost compared with fossil fuels.

2 - The environmental impact of large structures.

Improving technology and escalating fossil fuel costs and the second by the exploitation of sites remote from human habitation including off shore sites are addressing the first factor.

Wind energy is clean and safe it does not produce greenhouse gases in the same way as fossil-fuelled generating plants do. Wind energy has little or liabilities related to decommissioning of obsolete plants, unlike nuclear power. The environmental impact of wind energy has been investigated thoroughly in both Europe and the USA. Particular areas of concern that have been researched include noise emissions; the sun's reflection from the blades; and the threat to birds. Opinion surveys indicate that the majority of citizens in most European countries favour renewable energy sources such as wind power. Opinion surveys in areas of Denmark and UK with wind farms indicate that 70 to 80 % of the population is " supportive" or "unconcerned" with respect to the turbines.

Wind power has a number of advantages, these include:

- The economics of wind energy are good and improving - relative to other methods of generating electricity. For example, the energy invested in the production of a typical wind turbine has a "pay back" time (energy balance) of less than half a year of operation.

- Wind energy is a domestic source of energy and as with other renewable energy sources can improve a nation's degree of self-sufficiency.

- Wind turbines can be installed fast, plants of, 50 MW, can be in operation in less than a year from signing the contract. Wind turbines are modular and therefore more power can be added quickly as demand increases.

- Wind power has proved to be a reliable technology.

- Wind power is not only applicable in the industrialised areas and countries, but is an ideal technology for the electrification of rapidly industrialising countries.

- Wind power application can include all types of systems: grid connected wind farms, hybrid energy systems, and stand-alone applications such as battery chargers.

- The technological complexity of operating and maintaining wind turbines does not differ from that of other electrical machines in rural, developing communities: desalination plants, water pumps, etc.

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Consequently, today wind power is being included in the energy planning of the rapidly industrialising nations.

- Land-based wind energy has the potential of covering six times the world's electricity consumption, or one time the world's total energy consumption.

- The energy consumption for production, installation, operation and decommission of a wind turbine is usually earned back within 3 months of operation.

- Conventional and nuclear electricity production receives massive amounts of direct and indirect subsidies. If a comparison is made on real production costs, wind energy is competitive in many cases. If the so-called external costs are taken into account, wind energy is competitive in most cases. Furthermore, wind energy costs are continuously decreasing due to technology development and scale enlargement. On the other hand, the hidden costs of decommissioning nuclear power stations, and waste disposal are now coming to the fore.

- Studies show that the number of birds and bats killed by wind turbines is negligible compared to what's due to other human activities such as traffic, hunting, power lines and high-rise buildings. For example, in the UK with a few hundred turbines, about one bird is killed per turbine per year; cars alone kill 10 million per year.

  http://www.bwea.org/media/news/birds.html

- After decommissioning wind turbines, even the foundations are removed.

- Conventional and nuclear plants also have sudden unpredictable outages. Statistical analysis shows that 1000 MW of wind power can replace 300 MW of conventional power.

- The creation of a "burst electricity" industry, where excess electricity can be used extremely cheaply on windy days for opportunistic production, such as electrolysis for hydrogen fuel, and other processes that are efficient with intermittent electricity usage. This can prevent windmills from being forced to idle during days of excess power availability.

- Existing European hydropower plants have the capacity to store enough energy to supply one month's worth of European energy consumption. Improvement of the international grid would allow using this at relatively short term at low cost. Furthermore, geographically spread wind turbine parks used together produce power much more constantly. On the longer term, the electricity might be used to produce hydrogen. This could be used with fuel cells to produce electricity at times of low wind supply and as fuel for transport.

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- Improvement in energy efficiency should go hand in hand with the use of renewable energy.

- Wind turbines are beautiful, graceful machines that symbolise humans in harmony with the natural world.

- More recent wind farms have their turbines spaced further apart, due to the higher capacity of the individual wind turbines. They no longer have the cluttered look of the early wind farms.

- It is possible to hold a conversation directly underneath a modern wind turbine without any difficulty whatever and without raising one's voice. The modern turbine is quieter than its predecessors owing to improvements in the blade design. It makes a gentle "swish swish swish" sound that is quite pleasant and soothing. In addition, when it is windy the background noise of rustling trees, etc., exceeds the turbine noise.

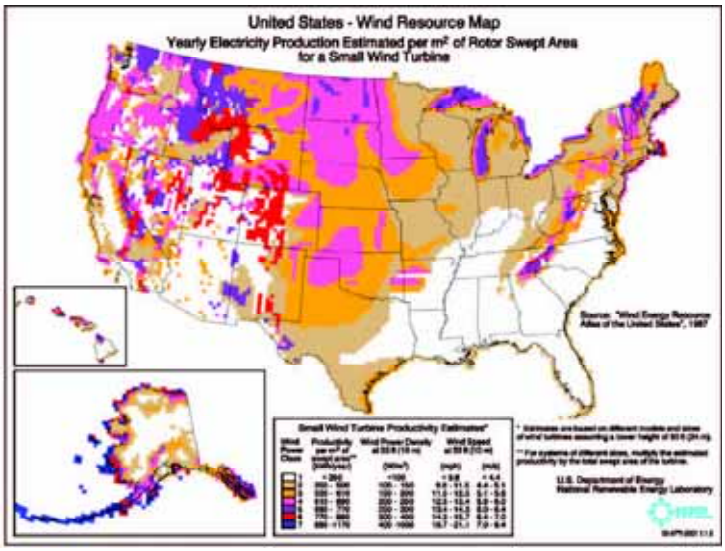
- Wind turbines have epistemological value, as well as artistic value. As a form of sculpture, wind turbines are a dynamic (moving) art form. As an epistemological sculpture, they also make visible the process of producing electricity. There is an obvious beauty to seeing the process and understanding how it works. Urban wind turbines like the 750 kW Lagerwey in Toronto are popular gathering places where people come to sit and contemplate, and enjoy the restful beauty of a sculpture in motion, or to bring their children to what essentially amounts to a good outdoor exhibit that's open 24 hours a day.

Can you use the wind's power?

Wind power alone cannot satisfy the world's increasing demand for electrical power. But wind energy represents a feasible supplement in a diversified energy supply portfolio. The best wind turbines start working at less than 4mph with most cutting in between 8 and 12 mph. Generally wind speed decreases inland and is consequently higher at the coast. The speed is also reduced by trees and buildings and is therefore less in a city than in open countryside. An average wind speed through the year of 10mph is usually required for a wind machine to produce electricity economically. Wind measurement devices can be hired or bought and are known as anemometers. They usually consist of small propellers or cups that produce a small measurable electric current.

The following image is a wind resource map for the USA.

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The wind resource estimates on this map refer to exposed areas such as hilltops and plains. More detailed wind resource information, including the Wind Energy Resource Atlas of United States, published by the U.S. Department of Energy (DOE), can be found at the National Wind Technology Center web site

http://www.nrel.gov/wind/

The DOE Windpowering America website at

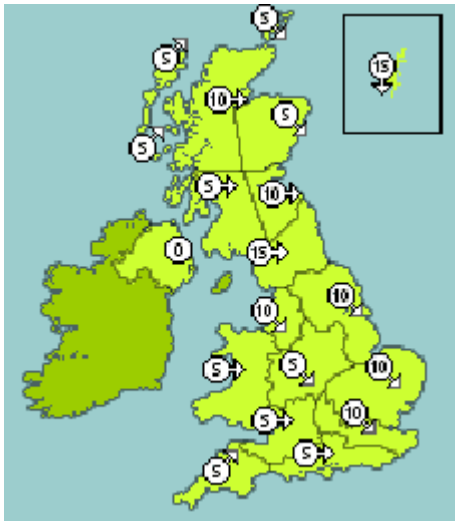
http://www.eren.doe.gov/windpoweringamerica/

A real time wind map of the UK can be found at

http://www.xcweather.co.uk/

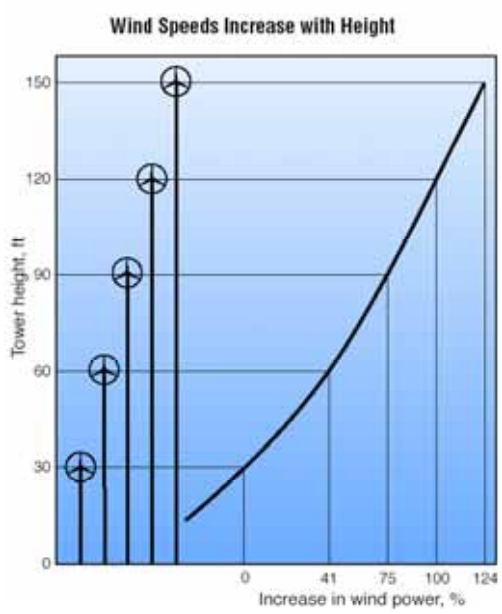
The United Kingdom is the windiest country in Europe the following map shows typical wind speeds.

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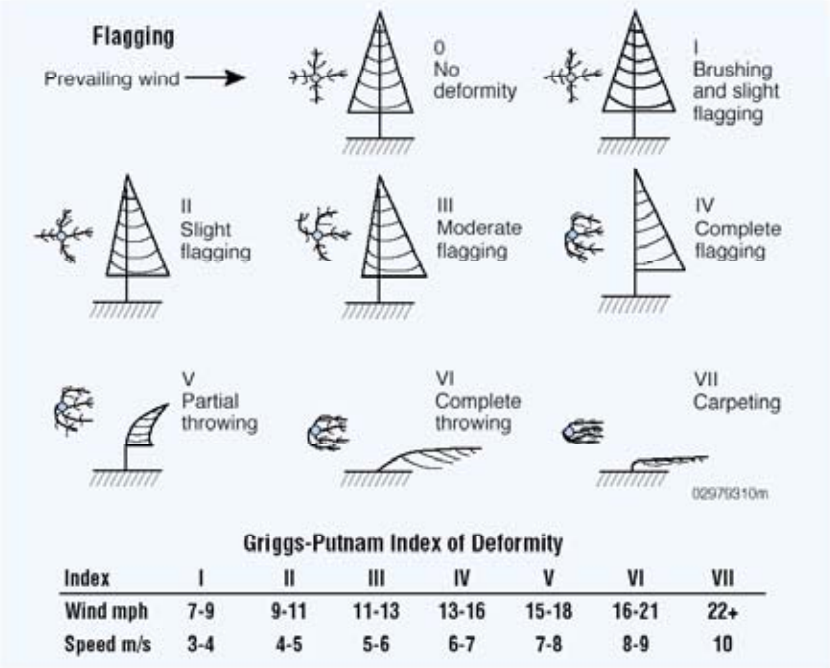
UK Wind Speed Map

Local airports can also often provide data however average wind speeds increase with height and may be 15%–25% greater at a typical wind turbine hub-height of 80 ft (24 m) than those measured at airport anemometer heights.



Observation of trees can also provide a good indication of wind speeds. The Beaufort Scale helps provide information on actual wind speeds whereas the Griggs-Putman index of deformity provides information on average wind speeds.

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One of the first scales to estimate wind speeds and the effects was created by Britain's Admiral Sir Francis Beaufort (1774-1857). He developed the scale in 1805 to help sailors estimate the winds via visual observations. The scale starts with 0 and goes to a force of 12. The Beaufort scale is still used today to estimate wind strengths.

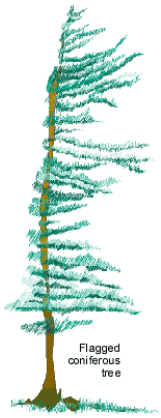
The Beaufort Scale for use on land

Beaufort Force	Description	Effects on land	Speed		
			Knots	km/h	Mph
0	Calm	Smoke rises vertically.	Less than 1	Less than 1	Less than 1
1	Light Air	Direction of wind shown by smoke drift, but not by wind vanes.	1 - 3	1 - 5	1 - 3
2	Light breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind.	4 -6	6 - 11	4 -7
3	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag.	7 - 10	12 - 19	8 - 12
4	Moderate breeze	Raises dust and loose paper; small branches are moved.	11 - 16	20 - 29	13 - 18
5	Fresh breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.	17 - 21	30 - 39	19 - 24
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	22 - 27	40 - 50	25 - 31
7	Near gale	Whole trees in motion; inconvenience felt when walking against the wind.	28 - 33	51 - 61	32 - 38
8	Gale	Breaks twigs off trees; generally impedes progress.	34 - 40	62 - 74	39 - 46
9	Strong gale	Slight structural damage occurs (chimney-pots and slates removed).	41 - 47	75 - 87	47 - 54
10	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	48 - 55	88 - 101	55 - 63
11	Violent	Very rarely experienced; accompanied by widespread damage.	56 - 63	102 -	64 - 73

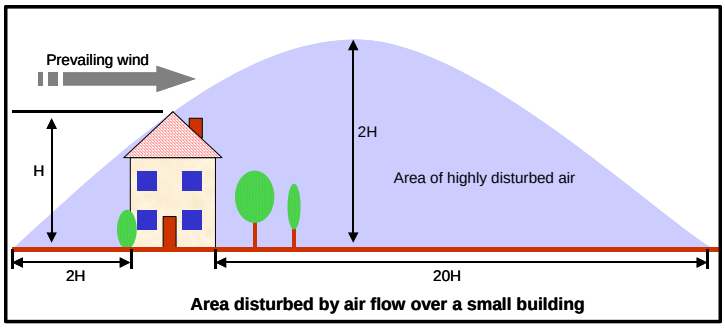
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	storm			117	
12	Hurricane	Whole hangars disappear.	>64	>119	>74

You can have varied wind resources within the same area. In addition to measuring or finding out about the annual wind speeds, you need to know about the prevailing directions of the wind at your site. If you live in complex terrain, take care in selecting the installation site. If you site your wind turbine on the top of or on the windy side of a hill, for example, you will have more access to prevailing winds than in a gully or on the leeward (sheltered) side of a hill in the same area. You also need to consider existing obstacles such as trees, houses, sheds, out buildings and electrical pylons. Don't forget to plan for future obstructions such as new buildings or trees that have not reached their full height.

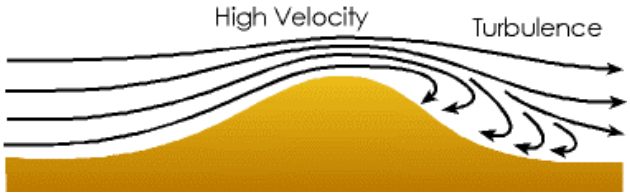


Room will be needed to raise and lower the tower for maintenance, and if your tower is guyed, you must allow space for the guy wires. Whether the system is stand-alone or grid-connected, you will also need to take the length of the wire run between the turbine and the load (house, batteries, water pumps, etc.) into consideration. A substantial amount of electricity can be lost as a result of the wire resistance—the longer the wire run, the more electricity is lost. Using more or larger wire will also increase your installation cost. Your wire run losses are greater when you have direct current (DC) instead of alternating current (AC). So, if you have a long wire run, it is advisable to invert DC to AC.



Area disturbed by air flow over a small building

The economics leads us to the second consideration, which is the cost of the system, and whether the power produced is less per unit than electricity supplied to you from the mains. This point may not be decisive in deciding whether wind power is for you as the satisfaction of building and running a wind power unit may be enough on its own without any financial benefits, in addition you will be generating pollution free power. Each site evaluation will take into account different components but generally they are as follows.



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- The total cost of installing the system - the wind generator itself, wiring, a tower or mountings, control system, batteries and an inverter should a 240-volt ac supply be required.

- The cost of installation at the site, such as scaffolding, should the unit be placed on top of an existing building and the cost of a survey of the best location using wind measurement instruments.

The costs should be set over a year and the cost of maintenance added. It is then simply a matter of dividing these costs by the kWh produced by the system. However when comparing the unit cost against the cost of electricity supplied via the mains it is worth considering that the power produced is tax free i.e. you do not have to earn the money to pay for it and therefore save income tax and any other taxes like VAT in the UK. Furthermore the annual cost will not rise significantly, where as electricity supplied to you may rise in the future.

To decide what unit would be practical it is wise to consider the average wind speed, the size of the site, the power required and the cost of the unit. In order to evaluate these it is perhaps best to look at some of the fundamentals behind windmill design. The actual position of the windmill on the site should take into account the position of existing and future buildings. Areas of turbulence caused by buildings subject the windmill and tower to undue stress.

Small-scale wind power is particularly suitable for remote off-grid locations where conventional methods of supply are expensive or impractical.
Most small wind turbines generate direct current (DC) electricity. Off-grid systems require battery storage and an inverter to convert DC electricity to AC (alternating current - mains electricity). A controller is also required to ensure the batteries are not over or under-charged and can divert power to another useful source (e.g. space and/or water heaters) when the battery is fully charged. It is common to combine this system with a diesel generator for use during periods of low wind speeds. A combined wind and diesel system gives greater efficiency and flexibility than a diesel only system. It allows the generator to be used at optimum load for short periods of time to charge batteries when there is little wind, rather than by constant use at varying loads.

Wind systems can also be installed where there is a grid connection. A special inverter and controller converts DC electricity to AC at a quality and standard that is acceptable to the grid. No battery storage is required. Any unused or excess electricity can be exported to the grid and sold to the local electricity supply company.

Systems up to 1kW will cost around £3000 whereas larger systems in the region of 1.5kW to 6kW would cost between £4,000 - £18,000 installed. These costs would be inclusive of the turbine, mast, inverters, battery storage (if

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required) and installation, however it's important to remember that costs always vary depending on location and the size and type of system.
Turbines can have a life of up to 20 years but will require service checks every few years to ensure they continue to work efficiently. For battery storage systems, typical battery life is around 6-10 years, depending on the type, so batteries may have to be replaced at some point in the system's life.

Last, one of the most important aspects to consider is safety. A windmill in a gale presents a great hazard if there is not a breaking system or proper control of the unit. It is therefore important to ensure that the unit has an adequate mounting if it is to be fixed to an existing building or if onto a tower, that the tower is of suitable strength and is secured by guy-rope type supports. The windmill should be placed in a position so that the revolving blades can not come into contact with any objects especially people, this is particularly important where space is limited such as on a boat. The siting of the unit should also take into account noise and vibration; the rotors make noise as they shed power when the blades stall. The vibration caused could be a problem for instance if the windmill is mounted on an inhabited building.

Wind turbine design

A windmill takes energy from the wind (fluid) and produces power. The maximum theoretical power is 16/27 of the wind's power this is known as the "Betz limit". The wind's energy, because it is moving, is in the form of kinetic energy and if the propeller captured all the energy or rotor there would not be airflow consequently it can be said that the "lost" energy is used to keep the air flowing.

The maximum power available P is equal to –

$K \times D \times A \times V^3$

Where
K is a constant (Betz Limit)
D is the density of air (kg/m^3)
A is the swept area of the blade (m^2)
V is the velocity of the wind (m/s)

It can be seen that by doubling the velocity of the wind the available power is increased eight times (2x2x2) and by doubling the blade diameter the available power is increased four times. When the power required is known and estimating the efficiency of the machine it is possible to size the rotor for the average wind speed available. Equally the efficiency that manufacturers claim can be calculated. It should be noted that when calculating the power available the efficiency of the total system should be used, that is, not only the generator and gearbox but also the transmission and storage.

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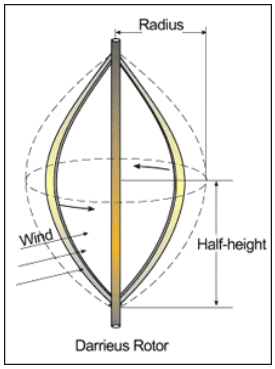
Wind turbines have "rated outputs" which give the best output at a particular wind speed. But this output must not be taken to mean power available i.e. rated output x hours, as the wind speed is not constant and will vary from around 1/10 to 1/3 of the figure.

Efficiencies achieved in practice are much less than the theoretical 59.3%(16/27), that of a traditional windmill with a small number of sail-like blades is a little over 5%. However since wind is often available in practically unlimited quantities, this "efficiency" can become of little significance.

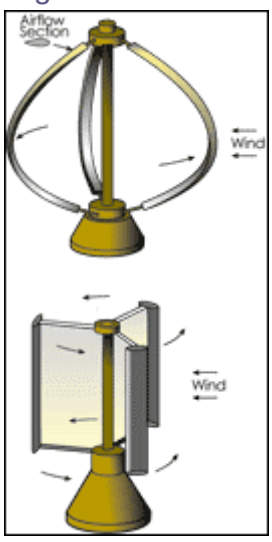
Types of Windmills

Wind units can be divided into two major types, horizontal axis and vertical axis machines.

Horizontal machines some times known as HAWT (Horizontal Axis Wind Turbines) are the traditional conventional design, they consist of a rotor with one to twenty blades driving a generator or a pump either directly or through a gearbox, chain or belt system. A tail vane or fantail is required to direct the machine into the wind.



They are usually more efficient than vertical axis units known as VAWT (Vertical Axis Wind Turbines). Savonious and Darius are two designs of vertical axis machines. This type of unit is often not situated on a tower and does not have to be directed into the wind. Materials and construction are usually cheaper than horizontal axis machines. The Savonious windmill was the brainchild of Sigrid Savonious of Finland. The racing driver of the 1930s said the secret of a good machine was to "add lightness and simplicate". Attaching two halves of vertically split oil barrel to a vertical axis produces a low speed high torque unit that can be used for pumping water and through a gearing mechanism, generating electricity, can make a simple unit. This design also has the advantage of an aerodynamic effect called the "Magnus principal"; the air moving over the convex face of the rotor forms suction. This means that there is force acting on the face of the rotor pulling it into the wind.



The Darius windmill was named after its French inventor. It is also known as catenary because of its profile when operating. The mill consists of slim aerofoil section blades taking up an oval or rugby ball shape when spinning due to the centrifugal forces exerted. The design gives a high output for the mass of the structure at relatively low cost. Darius units will often not start to turn by themselves and need either an electric start or use a small Savonious unit attached to the top. As the blades revolve they lose some energy as the head into the wind reducing the output.

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Other types of windmill design include an H shape vertical axis machine designed at Reading University by a team lead by Dr Peter Musgrove; the H rotor is centrally mounted and consists of very thin aerofoil of un-tapered section. It has the advantage of being simple and also has a feathering device. Robert Walker in Wales designed an unorthodox windmill. It consists of a cone facing into the wind and the rotor (horizontal) set behind it. The wind speed increases as it passes over and around the cone. Most of the units available commercially, are of the horizontal type. However DIY plans are available for vertical axis units.

Sizing your system

In order to estimate what size system you will require, you must first work out how much energy you use. This is simply a matter of working out the energy consumption of all the electrical appliances you use. The power rating in Watts (found on the makers plate on the back of the appliance), multiplied by the time in hours the appliance will be used for each day gives the amount of energy in Watt-hours you will need to generate each day in order to run the appliances. The more energy you need the bigger and more expensive the system becomes, so it is worth checking to make sure you are using energy efficiently at this stage. Fitting low energy light bulbs and using sources other than electricity for heat (i.e. kettles, cookers, etc on gas or wood fuel) will ultimately make a big difference in the overall cost of the system.

Here are some typical ratings in Watts of everyday appliances. (1000 Watts = 1kW)

Central Air Conditioner	5000
Electric Clothes Dryer	4800
Electric Water Heater	3000
Dish Washer	1500
Toaster	1000
Hair Dryer	1000
Drill - heavy duty	1000
Drill - light duty	220
Washing Machine	800
Dryer - motor only	500
TV - 21"	125
VCR	40
Refrigerator	120
Blender	350
Stereo	30
Rechargeable device	6
Computer & Monitor	110
Computer printer	120
Microwave	900
Food Processor	400
Vacuum Cleaner	650
Light - Incandescent	60 to 100
Light - Fluorescent	15 to 45
Low energy light……..	11 to 20

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Rotor Design (horizontal axis)

To produce the maximum power the generator must turn at the correct speed, it is therefore necessary to match the rotor design to the generator either through direct drive or through a gearbox. There are two types of rotor design.

High solidity, low tip speed ratio - typified by the Cretan sail rotor - the low RPM it most suited to pumping or electrical generation through a gearbox. High starting torque at rest enables good low wind speed performance. They are relatively easy to manufacture from sheet metal, timber and canvas. Wires and stiffening struts can be used with little reduction in performance. Blade design is not critical and accurate balancing is not required. The large amount of material needed to construct the rotor gives a high weight for the diameter and power produced. The large cross section also presents a problem and it is necessary to turn the machine out of high winds.

Low solidity, high tip speed ratio - the design usually consists of a two or three propeller type rotor, they are most often used for electrical generation as no gearbox or only a low cost gearbox is required. Higher efficiencies are usually achieved with this design compared with high solidity designs. The blades are usually costly to make and can be unreliable due to the high speeds and vibration. Impact damage can also be a problem. Straight grained woods, fibreglass and aluminium are all used as construction materials but fracture can still occur. Because very little torque is produced when the blade is stationary starting can be difficult. A small fan can be used to overcome this problem.

As both extremes have advantages and disadvantages, rotors are usually made to incorporate aspects from both designs, an example being a small aerofoil section with several blades.

Cut-in wind speed

This is the wind speed at which the wind generator begins producing. For all practical purposes, wind speeds below about 6 to 7 mph (3 m/s) provide little or no usable energy, even though the blades may be spinning. At best, this minimal output only overcomes the power losses caused by a long wire run or the voltage drop due to diodes. We are beginning to see high-tech controllers that are able to “store” the small amount of energy available at low wind speeds in the alternator windings. This energy is then pulsed to the batteries in a manner similar to a pulse width modulated charge controller.

Rated wind speed

This is the wind speed at which the wind generator reaches its rated output. Note that not all wind generators are created equal, even if they have comparable rated outputs. There is no industry standard for rated wind speed. The listed wind generator companies rate their turbine output at anywhere from 18 to 31 mph (8–14 m/s). This may not sound like a big issue until you

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understand that there is potentially 511 percent more power in a 31 mph wind than in an 18 mph wind.

Rated output

This measurement is taken at an arbitrary wind speed that the manufacturer designs for. It tends to be at or just below the governing wind speed of the wind generator. Any wind generator may peak at a higher output than the rated output. The faster you spin a wind generator, the more it will produce, until it overproduces to the point that it burns out. Manufacturers rate their generators at a safe level, well below the point of self-destruction.

You are not necessarily interested in the rated output of a wind generator. A turbine with a high rated wind speed will invariably cost less than one with a lower rated wind speed, for the same rated output. A higher wind speed gives certain wattage to the manufacturer at a smaller rotor diameter, smaller physical size of the generator, and subsequently less weight. All of this means less cost for the manufacturer, and less cost to you. But remember, it takes a higher wind speed to achieve that rating. In a 12 mph (5 m/s) average wind speed site, you will see 18 mph (8 m/s) winds a mere 3 percent of the time. But you will see 31 mph (14 m/s) winds for less than 0.2 percent of the time. Rated output comes to us from the photovoltaic industry, where panels are tested for output at a fixed light intensity and a fixed temperature. The wind industry has no such fixed standards. So, while comparing PVs based on rated wattage makes for great cost comparisons, comparing rated outputs is a poor way to compare wind generators. You are far better off comparing swept areas, or the KWH per month of electricity the different systems will produce at different average wind speeds.

Peak output

This figure may be the same as rated output, or it may be higher. Wind generators reach their peak output while governing, which occurs over a range of wind speeds above their rated wind speed. Although widely touted by some marketers, it has limited relevance to the buyer. To quote Hugh Piggott, “Peak or rated output specifications for small wind turbines can be red herrings unless you take the rated wind speed into account, and yet these specs are all the customers seem to want to know about.” Wind turbines are not PVs, don’t operate in the same manner, and should not be rated in the same way. What you should be asking is what wind energy engineer Eric Eggleston asked, “What will this wind generator do at my site with my average wind speed?”

Maximum design wind speed

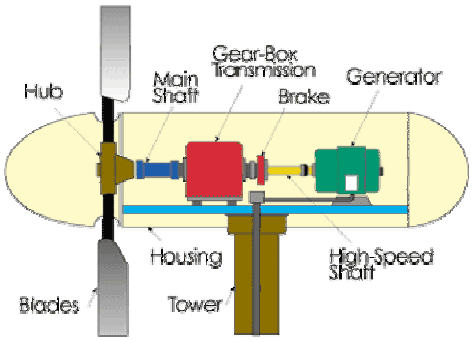
Often described in wind turbine literature, this term has little bearing on the expected life of a wind generator. Engineers, on paper, design wind generators to survive wind speeds of 120 mph (54 m/s) or more. Unfortunately, wind turbines are not tested for these survival speeds because it is a very difficult thing to test for, or to test repeatedly. Much of the survival speed documentation is not from actually testing turbines at those speeds, but from anecdotal situations. If you watch a wind generator sited on a short tower

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near trees and building you will see it hunt around continuously, all the while buffeted by the turbulence caused by the short installation height, along with the nearby ground based wind flow interference. It is suspected that more wind turbines are destroyed by turbulence than have seen destroyed in survival-rated high winds. Furthermore, when wind speeds reach 100 mph or more the wind turbine and flying debris rather than the wind itself can often damage tower.

Generators

To make electricity an electrical generator is required. The first wind generators used a dynamo. These have now been replaced with alternators designed to give high efficiencies at low speeds. Car alternators can be used however they are designed to run at high speed and are therefore not normally suitable without gearing or modification.



Standard alternators use electric fields that use power typically around ten percent of the power generated and are less efficient than permanent magnet alternators. This is particularly true at low wind speeds. Although permanent magnet alternators are far more suited to the generation of electricity using wind power they are very expensive. As energy is not needed to excite the electromagnetic winding efficiencies of 60 - 80 % can be achieved.

Towers

A wind turbine must have a clear shot at the wind to perform efficiently. Turbulence, which both reduces performance and "works" the turbine harder than smooth air, is highest close to the ground and diminishes with height. Also, wind speed increases with height above the ground. As a general rule of thumb, you should install a wind turbine on a tower such that it is at least 30 ft above any obstacles within 300 ft. Smaller turbines typically go on shorter towers than larger turbines. A 250 Watt turbine is often, for example, installed on a 30-50 ft tower, while a 10 kW turbine will usually need a tower of 80-120 ft. We do not recommend mounting wind turbines to small buildings that people live in because of the inherent problems of turbulence, noise, and vibration.

The least expensive tower type is the guyed-lattice tower, such as those commonly used for ham radio antennas. Smaller guyed towers are sometimes constructed with tubular sections or pipe. Self-supporting towers, either lattice or tubular in construction, take up less room and are more attractive but they are also more expensive. Telephone poles can be used for smaller wind turbines. Towers, particularly guyed towers, can be hinged at their base and suitably equipped to allow them to be tilted up or down using a winch or vehicle. This allows all work to be done at ground level. The purchaser can easily erect some towers and turbines, while others are best left to trained professionals. Anti-fall devices, consisting of a wire with a latching runner, are

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available and are highly recommended for any tower that will be climbed. Aluminium towers should be avoided because they are prone to developing cracks. Wind turbine manufacturers usually offer towers and purchasing one from them is the best way to ensure proper compatibility.

Energy Usage

As discussed earlier the two main uses for wind power are water pumping and the generation of electricity. Presumably anyone who purchases or constructs a unit capable of pumping water already has a use in mind. With electricity it can be put to use in different forms.

Most small windmills whether bought off the shelf or DIY will give a 12 volt or 24 volt dc output. dc stands for "direct current", it is the same form as that supplied by a car battery or a torch battery. This can be used to power direct current appliances like radios and electric motors. Many manufacturers supply a range of special appliances adapted to run on dc current from lights to refrigerators. Other dc equipment includes car, boat and caravan accessories. Many small portable televisions also run from a 12v-dc supply.

If this voltage and current type is not suitable for the appliances you wish to power there is an alternative. An instrument known as an "inverter" can be used to change the 12v or 24v supply into 240v ac. Ac standing for "alternating current". This is the type of electricity supplied by the main supply in most countries. In the USA, amongst others, the main supply is 115v ac.
Inverters have two main components, a transformer to change the voltage and electronic circuits to produce the alternating current. It should be noted however that inverters use quite a lot of power in carrying out this conversion. Inverters are sized or rated according to their potential power output, which is measured in Watts. The higher the output the more costly each unit is.

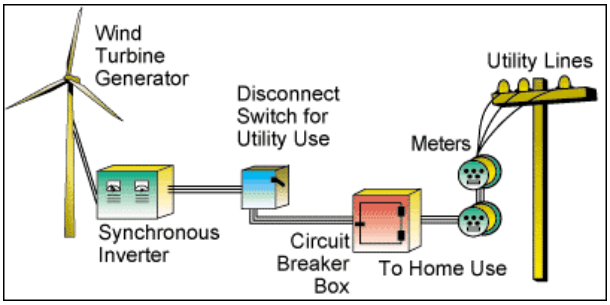
Household appliances use different amounts of power. Generally those which produce heat directly or indirectly such as electric fires or fridges use much more than those that do not such as cassette recorders and radios.

Grid-connected system

With a grid connected system the output of the wind turbine generator is directly connected to the existing mains electricity supply. This type of system can be used either for individual wind turbines or for wind farms selling (exporting) electricity to the national grid. If for export, such a wind farm would not directly serve the electricity needs of the farmer, but would be a business in its own right involving the generation and sale of electricity. An average household uses about 10,000 kilowatt-hours (kWh) of electricity each year. One megawatt of wind energy can generate between 2.4 million and 3 million kWh annually. Therefore, a megawatt of wind generates about as much electricity as 240 to 300 households use. The "number of homes served" is just a convenient way to translate a quantity of electricity into a familiar term that people can understand

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A grid connected wind turbine or turbines can be a good proposition if your consumption of electricity is high. Then the energy produced by the wind system can be used to reduce the energy taken from the grid. The value of avoided electricity purchases is generally significantly higher than the value that can be obtained from exporting power to the grid.



When a wind turbine connection to the mains supply is made it has to be approved by your local Regional Electricity Company. They will insist on the connection being to a high technical standard and therefore cost, incorporating power import and export metering and approved electrical protection equipment. They may also limit the size of the wind turbine that may be connected in a particular area depending on the loading of the electrical distribution system in the vicinity. For this reason it is easier to obtain a grid connection if the local grid is generally reliable and not overloaded.

For small wind turbines the cost of grid connection can be a substantial part of the total project cost. For this reason grid connection is generally a better option with larger wind turbines - usually 60kW or above.

Energy Storage

Batteries

Because you do not want to always use the electricity produced by a wind generator immediately a form of storage is usually required. The most readily available battery available is the lead acid battery used in cars, lorries, boats, etc. Sealed or maintenance free batteries are the best lead acid battery and can give up to 8 years of life. All batteries are very expensive but sometimes using second hand batteries can reduce this cost. Car batteries can be destroyed if not maintained carefully. Deep-cycle batteries are designed with this type of usage in mind and are available new or second-hand. Lead acid batteries can be very dangerous - explosive gases are released during charging and the acid contained within the battery is highly corrosive.

Batteries are essential in most systems, yet are expensive and will deteriorate eventually. Batteries store low voltage (up to 48V) DC electricity and need to be protected from over and under charging. Lead-acid batteries are the most cost effective, although other types such as nickel-cadmium are available. Deep cycle batteries are optimal for renewable energy applications, being designed to have up to 80% of their charge removed and repeatedly replaced over a period of 5-15 years (or 1000 ž2000 times). Motor vehicle batteries should not be used since they are specifically designed to give a short burst of high current and be immediately recharged again. They perform poorly if they are allowed to discharge more deeply. It is important that proper safety

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procedures are followed when dealing with batteries. [For further information on battery safety see BS 6287 (1983) Codes of practice for the safe operation of traction cells.]

Look for are batteries with the highest AH (Amp Hour) rating as possible. The higher the AH rating, the longer the battery will last without having to recharge it. The AH rating is the amount of hours that a battery will last with a 1 Amp current load attached to it at 80 degrees F. To make things even more complicated, some batteries have a RC (Reserve Capacity) rating. The RC is the number of minutes for the voltage of a battery to go below 10.5 Volts with a 25 Amp current attached to it at 80 degrees F. To simplify things, we'll just talk about AH and not RC. If you are at a store looking at batteries and they only have a RC on the battery, you can easily convert RC to AH by multiplying the RC by 0.6.

Batteries can be checked with a voltmeter or with a hydrometer. A hydrometer checks each cell for specific gravity and can be purchased at a car parts store. Before checking, recharge the battery and then remove the surface charge by letting it stand for several hours. Then check it and compare to the following table:

State of Discharge	Voltage Specific	Gravity
100%	12.65	1.265
75%	12.45	1.225
50%	12.24	1.190
25%	12.06	1.155
0%	11.89	1.120

Subtract .0012 volts for every 10 degrees below 80 degrees F or .004 specific gravity for every 10 degrees below 80 degrees F.

Hot water

Another method of storing the energy produced by a windmill is to use it to heat water. Hot water is a very usable form of storage, the amount of energy lost over time being dependent on the insulation around the hot water tank. This method of storage is best suited to larger wind chargers as it is most likely that the limited amount of energy produced by smaller units would be better utilised in the form of electricity for other purposes. Also low temperature water is also difficult to exploit unless it is a feed to another heating system.

Most domestic immersion heaters are rated at 3 kW, but 1 kW models are available. A thermostat must be incorporated to prevent the water in the tank from boiling. By using a load diverter priority can be given to charging batteries and any additional/spare load can be diverted to heat water. It is better to have a small amount of hot water than a large amount of warm water; therefore small water tanks are preferable. To increase the storage capacity more than one tank can be arranged in serial with an immersion heater in each. The tank nearest to the outlet should have the highest

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thermostat setting. The incoming cold water feed enters the coldest tank first, pushing this preheated water on to the next tank.

A wind powered immersion heater does not have to be the only means of heating the water. It can be used in conjunction with an existing immersion heater supplied by the mains by adapting or purchasing a new hot water tank to take the additional heater.

The thermostat controlling the wind powered heater should be set at a higher temperature than the thermostat controlling the immersion heater supplied by mains electricity. This will allow the home produced electricity to be used first. It is often possible to add an immersion heater to a hot water system heated by a boiler, central heating, etc. The thermostat should again be set higher on the immersion heater supplied by the home produced electricity than the thermostat on the boiler. Finally, it should be remembered that as long as the wind blows the windmill would produce electricity 24 hours a day.

Topping up wind generated electricity

Wind power is often chosen either because an electrical mains supply is not available on practical grounds such as with some caravans, houseboats, etc. or because it is too expensive to install because of the remote location. It would be unlikely that wind power could provide all the electricity required and therefore additional means of generating electricity may need to be considered. Systems available include photovoltaics, waterpower and conventional small generators, etc. The advantages and disadvantages of these systems are described below.

Photovoltaics (PV)

Photovoltaic cells (PVs) are a very different technology from solar water heating, and use light to generate electricity. They are particularly well suited to sites where a grid connection would be difficult or expensive or that are only used in the summer. For an independent power supply, solar works well with wind as there is a good balance of both over the year. Solar electricity, like electricity from other renewable energy sources, doesn't produce carbon dioxide or harm the environment.
Although start-up costs are higher than other renewable technologies, PVs have key advantages:

- no moving parts to fix so they are relatively easy to install and maintain
- they can be sited in urban areas and are not restricted in the way that wind and hydro-power systems are
- they can replace other roofing materials, for example tiles. The cells are embedded in a flat, waterproof material to form 'modules', which make ideal cladding material for walls and roofs
- they need not take up any additional land space.

It is hoped that efficiency gains will make PVs a very attractive proposition in the next two decades.

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Solar panels that produce electricity are expensive to buy and produce only relatively small amounts of electricity. They need to be sited in a good position and may take up a lot of valuable space. However they do have the advantage of producing pollution free energy and the output is greater in the summer, which is often when the wind is not so strong.

Photovoltaic systems use cells to convert solar radiation into electricity. The PV cell consists of one or two layers of a semi conducting material, usually silicon. When light shines on the cell it creates an electric field across the layers, causing electricity to flow. The greater the intensity of the light the greater the flow of electricity.

PV systems generate no climate changing gases, saving approximately 325kg of carbon dioxide per year for each kW peak installed (Kilowatt (kW) peak - PV cells are referred to in terms of the amount of energy they generate in full sun light). PV arrays now come in a variety of shapes and colours, ranging from grey 'solar tiles' that look like roof tiles, to panels and transparent cells that you can use on conservatories and glass to provide shading as well as generating electricity. As well as enabling you to generate free electricity they can provide an interesting alternative to conventional roof tiles!

You can use PV systems for a building with a roof or wall that faces within 90 degrees of south, as long as no other buildings or large trees overshadow it. If the roof surface is in shadow for parts of the day, the output of the system decreases. Another consideration is that the roof also be strong enough to hold the significant weight of the panels, especially if the panel is going to be placed on top of existing tiles. A trained and experienced installer should always carry out solar PV installations.

Prices for PV systems vary, depending on the size of the system to be installed, type of PV cell used and the nature of the actual building on which the PV is mounted. The size of the system is dictated by the amount of electricity required to be supplied.

For the average domestic system, costs can be around £4,000- £9,000 per kwp installed with most domestic systems usually between 1.5 and 2 kWp. Solar tiles cost more than conventional panels and panels that are integrated into a roof are more expensive than those that sit on top. If you intend to have major roof repairs carried out it may be worth exploring PV tiles as they can offset the cost of roof tiles.

Grid connected systems require very little maintenance, generally limited to ensuring that the panels are kept relatively clean and that shade from trees has not become a problem. The wiring and components of the system should however be checked regularly by a qualified technician.

Some local authorities in the UK for example require planning permission to allow you to fit a PV system, especially in conservation areas or on listed buildings. Always check with your local authority about planning issues before

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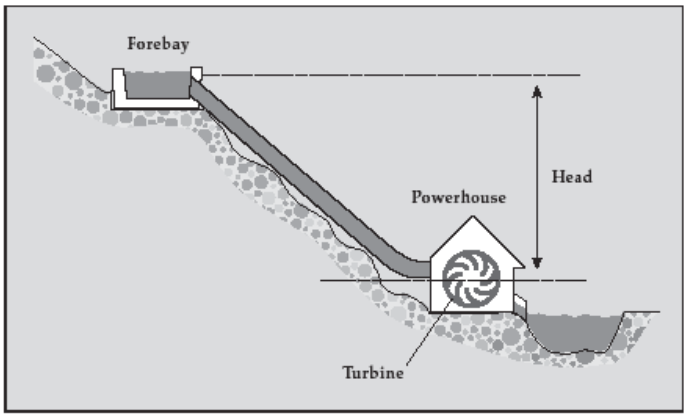
you have a system installed. Obtaining retrospective planning permission can be difficult and costly!

Water power

Obviously waterpower is only possible where there is a usable source of running water. Construction and installation is expensive and maintenance is relatively high. The energy produced is again pollution free.

Hydropower systems convert potential energy stored in water held at height to kinetic energy (or the energy used in movement) to turn a turbine to produce electricity.

Hydro Electricity can be one of the cheapest methods of providing off the grid renewable electricity, but it is also very site specific. One advantage is that on a good site you may not need batteries or an inverter - the turbines will often produce 240 volts AC and can just be turned on when needed. The ideal situation is one where there is no grid electricity (otherwise the capital cost of a system is generally too high to make it financially viable on a small scale), and a watercourse with a good flow and a high head. You will have to obtain an abstraction licence in the UK from the Environment Agency.



Head is the vertical distance the water falls. Higher heads require less water to produce a given amount of power.

A good hydro site depends on the 'head' of water (the vertical drop) and the flow rate. To estimate the energy in a water source, multiply the flow (in litres per second) by the head (in metres) by 10 (acceleration due to gravity). Divide your answer by 2 to account for losses and inefficiencies, and you will have a rough idea of the potential power generation in watts.

Although it will cost several thousand pounds to install a hydro system, in some situations it will be cheaper than paying the cost of connecting to the grid. The basic equipment for a 1kW battery charging system might cost £5,000 to £6,000, plus installation costs, while a larger system can cost tens of thousands of pounds.

Old watermills, and other low-head sites, are not usually good sites for generating electricity. A large, slow-moving body of water gives a high torque,

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which is needed by mills for mechanical work, whilst it is easier to generate electricity where there is a fast flow of water that can be channelled to hit the turbine at high pressure. However, some old waterwheels have been converted to generate electricity, so it may be worth looking into.

A micro hydro plant is below 100kW. Improvements in small turbine and generator technology mean that micro hydro schemes are an attractive means of producing electricity. Useful power may be produced from even a small stream. The likely range is from a few hundred watts (possibly for use with batteries) for domestic schemes, to a minimum 25kW for commercial schemes.

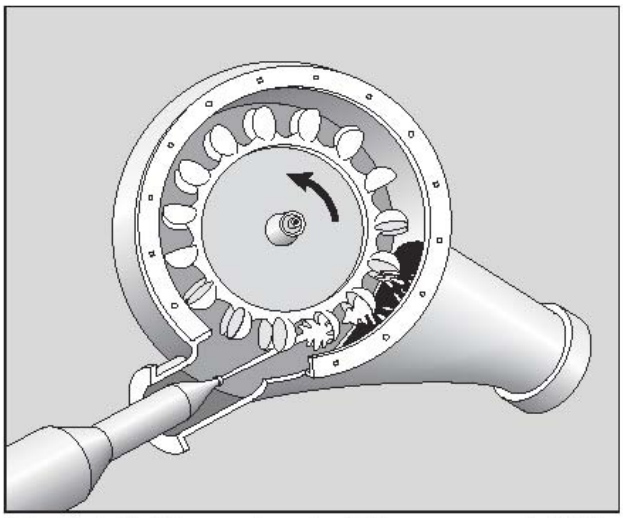
Hydropower requires the source to be relatively close to the site of power usage, or to a suitable grid connection. Hydro systems can be connected to the main electricity grid, or as a part of a stand-alone (off-grid) power system. In a grid-connected system, any electricity generated in excess of consumption on site can be sold to electricity companies.

In an off-grid hydro system, electricity can be supplied directly to the devices powered, or via a battery bank and inverter set up. Allowances should be made for any seasonal variations in water flow, which can affect the amount of electricity delivered to the system i.e. having a back up power system.
It is possible for single households with a mains connection located near a hydro source to install a micro hydro system. They can go off the grid entirely, or stay connected and sell excess electricity to the grid. The capital cost is high, but the prospect of zero or even negative electricity bills may tempt you!

Provided the resource is there, community hydro projects can also be a viable proposition. Potentially, there are great benefits in clubbing together to increase buying power or sharing expertise - although the work involved should not be underestimated.

Energy available in a body of water depends on the amount of water flowing per second, and the height (or head) that the water falls. The scheme's actual output will depend on how efficiently it converts the power of the water into electrical power (maximum efficiencies of over 90% are possible, but for small systems 50% is more realistic). Hydroelectric systems are generally divided into 2 categories, low and high head.

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Pelton wheels, like this one, can be purchased with one or more nozzles. Multi-nozzle systems allow a greater amount of water to impact the runner, which can increase wheel output.

This will depend on the resource available and your energy needs. For houses with no mains connection, but with access to a micro-hydro site, a good hydro system can generate a steady, more reliable electricity supply than other renewable technologies at a lower cost. Total system costs can still be high, but often less than the cost of a grid connection, and with no electricity bills to follow. Note that in off-grid applications the power is used for lighting and electrical appliances, however space and water heating can be supplied when available power exceeds demand.

Hydro costs are very site specific and are related to energy output.
For low head systems (not including the civil works - so assuming there was an existing pond or weir), costs may be in the region of £4,000 per kW installed up to about 10kW, and would drop per kW for larger schemes.
For medium heads, a fixed cost of about £10,000, and then about £2,500 per kW up to around 10kW - so a typical 5kW domestic scheme might cost £20-£25,000. Unit costs drop for larger schemes.

Turbines can have visual impact and produce some noise, but these can be mitigated relatively easily. The main issue is to maintain the river's ecology by restricting the proportion of the total flow diverted through the turbine.
You will need to talk to the relevant planning authorities to ensure the site and design is acceptable and identify any other permissions required.

Wave energy

Not for the home generator but the energy contained in ocean waves can potentially provide an unlimited source of renewable energy.

Wind generated waves on the ocean surface of the world have a total (estimated) power of 90 million GW. Because of the direction of the prevailing winds and the size of the Atlantic Ocean, the UK has wave power levels that are amongst the highest in the world. The wave energy industry, like the tidal

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one, sees itself as having the potential of the wind industry but is currently around 10 years behind it. In 2003 the total capacity was 0.5 MW.

The connection of wave machines to the electricity grid system can pose a number of technical challenges, which can make the connection requirements more complex than connections for conventional generating plant.

Diesel and petrol generators

As long as the supply of fuel is maintained this form of generation should be available at any time. Both diesel and petrol generators are readily available new and second hand. The diesel used to run such plant has a lower tax than diesel used for transport. They are however noisy and usually use fossil fuels which pollute the atmosphere. DIY diesel and petrol generators can be constructed and plans are available from www.energybook.co.uk or the marketplace www.wxtrade.com

Biomass

Energy from biomass is produced from organic matter of recent origin. It does not include fossil fuels, which have taken millions of years to evolve. The CO2 released during the generation of energy from biomass is balanced by that absorbed during the fuel's production. We call this a carbon neutral process.
Biomass is often called 'bio energy' or 'biofuels'. These biofuels are produced from organic materials, either directly from plants or indirectly from industrial, commercial, domestic or agricultural products. Biofuels fall into two main categories:

- Woody biomass includes forest products, untreated wood products, energy crops, short rotation coppice (SRC) e.g. willow, miscanthus (elephant grass).

- Non-woody biomass includes animal wastes, industrial and biodegradable municipal products from food processing and high-energy crops e.g. rape, sugar cane, maize.

For small-scale domestic applications of biomass the fuel usually takes the form of wood pellets, wood chips and wood logs.

There are two main methods of using biomass to heat a domestic property:

Stand-alone stoves providing space heating for a room.

- Can be fuelled by logs or pellets but only pellets are suitable for automatic feed
- Generally 6-12 kW in output
- Some models can be fitted with a back boiler to provide water heating.

Boilers connected to central heating and hot water systems.

- Suitable for pellets, logs or chips

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- Generally larger than 15 kW.

Stoves can achieve efficiencies of more than 80%. They are normally used to provide background heating whilst adding aesthetic value, as they are designed to be located in the living area of the house itself. Although many wood burning stoves act as space heaters only, the higher output versions may be fitted with an integral back boiler to provide domestic hot water and, if required, central heating via radiators.

There are many domestic scale log, wood-chip and wood pellet burning central heating boilers available. Log boilers require manual loading and may be unsuitable for some situations, whilst automatic pellet and wood-chip systems can be more expensive. Many boilers will dual-fire both wood chips and pellets, although the wood chip boilers will require larger hoppers to provide the same time interval between refuelling.

Boilers can be designed with an integral hot water energy storage tank or accumulator tank that stores water up to 90 Deg C, enabling the supply of heat to be further decoupled from the combustion of the fuel. This is particularly helpful with log boilers where systems operate at full load and the matching of demand with load is performed by the accumulator.

You should consider the following issues if you are considering a biomass boiler or stove. An accredited installer will be able to provide more detailed advice regarding suitability.

Fuel: It is important that you have storage space for the fuel, appropriate access to the boiler for loading and a local fuel supplier.

Flue: The vent material must be specifically designed for wood fuel appliances and there must be sufficient air movement for proper operation of the stove. Chimneys can be fitted with a lined flue.

Regulations: The installation must comply with all safety and building regulations (see Part J of the Building Regulations).

Smokeless zone: Wood can only be burnt on exempted appliances, under the Clean Air Act. This mainly applies to domestic appliances.
Planning: If the building is listed, or in an area of outstanding natural beauty (AONB), then you will need to check with your Local Authority Planning Department before a flue is fitted.

Capital costs: This generally depends on the type and size of system you choose but installation and commissioning costs tend to be fairly fixed. Stand alone room heaters generally cost £1500 - £3000 installed. The cost for boilers varies depending on the fuel choice; a typical 20kW (average size required for a three bed semi detached house) pellet boiler would cost around £5000 installed, including the cost of the flue and commissioning. A manual log feed system of the same size would be slightly cheaper.

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Running costs: Unlike other forms or renewable energy biomass systems require you to pay for the fuel. Fuel costs are generally dependant on the distance from your fuel supplier; if you have a supplier near by this will reduce the costs of the fuel considerably. As a general rule the running costs will be more favourable if you live in an off gas area. Payback: This will depend on the fuel being replaced and the type of wood fuel being used but will be more favourable in off gas grid areas.

Producing energy from biomass has both environmental and economic advantages. It is most cost-effective when a local fuel source is used, which results in local investment and employment. Furthermore, biomass can contribute to waste management by harnessing energy from products that are often disposed of at landfill sites.

Solar water heating

Solar water heating systems gather energy radiated by the sun and convert it into useful heat in the form of hot water. This technology is well developed with a large choice of equipment to suit many applications. Solar water heating systems work alongside conventional water heaters to provide hot water.

It can provide almost all of your hot water during the summer months and about 50% year round. It will reduce your impact on the environment - the average domestic system can reduce carbon dioxide emissions by 0.25-0.5 tonne per year, depending on the fuel replaced. The system which best suits your needs depends on a range of factors, including:

- Amount of south facing roof space;
- Existing water heating system (e.g. some gas combi boilers may not be suitable);
- The budget you have for the project.

Solar water heating can be used for domestic water heating and also for larger scale applications such as swimming pools. A solar water heating system for domestic hot water comprises three main components: solar panels; hot water cylinder; and a plumbing system.

Solar panels are fitted to your roof and retain heat from the sun's rays and transfer this heat to a fluid. A hot water cylinder stores the hot water that is heated during the day and supplies it for use later. The plumbing system is made up of simple piping and sometimes a pump, which moves the fluid around the system.

Preferably you will need 2-4m^2 of southeast to southwest facing roof space that receives minimal shading during the main part of day.
Space to locate an additional water cylinder if required.

Costs vary due to a range of factors. The typical installation costs for flat plate collectors is £2,000 - £3,000 while evacuated tube systems will cost £3,500 - £4,500.

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Alternatively you can fit or build the system yourself. It can work out cheaper but will take longer and you'll need a certain level of skill. However, you should bear in mind that DIY jobs are not eligible for grant funding.

Solar hot water systems generally come with a 10-year warranty and require very little maintenance. A yearly check by the householder and a more detailed check by a professional installer every 3-5 years should be sufficient (although you should consult your system supplier for exact maintenance requirements).

Over 44,000 solar water heating panels have been installed in the UK to date. Solar panels contain water that is heated by the sun, and this then usually goes through a coil in a hot water cylinder, transferring the heat to the water there. You need to have a conventional water heating system as well, such as a gas or oil fired boiler, or perhaps a back-boiler on a wood stove, to top up the heat from the panels when necessary and provide hot water and space heating in the winter. (If wood comes from sustainable managed forests, it is potentially a renewable fuel and is carbon neutral as it absorbs the same amount of carbon dioxide when growing as it gives off when burnt. It is important that wood is well seasoned and burnt efficiently, or it will give off harmful dioxins.) In most cases solar water heating panels will not provide space heating because there is insufficient sun in the winter, when you need heating most.

If your boiler needs replacing, a condensing boiler is most efficient and you can find out further details in the UK from your local Energy Efficiency Advice Centre (Free phone 0800 512 012). Condensing boilers are more expensive but the savings on fuel should compensate for the extra cost within a few years. Indeed building regulations require that all new and replacement gas and oil fired boilers are condensing unless.

You can add solar panels to most existing hot water systems, though you will usually have to add an additional hot water cylinder or change your existing one to a twin coil cylinder. It can be more difficult to use solar water heating with a combi boiler because they are designed to take cold mains pressure water, and solar systems tend to supply hot or warm, low pressure water. Check with the boiler manufacturer or with a solar engineer to see if your boiler is suitable. Solar water heating is often ideal for swimming pools.

Ideally solar panels should be placed somewhere south facing and free of shade, and they can be mounted on the roof or at ground level. You may need a pump to circulate the water round and some regulating equipment.

There are two main types of commercial solar water heating panel available - flat plate and evacuated tubes. Although evacuated tubes are more efficient they are also more expensive and if you spend too much on installing a system you may not necessarily get your money back within its lifetime. (Though it would still have environmental benefits). You can compensate for the lower efficiency of flat plate collectors by installing a larger surface area.

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The cost of a flat plate system, including installation, for an average house ranges from about £2,000 to £4,000. Evacuated tube systems usually cost from £3,500 to £5,500. However the price will depend on the particular situation - whether you need scaffolding, for example. There are lots of solar water heating installers around, so it is always worth getting several quotes to compare prices. Beware of companies trying to pressure people into buying a system on the spot by offering special discounts, which in actual fact may not offer a real saving. DIY panels can be installed from around £500.

Ground source heat pumps (GSHP)

Ground source heat pumps (GSHP) transfer heat from the ground into a building to provide space heating and, in some cases, pre-heating domestic hot water. For every unit of electricity used to pump the heat, 3-4 units of heat are produced. As well as ground source heat pumps, air source and water source heat pumps are also possible.

The main elements of a GSHP are:

Ground loop - comprises lengths of pipe buried in the ground, either in a borehole or a horizontal trench. The pipe is usually a closed circuit and is filled with a mixture of water and antifreeze, which is pumped round the pipe absorbing heat from the ground.

Heat pump - although we may not know it heat pumps are very familiar to us - fridges and air conditioners are both examples. A heat pump has three main components:

1. **Evaporator** - (e.g. the squiggly thing in the cold part of your fridge) takes the heat from the water in the ground loop;

2. **Compressor** - (this is what makes the noise in a fridge) moves the refrigerant round the heat pump and compresses the gaseous refrigerant to the temperature needed for the heat distribution circuit. Condenser, (the hot thing at the back of your fridge) gives up heat to a hot water tank that feeds the distribution system;

3. **Heat distribution system** - consists of under floor heating or radiators for space heating and in some cases water storage for hot water supply.

Three options are available for the ground loop: borehole, straight horizontal and spiral horizontal (or 'slinky'). Each has different characteristics allowing you to choose the most suitable for your property. Horizontal trenches can cost less than boreholes, but require greater land area. For slinky coil, a trench of about 10m in length will provide for about 1kW of heating load.

The installed cost of a typical 8kW system varies between £6,000 and £10,000 plus the cost of the distribution system. Naturally costs are

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dependent on property and location so the cost for a system for your home may different to the estimate above.

The efficiency of a GSHP system is measured by the Coefficient of Performance (CoP). This is the ratio of the number of units of heat output for each unit of electricity input used to drive the compressor and pump for the ground loop. Typical CoPs range between 2.5 to 4. The higher end of this range is for under floor heating, because it works at a lower temperature (30-35C) than conventional radiators.

Based on current fuel prices, assuming a CoP of 3-4, a GSHP can be a cheaper form of space heating than oil, LPG and electric storage heaters. It is however more expensive than mains gas. If grid electricity is used for the compressor and pump, then an economy 7 tariff usually gives the lowest running costs.

You should consider the following issues if you are considering a ground source heat pump. An accredited installer will be able to provide more detailed advice regarding suitability.

- The type of heat distribution system. GSHPs can be combined with radiators but under floor heating is better as it works at a lower temperature.
- Is there space available for a trench or borehole to accommodate a ground loop?
- Is the ground material suitable for digging a trench or borehole?
- What fuel is being replaced? If it is electricity, oil, LPG or any other conventional fossil fuel the payback will be more favourable. This makes heat pumps a good option for off gas grid areas.
- Do you want to be 100% renewable? If so, purchase green electricity, or install solar PV or some other form of renewable electricity generating system to power the compressor and pump.
- Do you require a back up heating system?
- Is there also a cooling requirement?
- Is the system for a new building development? Combining the installation with other building works can reduce costs.
- Can you incorporate insulation measures? Including wall, floor and loft insulation will reduce your heat demand.

Visit the energybook marketplace to find great wind power products, books and more. Place you products on the marketplace.

http://www.wxtrade.com

NOTICE

The information contained in this guide has been given in good faith and is believed to be accurate at the time of writing. Whilst every effort has been made to obtain the correct information, no liability can be accepted for any information that is incorrect or misleading.

Website links

Energybook and associated websites

http://www.energybook.co.uk
A great website developed by the author of this guide it provides lots of information on renewable energy and sustainable living

http://www.wxtrade.com
The energybook marketplace - buy and sell renewable energy and sustainable living products for free. Hundreds of great products.

http://www.ometoremember.co.uk
Web based bookshop selling fiction and non-fiction books including renewable energy books.

Wind energy associations

ANEV - associazione nazionale energia del vento (I)
AWEA - American Wind Energy Association (USA)
APPA - Asociación de Productores de Energías Renovables (ES)
Austrian Wind Energy Association (A)
AUSWEA - Australian Wind Energy Association (AUS)
BWE - Bundesverband Wind Energie e.V., German Wind Energy Association (D)
BWEA - British Wind Energy Association (GB)
CANWEA - Canadian Wind Energy Association (CAN)
Les Compagnons d'Eole (B)
DV - Danmarks Vindmølleforening - Danish Wind Turbine Owners' Association (DK)
Dansk Selskab for Vindenergi (DK)
EOLE (CAN) (pour les francophones)
Estonian Wind Power Association (EST)
EWEA, European Wind Energy Association (EU)
Finnish Wind Power Association (FIN)
Global Wind Energy Council (GWEC)
Vindkraftföreningen Finland, Finnish Wind Energy Association (Swedish language)
IWEA, Irish Wind Energy Association (IE)
New Zealand Wind Energy Association (NZ)
PEE - Plataforma Empresarial Eólica (ES)
South African Wind Energy Association (ZA)
Suisse-Eole (CH)
Syndicat des Energies Renouvelables (FR)

Magazines and information services

Windpower Monthly Good international coverage of the wind business.
WindStats Newsletter Articles plus loads of statistics on wind energy production in many parts of the world.
Wind Directions is the magazine of the European Wind Energy Association, published six times a year, giving current developments and news on the wind energy industry in Europe.
Windpower Monthly publishes news and critical analyses of key issues about wind power and its markets. Includes The Windicator, the renowned page of market indicators, giving a country by country breakdown of installed capacity.
New Review is the Quarterly Newsletter for the UK New and Renewable Energy Industry, principally covering: wind, solar, biomass and hydro energy developments. Produced by ETSU on behalf of the DTI.
WindStats Newsletter is a quarterly international wind energy publication with news, reviews, wind turbine production and operating data from over 12,000 wind turbines, plus much more.
Renewable Energy World accentuates the achievements and potential of all forms of renewable energy sources and the technologies being developed to harness them. In this on-line version there are full text selected articles, abstracts, back issue information, and links to all of the other renewable energy information sources at James & James including its international database of renewable energy suppliers and services.
Renew On-Line is an edited, text only, version of parts of the News sections of RENEW, the journal of NATTA, the independent national UK Network for Alternative Technology and Technology Assessment. Members include the Energy and Environment Research Unit (EERU) and the Open University.
CADDET provides international information on renewable energy on full-scale commercial projects which are operating in the member countries, currently Australia, Belgium, Denmark, Finland, Japan, The Netherlands, Norway, Sweden, United Kingdom, United States and the European Commission (DGXVII - Energy). The CADDET programme covers the full range of renewable energy technologies.
EuroREX (European Renewable Energy Exchange) is an on-line commercial information service and newsletter created by a network of energy experts from 30 European countries. Its aim is to provide up-to-date information on renewables directly from professionals working in the field. European Renewable Energy exchange
Solstice is the Internet information service of the Renewable Energy Policy Project and the Center for Renewable Energy and Sustainable Technology (REPP-CREST). Sustainable energy and development information as well as renewable energy, energy efficiency and sustainable living
World-wide Information System for Renewable Energy (WIRE).
Wind Engineering. A bi-monthly journal which publishes technical papers on all aspects of wind energy systems.

Places to visit in the United Kingdom

The Centre for Alternative Technology in Wales is an educational charity striving to achieve the best cooperation between the natural, technological and human worlds. CAT tests, lives with and displays strategies and tools for doing this. CAT has it's own wind turbine as part of their work for a sustainable future.
The EcoTech Centre at Swaffham in Norfolk is an educational charity which aims to stimulate and inform people about the need for sustainable development. The Centre grounds include organic gardens, a biomass power station and one of the largest wind turbines in the world.
The Earth Centre at Doncaster encompasses a range of environmental exhibitions and activities. Tel 01709 512000 for further information.
The Gaia Energy Centre in Cornwall is a centre for the promotion of, and education about, renewable and sustainable energy and energy conservation.
Many wind farms have visitor centres or opportunities to see the turbines at closer range. Specific details can be found in our map of wind farms of the UK.

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Scientific and research institutions

The Wind Turbine Research Group at Cranfield Universtity.
Institute for Wind Energy at Delft University of Technology in The Netherlands.
National Wind Technology Center at The National Renewable Energy Laboratory. The U.S. Department of Energy's premier laboratory for renewable energy and energy efficiency research, development and deployment.
Risoe National Laboratory Wind Energy and Atmospheric Physics department.The research of the department aims develop new opportunities for industry and society in the exploitation of wind power and to map and alleviate atmospheric aspects of environmental problems in collaboration with the National Environmental Research Institute.
The Netherlands Energy Research Foundation ECN is the leading institute for energy research in the Netherlands. Research is carried out under contract from the government and from national and foreign organisations and industries. ECN's activities are concentrated in six priority areas: solar energy, wind energy, biomass, clean fossil, energy efficiency, and policy studies.
Wind Energy Technology at Sandia National Laboratories. Applied research in aerodynamics, structural dynamics, fatigue, materials, manufacturing, controls, and systems integration to understand unsolved technology problems and to provide better design tools. New efforts investigate how rare atmospheric events can impact wind turbine long-term structural integrity and how advanced data handling techniques can be successfully applied to the difficult field environment of operating wind turbines.
Electric Power Research Institute (EPRI) - science and technology solutions for the global energy industry.

General wind power links

www.countryguardian.net
Country Guardian is a UK conservation group focused on the environmental damage caused by commercial windfarms in areas of national or local landscape value. It is not opposed to wind energy as such, but in practice almost all onshore sites which are windy enough are environmentally sensitive.
www.cefncroes.org.uk
Cefn Croes Wind Farm Campaign - An American backed company, the Renewable Development Company (RDC), wishes to build Britain’s largest wind power station yet in the heart of Mid Wales. RDC proposes to build 39 enormous turbines on Cefn Croes, a wild expanse of upland above the villages of Cymystwyth.
www.world-nuclear.org/info/inf10.htm
Renewable Energy and Electricity - good article on the alternatives to fossil fuels in electricity generation - Technology to utilise the forces of nature for doing work to supply human needs is as old as the first sailing ship. There is a fundamental attractiveness about harnessing such forces in an age which is very conscious of the environmental effects of burning fossil fuels.
www.cprw.org.uk/press/pressind.htm
Campaign for the Protection of Rural Wales - Index of Press Notices - Includes several press notices on the subject of wind turbines in Wales.
www.natwindpower.co.uk/northhoyle/northhoyle.htm
National Wind Power (NWP) is proposing to develop a wind farm off the North Wales coast. The proposed project, known as North Hoyle Offshore Wind Farm (North Hoyle), is situated 4-5 miles off the coast between Prestatyn and Rhyl and will consist of 30 wind turbines with a total installed capacity of between 60-90MW.
http://news.bbc.co.uk/hi/english/uk/wales/newsid_1432000/1432541.stm
Wind farm plans scrapped - Company withdraws its plans for 26 turbines - Controversial plans for a £30m wind farm development on Denbigh Moors have been scrapped after rare birds were found on the site.

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www.offshorewindfarms.co.uk
With the first offshore wind turbines in the UK already generating electricity at ~5p per unit, the further development of the offshore wind industry is an exciting prospect, and one which will see significant growth over the next decade.
www.cru.uea.ac.uk/~mikes/norfolk/wind/
Norfolk wind turbines - A total of 853 turbines currently produce 405 megawatts of electricity in the UK, enough to meet the needs of quarter of a million homes annually (BWEA). Norfolk generates 5.25 megawatts (about 1.3% of total UK production, versus about 1.2% of UK population.)
www.britishwindenergy.co.uk
British Wind Industry Association - With a membership of over 500, including more than 180 corporate members, generating an annual turnover of 1,000,000 ecus, the BWEA is uniquely placed to consolidate and extend the wind energy industry in the UK.
www.windpower.org
Danish Wind Industry Association - read about Wind Energy - More than 100 animated pages and calculators on wind resources, wind turbine technology, economics, and environmental aspects of wind energy in the Guided Tour section.
www.indianwindpower.com
Indian Wind Turbine Manufacturers Association - Power generation from wind has emerged as one of the most successful programmes in the renewable energy sector, and has started making meaningful contributions to the overall power requirements of some States.
news.bbc.co.uk/hi/english/uk/england/newsid_1777000/1777268.stm
Wind farm closed after blade snaps - The blade sits at the top of a 93-metre-high column. A turbine propeller blade has folded in half at the UK's first electricity-generating offshore wind farm, at Blyth, in Northumberland.
www.dti.gov.uk/renewable/wind.html
Introduction - Wind represents a vast source of energy which man has harnessed for over 2000 years. As the UK is the windiest country in Europe, wind power is one of the UK's most promising renewable energy technologies and already provides electricity for nearly a quarter of million homes.
www.natwindpower.co.uk/
As environmental protection and sustainable development are now top priorities world wide, we all need to consider carefully how the energy that we consume should be produced.
www.cprw.org.uk/wind/windindc.htm
Campaign for the Protection of Rural Wales - Wind Power Generation - CPRW's View: In the process of encouraging renewable energy Government policies on wind power fail to provide sufficient recognition of the the need to conserve the landscape and environment of rural Wales.
www.scotland.gov.uk/news/2001/06/se1472.asp
Scottish Executive - UK'S FIRST WIND TURBINE FACTORY TO BE BUILT IN THE HIGHLANDS - The UK's first wind turbine factory will be built in Scotland, Highlands and Islands Minister, Alasdair Morrison announced today. The facility at Machrihanish, near Campbeltown will create 124 direct jobs and 44 indirect for the local economy.
www.foe.co.uk/pubsinfo/infoteam/pressrel/2001/20010619115149.html
Friends Of the Earth welcomes UK's first wind turbine factory - 19 Jun 2001- 'Swords into ploughshares' as military base becomes renewable energy plant - Friends of the Earth today warmly welcomed the announcement by the Scottish Executive and Danish firm Vestas Wind Systems of the UK's first commercial scale wind turbine plant.
www.guardian.co.uk/Archive/Article/0,4273,4195427,00.html
MoD tries to veto wind farm sites - Trade department's expansion of renewable energy undermined by its backing for RAF objections to onshore and offshore plants
www.cprw.org.uk/press/pn250102.htm
Cefn Croes Ceredigion: Conservation groups call for Public Inquiry into UK's biggest wind power station. Today, six major conservation bodies, with a joint membership in Wales of many thousands, sent a letter to The Rt. Hon. Patricia Hewitt MP, Secretary of State for Trade and Industry protesting "in the strongest possible terms" about the declaration of the Energy Secretary.
education.guardian.co.uk/higher/engineering/story/0,9840,653199,00.html

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Cold blow - Wednesday February 20, 2002 - For some, they are blights on a glorious landscape; for others, they mean clean energy and economic lifelines for rural communities. John Vidal looks at the battle over windfarms in mid-Wales.

www.sustdev.org/energy/articles/energy/edition2/index.shtml

An Assessment of the Impact of Wind Turbines on Birds at Ten Windfarm Sites in the UK by Ruth Thomas, University College London, UK

American Wind Energy Association (AWEA)

Since 1974, AWEA has advocated the development of wind energy as a reliable, environmentally superior energy alternative in the United States and around the world. AWEA's **Green Power Factsheets** provide answers to basic questions about Green Power, including what it is, the rationale for purchasing it, and procedures for buying it.

Choosing a Home-Sized Wind Generator

The August/September 2002 issue of **Home Power Magazine** is a must-read for anyone contemplating installing a wind generator. Home Power leads the reader through all the steps necessary to arrive at the answer to this key question about wind systems: which one should you choose. The entire 17-page article can be downloaded from Home Power's website.

Consumer's Guide to Renewable Energy in Arkansas

While intended for Arkansas residents and businesses, much of the information presented in this publication also applies to residents in other states. Includes useful information on solar, wind, and renewable fuels.

Electric Power Research Institute (EPRI) is recognized as a world leader in creating science and technology solutions for the energy industry and for the benefit of the public. EPRI's technical program spans virtually every aspect of power generation, delivery, and use, including environmental considerations. The organization serves more than 1,000 energy organizations worldwide and draws on a global network of technical and business expertise to help solve energy problems.

Energy Resources Research Laboratory (ERRL)

The ERRL at Oregon State University has managed the data collection, quality assurance, and analysis for the Bonneville Power Administration's wind energy resource studies since 1978 and manages other data management activities for transmission line research. It maintains a large data base of wind data for the Pacific Northwest. This web page summarizes the wind statistics of the five Bonneville Power Administration's long-term wind monitoring sites in the Pacific Northwest.

Guided Tour on Wind Energy

Switch to the UK flag for the English website. Want to know where wind energy comes from? Want to learn about the Coriolis Force, global winds, geostrophic wind, wind speed measurement, the wind rose, wind shear, and wind shade? Need to find a wind shade calculator, information about wind turbine components, rotor blades, and wind energy economics? Answers to all your questions about wind energy can be found at the Danish Wind Turbine Manufacturers Association's Guided Tour on Wind Energy. The website includes wind resource calculators and features more than 100 animated pages on wind resources, wind turbine technology, and economics. Each of the nine tours is a self-contained unit, so you may take the tours in any order.

Minnesotans for an Energy-Efficient Economy (ME3) website provides many pages of wind energy information, including a wealth of links to utilities, research and other organizations, wind industry companies, federal government resources and wind energy publications and miscellaneous information.

Montana Wind Energy Atlas

The Montana Wind Energy Atlas is a comprehensive analysis of wind energy data available as of 1987. Data collected by a variety of public and private organizations at 158 wind monitoring sites around Montana were reviewed. Data from 56 sites are analyzed in the Atlas. Information on the sites and the data collection programs is included. While more data have been gathered since the Atlas was published, it remains the only publicly available collection of data from numerous sites. These historical data should be useful for preliminary identification of potential sites. The Atlas is available on line at the Montana Department of Environmental Quality Energize Montana website.

National Wind Coordinating Committee (NWCC)

A U.S. consensus-based collaborative formed in 1994, NWCC identifies issues that affect the use of wind power, establishes dialogue among key stakeholders, and catalyzes appropriate activities to support the development of an environmentally, economically, and politically

sustainable commercial market for wind power. NWCC members include representatives from electric utilities and support organizations, state legislatures, state utility commissions, consumer advocacy offices, wind equipment suppliers and developers, green power marketers, environmental organizations, and state and federal agencies.

Wind Energy Basics

Provides information about wind, including how wind turbines work, advantages and disadvantages of its use, wind energy use throughout history, U.S. wind energy resource potential, and current research and development.

Renewable Resource Data Center (RReDC)

Provides information on several types of renewable energy resources in the United States, in the form of publications, data, and maps. An extensive dictionary of renewable energy related terms is also provided. The News section announces new products on the RReDC, which is supported by the U. S. Department of Energy's Resource Assessment Program and managed by the Photovoltaics Technology Division of the Office of Energy Efficiency and Renewable Energy.

Small Wind Electric Systems – A Montana Consumer's Guide (PDF)

Learn about small wind systems and whether one is right for you in a this new booklet published jointly by the U.S. Department of Energy, the National Center for Appropriate Technology, and the Montana Department of Environmental Quality. The booklet includes a wind resource map of Montana, an explanation of state incentives for installing a wind system, and a list of contacts for more information.

Small Wind Electric Systems – A U. S. Consumer's Guide (PDF)

This guide provides basic information you need to answer those questions and to address the many factors you need to consider to successfully install a small wind energy system and get maximum production.

Small Wind Energy Systems for the Homeowner

This publication will help you decide whether a wind system is practical for you. It explains the benefits, helps you assess your wind resource and possible sites, discusses legal and environmental obstacles, and analyzes economic considerations such as pricing.

Small Wind System Slide Shows

Downloadable slide shows from the American Wind Energy Association.

Solar and Wind Easements

Montana's solar and wind easement provisions allow property owners to create solar and wind easements for the purpose of protecting and maintaining proper access to sunlight and wind. While 32 other states have solar easement provisions, only three other states have created specific provisions for the creation of wind easements. Montana's solar easement law was enacted in 1979 and the wind easement was enacted in 1983. For more information, contact Tom Livers, Montana Department of Environmental Quality, at 406-444-6776.

Utility Wind Interest Group (UWIG)

A non-profit corporation whose mission is to accelerate the appropriate integration of wind power for utility applications through the coordinated efforts and actions of its members, in collaboration with public and private sector stakeholders. Membership is open to utilities and other entities that have an interest in wind generation.

What Landowners Need to Know About Attracting Wind Energy Developers to Their Land in North Dakota

Published by the University of North Dakota at Grand Forks, this brochure can help Montanans faced with questions about developing wind resources on their land. It includes partial lists of nonprofit wind energy contacts, websites, and with landowner information.

AWEA's **Wind Directory**

Search this directory to obtain wind energy services and equipment from companies who have demonstrated a commitment to wind and renewable technology and adhere to AWEA's code of business ethics.

Wind Energy Atlas

Estimates wind energy resource for the United States and its territories and indicates general areas where a high wind resource may exist. This information is valuable to wind energy developers and potential wind energy users because it allows them to choose a general area of estimated high wind resource for more detailed examination. A siting document, such as that written by Hiester and Pennell (1981), can assist a potential user in going from wind resource assessment to site selection.

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Wind Energy Finance Website
Operated by the National Renewable Energy Laboratory, this website allows users to calculate online the cost of electricity generated by a wind system. The website lets users create a new project on screen (or modify an existing project) by entering values for numerous assumptions step-by-step until enough information has been entered to calculate the project cost. Projects added or modified are stored convenience and are available the next time a user logs in.
Wind Energy Potential in the United States
Estimates of the electricity that could potentially be generated by wind power and of the land area available for wind energy have been calculated for the contiguous United States. The estimates are based on published wind resource data and exclude windy lands that are not suitable for development as a result of environmental and land-use considerations.
Wind Potential in the United States: U.S. Wind Maps
Maps showing the U.S. annual wind power resource, annual wind power resource in Alaska and Hawaii and the percent of U.S. land area with an annual wind resource of Class 3 or above.
Wind Powering America
A commitment to dramatically increase the use of wind energy in the United States. This initiative works to establish new sources of income for American farmers, Native Americans, and other rural landowners, and meet the growing demand for clean sources of electricity. Website offers a host of useful information on topics such as wind resource assessment, siting, transmission, economics, utility integration, project development, and policy issues.
Wind Power in Montana
Pages from a Wind Powering America publication that focus on Montana.
Wind Workshop Presentations On Line
Presentation from the Wind Powering Montana Workshop October 3, 2001, in Big Sky. Translated from PowerPoint into viewable web pages.
Windustry
Focuses on economic development from wind energy, valuation of environmental benefits, and distributed generation. Windustry promotes wind energy through outreach, educational materials, and technical assistance to rural landowners, local communities and utilities, and state, regional, and non-profit collaborations. Website features wind basics, wind opportunities, wind turbine sites, a wind calculator, curriculum, resource library, and news and events.

Homebuilt wind turbines

Scoraig Wind Electric
Hugh Piggott's homebuilt wind power homepage. Great information about small-scale wind power--one of the best websites out there. Lots of interesting pages and links. Blade design and construction techniques, Tip Speed Ratio explained in plain english, Rotor design info and other downloads, and pictures and information about Hugh's Brakedrum Windmill. The newest pages of his site describe in detail the axial flux designs that Hugh is building at his seminars now, both an 8-foot dia. and 4-foot dia. model. You can order the plans for these new machines from his site.
WindStuffNow.com
Ed Lenz's excellent homebuilt wind power site. Lots of projects! Alternators from scratch, converting induction motors to permanent-magnet alternators, useful formulas, blade building, 3-phase explained in plain English, inexpensive blade design software, and more. Really cool site, with lots of informative pictures too.
Building a Wind Generator from Scratch
Chuck Morrison's highly informative homebuilt windmill site. A 7ft. rotor with lots of pictures and templates of rotor construction. Powered by a fan motor re-wound into an alternator. Great project!
Andy Little's Homemade Wind Generator
Uses a homebrew PM alternator based on Hugh Piggott's design. In use for pumping water electrically. Lots of photos and information about how it was built, very informative site if you want to build an axial-flux machine from scratch!

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Otherpower.com's Homebrew Wind Generators
A collection of all of our experiments with wind power, including our Volvo brake disc wind generator designs. A great resource for the homebrew wind experimentor, with lots of informative photos.
Mike Klemen's Wind Generator Page
Lots of information, photos, maintenance logs, reliability reports, windmill sound clips and data acquisition plots from a variety of working wind installations. A really nice site!
Detronics.net
Wind turbine and wind data acquisition dealer, with a very informative website. He's flying a Bergey XL.1 and a SWWP Air X at his wind test site, and posts the collected monthly data to this site, along with solar data. The numbers show very dramatically how important swept area is!
Paul Gipe's Website
Lots of small- and large-scale wind power articles and information from an expert in the field. Paul Gipe is also an active participant in the AWEA wind Discussion Board, and has written excellent books on the subject.
Airheads -- the GarboGen wind generator
The GarboGen is a wind generator designed by Jerry and built by him and many others worldwide -- made from a surplus garbage disposal motor converted into a permanent magnet alternator, and plastic blades on a metal hub to drive it. Many detailed pictures on the site, and the blades and hubs are available for purchase inexpensively.
Savonious Rotor
Savonious Rotor windmill sketches and information from Australia. This windmill design is built from 55gallon oil drums.
TopGreen.co.uk
Homebuilt brake disc wind turbine information and pictures from the hamlet of Top Green, Sibthorpe, Nottinghamshire. An excellent array of pictures of every step of the construction process.
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Steve's Tape Drive Motor Wind Turbine
Lots of great photos and construction details about this working, flying wind turbine made with a tape drive motor as the generator.
Picoturbine.com
Includes a unique educational windmill kit, wind power books, and Savonius rotor simulator software, as well as many links.
Dragonfly Power
Home of the Dragonfly Wind Generator, a very interesting design that uses an automotive alternator and gearing. Neat furling and field control system.
The Back Shed
Homebuilt wind turbine site from an Australian friend from our discussion board. Lots of pictures and construction details, plus kits for sale based on Fisher-Paykel smartdrive motors converted to alternators. The kits take care of the complicated metalworking bits for you. This site is well worth checking out!

http://www.energybook.co.uk
A great website developed by the author of this guide it provides lots of information on renewable energy and sustainable living
http://www.wxtrade.com
The energybook marketplace - buy and sell renewable energy and sustainable living products for free. Hundreds of great products.
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