Wind Power

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Wind farm on South Point, Big Island of Hawaii

Wind power is the kinetic energy of wind, or the extraction of this energy by wind turbines. In 2004, wind power became the least expensive form of new power generation, dipping below the cost per kilowatt-hour of coal-fired plants[1]. Wind power is growing quickly, at about 37%[2], up from 25% growth in 2002. In the United States, as of 2003, wind power was the fastest growing form of electricity generation on a percentage basis[3]. In the late-1990s, the cost of wind power was about five times what it is in 2005, and that downward trend is expected to continue as larger multi-megawatt turbines are mass-produced.[4] Contents

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Wind energy Main article: Wind

An estimated 1 to 3 percent of the energy from the Sun that hits the earth is converted into wind energy. This is about 50 to 100 times more energy than what is converted into biomass by all the plants on earth through photosynthesis. Most of this wind energy can be found at high altitudes where continuous wind speeds of over 160 km/h (100 mph) are common. Eventually, the wind energy is converted through friction into diffuse heat all through the earth's surface and atmosphere.

While the exact kinetics of wind are extremely complicated and relatively little understood, the basics of its origins are relatively simple. The earth is not heated evenly by the sun. Not only do the poles receive less energy from the sun than the equator does, but dry land heats up (and cools down) more quickly than the seas do. The differential heating powers a global atmospheric convection system reaching from the earth's surface to the stratosphere which acts as a virtual ceiling.

The change of seasons, change of day and night, the Coriolis effect, the irregular albedo (reflectivity) of land and water, humidity, and the friction of wind over different terrain are some of the many factors which complicate the flow of wind over the surface. [edit]

Wind variability and turbine power

A Darrieus wind turbine

The power in the wind can be extracted by having it act on moving wings that exert torque on the rotor. The amount of power transferred depends on the wind speed (cubed), the swept area (linearly), and the density of the air (linearly).

The mass flow of air that travels through the swept area of a wind turbine varies with the wind speed and air density. As an example, on a cool 15 °C (59 °F) day at sea level, air density is about 1.22 kilograms per cubic metre (it gets less dense with higher humidity). An 8 m/s breeze blowing through a 100 meter diameter rotor would move about 76,000 kilograms of air per second through the swept area.

The kinetic energy of a given mass varies with the square of its velocity. Because the mass flow increases linearly with the wind speed, the wind energy available to a wind turbine increases as the cube of the wind speed. The power of the example breeze above through the example rotor would be about 2.5 megawatts.

As the wind turbine extracts energy from the air flow, the air is slowed down, which causes it to spread out and diverts it around the wind turbine to some extent. A German physicist, Albert Betz, determined in 1919 that a wind turbine can extract at most 59% of the energy that would otherwise flow through the turbine's cross section. The Betz limit applies regardless of the design of the turbine. More recent work [5] by Gorlov shows a theoretical limit of about 30% for propeller-type turbines. Actual efficiencies range from 10% to 20% for propeller-type turbines, and are as high as 35% for three-dimensional vertical-axis turbines like Darrieus or Gorlov turbines.
Distribution of wind speed (red) and energy (blue) for all of 2002 at the Lee Ranch facility in Colorado. The histogram shows measured data, while the curve is the Raleigh model distribution for the same average wind speed. Energy is the Betz limit through a 100 meter diameter circle facing directly into the wind. Total energy for the year through that circle was 15.4 gigawatt-hours.

Windiness varies, and an average value for a given location is not in itself a clear indication of the amount of energy a wind turbine could yield there. The distribution model most frequently used is the Raleigh model, an example of which is plotted to the right against an actual measured dataset.

Because so much power is generated by higher windspeed, much of the average power available to a windmill comes in short bursts. The 2002 Lee Ranch sample is telling: half of the energy available arrived in just 15% of the operating time.

Since wind speed is not constant, a wind generator's annual energy production is never as much as its nameplate rating multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. A well-sited wind generator will have a capacity factor of as much as 35%. When comparing the size of wind turbine plants to fueled power plants, it is important to note that 1000 kW of wind-turbine potential power would be expected to produce as much energy in a year as approximately 350 kW of fuel-fired generation. Though the short-term (hours or days) output of a wind-plant is not completely predictable, the annual energy of output tends to vary only a few percent between years. [edit]

Wind power density classes

Wind maps in the United States and Europe classify areas into seven arbitrarily defined classes of wind power density, analogous to the five classes of hurricane force.

Each class is a range of power densities, so that an area rated as class 4, for example, would have an average power density from 200 to 250 W/m2 at 10 m above ground. Generally, economic development of wind power for electricity generation takes place in areas rated Class 3 or higher. Table 1-1 Classes of wind power density at 10 m and 50 m(a). [6]

Wind Power Class	10 m (33 ft) Wind power density (W/m2)	Speed(b) m/s (mph)	50 m (164 ft) Wind power density (W/m2)	Speed(b) m/s (mph)
1	0	0	0	0
	100	4.4 (9.8)	200	5.6 (12.5)
2	150	5.1 (11.5)	300	6.4 (14.3)
3	200	5.6 (12.5)	400	7.0 (15.7)
4	250	6.0 (13.4)	500	7.5 (16.8)
5	300	6.4 (14.3)	600	8.0 (17.9)
6	400	7.0 (15.7)	800	8.8 (19.7)
7	1000	9.4 (21.1)	2000	11.9 (26.6)

(a) Vertical extrapolation of wind speed based on the 1/7 power law. (b) Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, speed increases 3%/1000 m (5%/5000 ft) elevation. [edit]

Turbine siting

Map of available wind power over the United States. Color codes indicate wind power density class.

As a general rule, wind generators are practical where the average wind speed is greater than 20 km/h (5.5 m/s or 12.5 mph). Obviously, meteorology plays an important part in determining possible locations for wind parks, though it has great accuracy limitations. Meteorological wind data is not usually sufficient for accurate siting of a large wind power project. An 'ideal' location would have a near constant flow of non-turbulent wind throughout the year, and wouldn't suffer too many sudden powerful bursts of wind.

The wind blows faster at higher altitudes because of the reduced influence of drag of the surface (sea or land) and the reduced viscosity of the air. The variation in velocity with altitude, called wind shear is most dramatic near the surface. Typically, the variation follows the 1/7th power law, which predicts that wind speed rises proportionally to the seventh root of altitude. Doubling the altitude of a turbine, then, increases the expected wind speeds by 10% and the expected power by 34%.

Wind farms or wind parks often have many turbines installed. Since each turbine extracts some of the energy of the wind, it is important to provide adequate spacing between turbines to avoid excess energy loss. Where land area is sufficient, turbines are spaced three to five rotor diameters apart perpendicular to the prevailing wind, and five to ten rotor diameters apart in the direction of the prevailing wind, to minimize efficiency loss. The "wind park effect" loss can be as low as 2% of the combined nameplate rating of the turbines.

Utility-scale wind turbine generators have low temperature operating limits which restrict the application in areas that routinely experience temperatures less than −20 °C. Wind turbines must be protected from ice accumulation, which can make anemometer readings inaccurate and which can cause high structure loads and damage. Some turbine manufacturers offer low-temperature packages at a cost of a few percent of the turbine cost, which include internal heaters, different lubricants, and different alloys for structural elements, to make it possible to operate the turbines at lower temperatures. If the low-temperature interval is combined with a low-wind condition, the wind turbine will require station service power, equivalent to a few percent of its output rating, to maintain internal temperatures during the cold snap. For example, the St. Leon, Manitoba project has a total rating of 99 MW and is estimated to need up to 3 MW (around 3% of capacity) of station service power a few days a year for temperatures down to −30 °C. This factor affects the economics of wind turbine operation in cold climates.[1] [edit]

Onshore

Onshore turbine installations tend to be along mountain ridges or passes, or at the top of cliff faces. The change in ground elevation causes the wind velocities to be generally higher in these areas, although there may be a lot of variation over relatively short distances (a difference of 30 m can sometimes mean a doubling in output). Local winds are often monitored for a year or more with anemometers and detailed wind maps constructed before wind generators are installed.

For smaller installations where such data collection is too expensive or time consuming, the normal way of prospecting for wind-power sites is to directly look for trees or vegetation that is permanently "cast" or deformed by the prevailing winds. Another way is to use a wind-speed survey map, or historical data from a nearby meteorological station, although these methods are less reliable.

Sea shores also tend to be windy areas and good sites for turbine installation, because a primary source of wind is convection from the differential heating and cooling of land and sea over the course of day and night. Winds at sea level carry somewhat more energy than winds of the same speed in mountainous areas because the air at sea level is more dense.

Unfortunately, windy areas tend to be picturesque, and so there is a great deal of opposition to the installation of wind turbines on what would otherwise appear to be ideal sites. [edit]

Offshore

Wind often flows briskly and smoothly over water since there are no obstructions. The large and slow turning turbines of this offshore wind farm near Copenhagen take advantage of the moderate yet constant breezes at this location.

Offshore wind turbines are considered to be less unsightly (they can be invisible from shore), and because the winds are usually more potent offshore, such turbines don´t need to reach quite as high into the air. However, offshore conditions are harsh, abrasive, and corrosive, and it is often impossible or near-impossible to repair a broken down turbine in open waters.

In stormy areas with extended shallow continental shelves and sand banks (such as Denmark), turbines are reasonably easy to install, and give good service - Denmark's offshore wind generation provides about 20% of total electricity demand in the country, while generating more than 20,000 jobs [7]. At the site shown, the wind is not especially strong but is very consistent. The largest offshore wind turbines in the world are 3.6MW rated machines that are installed in a small group of seven turbines off the east coast of Ireland about 60km south of Dublin. The turbines are located on a sandbank approximately 10km from the coast that has the potential for the installation of 500MW of generation capacity. As of 2006, the largest offshore wind farm is Horns Rev which is located 15km west of Jutland, Denmark [8]. [edit]

Airborne

Main article: Airborne wind turbine

It has been suggested that wind turbines might be flown in high speed winds at high altitude. No such systems currently exist in the marketplace. An Ontario company, Magenn Power, Inc., is attempting to commercialize tethered aerial turbines suspended with helium. [edit]

Utilization [edit]

Large scale

Total windpower capacity (late 2004)[9]

Rank	Nation	Windpower capacity (MW)
01	Germany	16,628 (18,428 in 2005)
02	Spain	8,263 (10,028 in 2005)
03	USA	6,752 (9,149 in 2005)
04	Denmark	3,118
05	India	2,983
06	Italy	1,265
07	Netherlands	1,078
08	Japan	940
09	United Kingdom	897
10	China	764
11	Austria	607
12	Portugal	523
13	Greenland	466
14	Canada	444
15	Sweden	442
16	France	390
17	Australia	380
18	Ireland	353
19	New Zealand	170
20	Norway	160
	Other	951
	World total	47,574

There are now many thousands of wind turbines operating in various parts of the world, with a total capacity of over 47,317 MW of which Europe accounts for 72% (2005). It was the most rapidly-growing means of alternative electricity generation at the turn of the century and provides a valuable complement to large-scale base-load power stations. World wind generation capacity quadrupled between 1997 and 2002. 90% of wind power installations are in the US and Europe.

Germany, Spain, Denmark, and the United States have made considerable investments in wind generated electricity. Denmark is especially a leader in the manufacturing and use of wind turbines, with a commitment made in the 1970s to eventually produce half of the country's power by wind. In December 2003, General Electric installed the world's largest offshore wind turbines in Ireland, and plans are being made for more such installations on the west coast, including the possible the use of floating turbines.

Germany already produces 40% of the entire world's wind power, and the hope is that by 2010, wind will meet 12.5% of German electricity needs. Germany has 16,000 wind turbines, mostly concentrated in the north of the country, near the border with Denmark - including the biggest in the world, owned by the Repower company. In 2005, the goverment of Spain approved a new national goal for installed wind power capacity of 20,000 MW by 2012. While the United States government lost interest when the price of oil dropped after the 1970s oil crisis, the Danes and Germans continued their efforts and now are a leading exporter of large turbines (each generating 0.66 to 5.0 megawatt).

Wind accounts for 0.4% of the total electricity production on a global scale (2002). Germany is the leading producer of wind power with 35% of the total world capacity in 2005 (10% of German electricity). Spain and the United States are next in terms of installed capacity. According to the American Wind Energy Association, wind generated enough electricity to power 0.4% (1.6 million households) of total electricity in US, up from less than 0.1% in 1999. Germany's Schleswig-Holstein province generates 25% of its power with wind turbines. Denmark generates over 20% of its electricity with wind turbines, the highest percentage of any country and is fourth in the world in total power generation. In 2005, both Germany and Spain have produced more electricity from wind power than from hydropower plants.

After Germany, Spain, the United States, and Denmark, India ranks 5th in the world with a total wind power capacity of 3500 MW. Almost half of this capacity (1600 MW) was added in the last two years, and of new electricity capacity additions in the country, wind power accounted for over 20% of the total in that period. Currently wind power generates 3% of all electricity produced in India. Unlike the others in the top 5, India's estimated wind power potential is pretty low at just 45 gigawatts, while world wide potential is estimated at 72 terawatts, with the US and Northern Europe among the regions with the maximum potential.

On August 15, 2005, China announced it would build a 1000-megawatt wind farm in Hebei for completion in 2020. China reportedly has set a generating target of 20 million kilowatts by 2020 from renewable energy sources - it says indigenous wind power could generate up to 253 million kilowatts.[10]

Another growing market is Brazil, with a wind potential of 143 GW.[11] The federal government has created an incentive program, called Proinfa[12], to build production capacity of 3300 MW of renewable energy for 2008, of which 1422 MW through wind energy. The program seeks to produce 10% of Brazillian electricity through renewable sources. Brazil produced 320 TWh in 2004. [edit]

Small scale

This rooftop-mounted urban wind turbine charges a 12 volt battery and runs various 12 volt appliances within the building on which it is installed.

Wind turbines have been used for household electricity generation in conjunction with battery storage over many decades in remote areas. Household generator units of more than 1 kW are now functioning in several countries.

To compensate for the varying power output, grid-connected wind turbines utilise some sort of grid energy storage. Off-grid systems either adapt to intermittent power or use photovoltaic or diesel systems to supplement the wind turbine.

Wind turbines range from small four hundred watt generators for residential use to several megawatt machines for wind farms and offshore. The small ones have direct drive generators, direct current output, aeroelastic blades, lifetime bearings and use a vane to point into the wind; while the larger ones generally have geared power trains, alternating current output, flaps and are actively pointed into the wind. As technology progresses, large generators are becoming as simple as small generators. Direct drive generators and aeroelastic blades for large wind turbines are being researched and direct current generators are sometimes used.

In urban locations, where it is difficult to obtain large amounts of wind energy, smaller systems may still be used to run low power equipment. Distributed power from rooftop mounted wind turbines can also alleviate power distribution problems, as well as provide resilience to power failures. Equipment such as wireless internet gateways may be powered by a wind turbine that charges a small battery, replacing the need for a connection to the power grid and/or maintaining service despite possible power grid failures.

Small-scale wind power in rural Indiana.

The Lakota turbine by Aeromax is approximately 7 feet (2 m) in diameter and produces 900 watts of three phase power. It uses a three phase rectifier and charge controller so that it is free to spin at whatever speed is optimal for a given wind condition. Lightweight materials (the entire turbine weighs only 16kg (35 pounds)) allow it to respond quickly to the gusts of wind typical of urban settings. It attaches to a size 9 structural pipe (similar to a TV antenna mast). The Lakota is very quiet. Even when standing up on the roof right next to the mast it is inaudible. Climbing up the mast, it is still inaudible from just a few feet under the turbine. A dynamic braking system regulates the speed by dumping excess energy, so that the turbine continues to produce electricity even in high winds. The dynamic braking resistor may be installed inside the building, so that the 'heat loss' will heat the inside of the building (i.e. during high winds when more heat is lost by the building, more heat is also produced by the braking resistor). The proximal location makes low voltage (12 volt, or the like) energy distribution practical, e.g. in a typical installation the braking resistor can be located just inside to where the mast is attached to the building. Such small-scale renewable energy sources also impart a beneficial psychological effect on building owners, so that they begin to take on a keen awareness of electricity consumption, possibly reducing their consumption down to the average level that the turbine can produce. [edit]

Controversy

The debate around wind energy is heated and often emotional. Arguments of both parties are listed below. [edit]

Arguments of opponents

Some of the over 4000 wind turbines at Altamont Pass, in California. Developed during a period of tax incentives in the 1980s, this wind farm has more turbines than any other in the United States. These kilowatt turbines cost several times more per kw/h and spin much more quickly than modern megawatt turbines, endangering birds and making noise. These units are likely Enertech E44-40kWs. [edit]

Economics

- In order to compete with traditional sources of energy, wind power often receives financial incentives. In the United States, wind power receives a tax credit of 1.9 cents per kilowatt-hour produced, with a year inflationary adjustment. However, in 2004 when the U.S. production tax credit had lapsed for nine months, wind power was still a rapidly growing form of electrical generation. Another tax benefit is accelerated depreciation. Many American states also provide incentives, such as exemption from property tax, mandated purchases, and additional markets for "green credits." Countries such as Canada and Germany also provide tax credits and other incentives for

wind turbine construction. Although other energy sources are also subsidized, the amount per kilowatt-hour may be much higher for wind.
- Maintenance of wind turbines can be difficult and expensive. Repairs require a much more complicated and expensive operation than ground based generation.
- Many potential sites for wind farms are far from demand centers, requiring substantially more money to construct new transmission lines and substations. [edit]

Yield
- The goals of renewable energy development are reduction of reliance on fossil and nuclear fuels, reduction of greenhouse gas and other emissions, and establishment of more sustainable sources of energy. Some critics question wind energy's ability to significantly move society towards these goals. They point out that 25-30% annual load factor is typical for wind facilities. The intermittent and nondispatchable nature of wind turbine power requires that "spinning reserves" are kept burning for supply security. More frequent ramping of such plants means lower efficiency and possibly greater emissions.
- Electric power production is only part (about one to two fifths[13]) of a country's energy use, and wind power does nothing to mitigate the larger part of the effects of energy use. For example, despite aggressive installation of wind facilities in the U.K., that country's CO2 emissions continued to rise in 2002 and 2003 (Department of Trade and Industry). Greenhouse gas emissions in Denmark rose 6.2% in 2003 (National Environmental Research Institute).

- Groups such as the UN's Intergovernmental Panel on Climate Change state that the desired mitigation goals can be achieved at lower cost and to a greater degree by continued improvements in general efficiency — in building, manufacturing, and transport — than by wind power. A study by the Irish Grid into expanding wind power similarly concluded that, "The cost of CO2 abatement arising from using large levels of wind energy penetration appears high relative to other alternatives." [edit]

Ecological footprint
- The construction of a large facility is also far from ecologically neutral if the location has no previous development. It requires roads, foundations, clearing of trees, and construction of power lines. The clearing of trees is necessary since obstructions within a distance ten times the height of the turbine reduce yield dramatically. A distance of twenty times is preferred.
- A wind farm that produces the energy equivalent of a conventional power plant would have to cover an area of approximately 300 square miles. [14]
- Offshore sites eliminate some of these objections, but raise others such as dangers to navigation and the possible adverse effect of low-frequency vibration and shadow flicker on aquatic mammals.
- Another important complaint is that windmills kill too many birds, especially birds of prey. Siting generally takes into account bird flight patterns, but most paths of bird migration, particularly for birds that fly by night, are unknown. Although a Danish survey in 2005 (Biology Letters 2005:336) showed that less than 1% of migrating birds passing a wind farm in Rønde, Denmark, got close to collision, the site was studied only during low-wind non-twilight conditions. A survey at Altamont Pass, California conducted by a California Energy Commission in 2004 showed that turbines killed 4,700 birds annually (1,300 of which are birds of prey). Radar studies of proposed sites in the eastern U.S. have shown that migrating songbirds fly well within the reach of large modern turbines.
- The numbers of bats killed by existing facilities has troubled even industry personnel [15]. A six-week study [16] in 2004 estimated that over 2200 bats were killed by 63 turbines at two sites in the Eastern US. This study suggests some site locations may be particularly hazardous to local bat populations, and that more research is urgently needed. [edit]

Scalability
- The large number of turbines required for a viable wind plant, and the huge number of plants required to meet the ambitious goals of the wind industry and governments, ensures that more people and wildlife habitat will be affected by them. [edit]

Aesthetics
- There is resistance to the establishment of land based wind farms owing to perceptions that they are noisy and contribute to "visual pollution." Moving the turbines offshore mitigates the problem, but offshore wind farms are more expensive to maintain and there is an increase in transmission loss due to longer distances of power lines.

- The large installations of a modern wind facility are typically 100 m high to the tip of the rotor blade, and, besides the continuous motion of the 35-m-long rotor blades through the air, each time the blade passes the tower a deep subsonic thump is produced, which is a form of noise pollution.
- Some residents near windmills complain of "shadow flicker," which is the alternating pattern of sun and shade caused by a rotating windmill casting a shadow over residences. Efforts are made when siting turbines to avoid this problem. [edit]

Arguments of supporters

Erection of an Enercon E70-4

Supporters of wind energy state that: [edit]

Yield

- Wind power is a renewable resource, which means using it will not deplete the earth's supply of fossil fuels. It also is a clean energy source, and produces no carbon dioxide, sulfur dioxide, particulates, or any other type of air pollution, as do conventional fossil fuel power sources.
- Wind's long-term technical potential is believed 5 times current global energy consumption or 40 times current electricity demand. This requires 12.7% of all land area, or that land area with Class 3 or greater potential at a height of 80 meters. It assumes that the land is covered with 6 large wind turbines per square kilometer. Offshore resources experience mean wind speeds ~90% greater than that of land, so offshore resources could contribute substantially more energy.[17][18]. This number could also increase with higher altitude ground based or airborne wind turbines [19]. [edit]

Coping with intermittent wind power

- As the fraction of energy produced by wind ("penetration") increases, different technical and economic factors affect the electric power grid and storage facilities. Large networks, connected to multiple wind plants at widely separated geographic locations, may accept a higher penetration of wind than small networks or those without storage systems or economical methods of compensating for the variability of wind. In systems with significant amounts of existing pumped storage (e.g. UK, eastern US) this proportion may be higher; isolated, relatively small systems with only a few wind plants may only be stable and economic with a lower fraction of wind energy (e.g. Ireland).
- On most large power systems a moderate proportion of wind generation (typically <10%) can be connected without the need for storage of any kind. This is explained below. For larger proportions (>20%). storage may be economically attractive or even technically necessary.
- Long-term storage of electrical energy involves substantial capital costs, space for storage facilities, and some portion of the stored power will be lost during conversion and transmission. The percentage retrievable from stored power is called the "efficiency of storage." The cost incurred to "shape" intermittent wind power for reliable delivery is about a 20% premium for most wind applications on large grids, but approaches 50% of the cost of generation when wind comprises more than 70% of the local grid's input power. Large scale energy storage includes pumped hydro and other mechanical forms of storage, as well as stationary hydrogen electrolysis and fuel cells and other forms of chemical storage.
- Electricity demand is variable but generally very predictable on larger grids—errors in demand forecasting are typically no more than 2%. Because conventional powerplants can drop off the grid within a few seconds,for example due to equipment failures, in most systems the output of some coal or gas powerplants is intentionally part-loaded to follow demand and to replace rapidly lost generation. The ability to follow demand (by maintaining constant frequency) is termed "response." The ability to quickly replace lost generation, typically within timescales of 30 seconds to 30 minutes, is termed "reserve." Nuclear power plants in contrast are not very flexible and are not intentionally part-loaded. A power plant that operates in a steady fashion, usually for many days continuously, is termed a "base load" plant. As a consequence of these arrangements most grids' production systems are already equipped with an array of substantial, quickly adjustable back-up techniques.
- What happens in practice therefore is that as the power output from wind varies, part-loaded conventional plants, which must be there anyway due to changing demand, adjust their output to compensate; they do this in response to small changes in the frequency (nominally 50 or 60 Hz) of the grid. In this sense wind acts like "negative" load or demand.
- The maximum proportion of wind power allowable in a power system will thus depend on many factors, including the size of the system, the attainable geographical diversity of wind, the conventional plant mix (coal, gas, nuclear) and seasonal load factors (heating in winter, air-conditioning in summer) and their statistical correlation with wind output. For most large systems the allowable penetration fraction (wind nameplate rating divided by system peak demand) is thus at least 15% without the need for any energy storage whatsoever. Note that the interconnected electrical system may be much larger than the particular country or state (e.g. Denmark, California) being considered.
- The allowable penetration may of course be further increased by increasing the amount of part-loaded generation available, or by using energy storage facilities, although if purpose-built for wind energy these may significantly increase the overall cost of wind power.
- Existing European hydroelectric power plants can store enough energy to supply one month's worth of European electricity consumption. Improvement of the international grid would allow using this in the relatively short term at low cost, supplementing wind power. Excess wind power could even be used to pump water up into collection basins for later use.
- Energy Demand Management or Demand-Side Management refers to the use of communication and switching devices which can release deferrable loads quickly to correct supply/demand imbalances. Incentives can be created for the use of these systems, such as favorable rates or capital cost assistance, encouraging consumers with large loads to take advantage of renewable energy by adjusting their loads to coincide with resource availability. For example, pumping water to pressurize municipal water systems is an electricity intensive application that can be performed when electricity is available.[20]

- In energy schemes with a high penetration of wind energy, secondary loads, such as desalination plants and electric boilers may be encouraged because their output (water and heat) can be stored.The utilization of "burst electricity", where excess electricity is used on windy days for opportunistic purposes greatly improves the economic efficiency of wind turbine schemes. An ice storage device has been invented which allows cooling energy to be consumed during resource availability, and dispatched as air conditioning during peak hours.
- Multiple wind farms spread over a wide geographic area and gridded together produce power much more constantly.
- Electricity produced from solar energy could be a counter balance to the fluctuating supplies generated from wind. It tends to be windier at night and during cloudy or stormy weather, so there is likely to be more sunshine when there is less wind. [edit]

Ecological footprint

Center pivot irrigation in Egypt. Turbines could be sited in the unused spaces between the circular fields.

- The energy consumption for production, installation, operation and decommission of a wind turbine is usually earned back within 3 months of operation.
- After decommissioning wind turbines, even the foundations are removed.
- Studies show that the number of birds killed by wind turbines is negligible compared to the amount that die as a result of other human activities such as traffic, hunting, power lines and high-rise buildings and especially the environmental impacts of using non-clean power sources. For example, in the UK, where there are a few hundred turbines, about one bird is killed per turbine per year; 10 million per year are killed by cars alone. Another study suggests that migrating birds are somewhat smarter than we give them credit, those birds which don't modify their route and continue to fly through a wind farm are quite capable of avoiding windmills[21], at least in the low-wind non-twilight conditions studied. In the UK, the Royal Society for the Protection of Birds (RSPB) concluded that "The available evidence suggests that appropriately positioned wind farms do not pose a significant hazard for birds" (see RSPB statement on wind farms). It notes that climate change poses a much more significant threat to wildlife, and therefore supports wind farms and other forms of renewable energy.
- Clearing of wooded areas is often completely unnecessary for grounded turbines, as the practice of farmers leasing their land out to companies building wind farms is becoming ever more common. Farmers receive annual lease payments of two thousand to five thousand dollars per turbine[22]. What's more, the land can still be used for farming and cattle grazing.
- The ecological and environmental costs of wind plants are entirely paid for by those using the power produced, with no long-term effects on climate or local environment left for future generations.
- Less than 1% of (the land) would be used for foundations and access roads, the other 99% could still be used for productive farming. [23] Turbines can be sited on land unused in techniques such as center-piviot irrigation. [edit]

Economic feasibility

- Conventional and nuclear power plants receive massive amounts of direct and indirect governmental subsidies. If a comparison is made on real production costs, wind energy is competitive in many cases. If the full costs (environmental, health, etc.) 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.
- Nuclear power plants receive special immunity from the disasters they may cause, which prevents victims from recovering the cost of their continued health care from those responsible, even in the case of criminal malfeasance.
- Conventional and nuclear plants also have sudden unpredictable outages (see above). Statistical analysis shows that 1000 MW of wind power can replace 300 MW of conventional power. [edit]

Aesthetics

- It is possible to hold a conversation directly underneath a modern wind turbine without any difficulty whatsoever and without raising one's voice. The modern turbine is quieter than its predecessors owing to improvements in the blade design.
- Newer wind farms have their turbines spaced further apart, due to the greater power of the individual wind turbines. They no longer have the cluttered look of the early wind farms.
- Wind turbines can be positioned alongside motorways, which significantly reduces aesthetic concerns as there are nowhere near as many calls for the improvement of the aesthetic quality of motorways as there are to remove fossil fuel consuming power plants. [edit]

See also

- Effects of global warming
- Green energy
- Green tax shift
- Renewable energy
- Nuclear power

- Nuclear power phase-out
- Solar power
- Wind farm
- Wind turbine [edit]

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- The World Wind Energy Association WWEA
- German Wind Energy Association BWE
- Spanish Wind Energy Association (Asociación Empresarial Eólica)
- The British Wind Energy Association
- American Wind Energy Association
- European Wind Energy Association Extensive information and myth debunking in the report: windenergy the facts.
- Canadian Wind Energy Association
- Alliance to Protect Nantucket Sound Citizens group opposed to plans for USA's first offshore wind facility.
- Capewind -- Website of USA's first offshore wind facility.
- Country Guardian -- A UK NGO opposed to the construction of wind turbines.
- National Wind Watch -- A US coalition of citizens and grassroots groups to promote knowledge and raise awareness of the damaging impacts of industrial wind turbine development.
- Industrial Wind Energy Opposition -- Resources for debunking claims, documenting ill effects, and fighting the spread of industrial wind power
- Gardner Mountain NH USA -- "A public community site" trying to stop some local wind turbine development.

- Iberica 2000.org - On the serious impact of wind farms on birds.
- "Wind turbines a breeze for migrating birds" - Birds avoid windmills.
- Commentary on preceding paper - Birds have to fly farther to avoid windmills, fair-weather study finds.
- "We Must Increase Our Gust" - On wind power's ability to replace other sources, with lively forum discussion.

- "Shooting Down the Breeze" - On wind power industry's ambivalent concern about wildlife impacts, also with lively forum discussion.
- Wind Works --An extensive personal site on windpower. Nuanced pro wind energy.
- yes2wind -- A website by Greenpeace, Friends of the Earth and the WWF in support of wind energy and debunking claims of the anti-wind energy lobby.
- wind-farm -- A website for news, articles, and discussion of wind facilities.
- ExternE -- The European research project about the external costs of energy production in general.
- Wind systems - On the site of the Australian Greenhouse Office.
- Windpower Monthly -- Wind Energy Magazine.
- Enertrag.de -- A German energy company investing in wind turbines. Owns 13 wind parks as of October 2004.
- African Wind Energy Association -- AfriWEA is a non-profit organisation formed in 2002 to encourage manufacturers, developers, governments, renewable energy owners and individuals to promote and support wind energy development on the African continent
- POWER - Pushing Offshore Wind Energy Regions -- POWER is an European Interreg project which establishes a discussion platform and a support of European regions in the development of offshore-windenergy projects. [edit]

Wind Power projects
- Cape Wind (Massachusetts)
- Judith Gap Wind Farm (Montana) now on-line
- Windiberica Wind Farm Projects (Spain)
- Mawson Station - High Penetration (>90%) Wind Diesel at Mawson Station in Antarctica.
- Denham - Wind Diesel in Western Australia.
- Wenerenergi Sweden [edit]

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- A new gust of wind projects across the US High natural-gas prices and global-warming concerns may help wind energy gain critical mass. By Mark Clayton, Christian Science Monitor, January 19, 2006
- Green Mountain
- "Wind versus water: Measuring the potential of our renewable resources" from Canadian Geographic
- Climate Change Chronicles article about offshore wind energy in Europe
- Wind farms could meet energy needs
- Wind Power Related News
- Wind power
- Wenerenergi