The Most Frequently Asked Questions About Wind Energy

American Wind Energy Association

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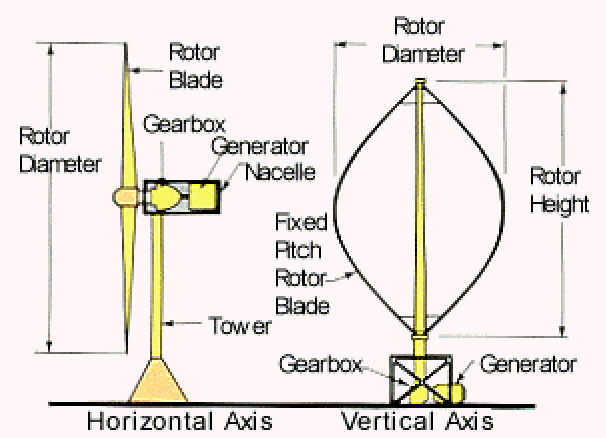
Wind Energy Basics

What is a wind turbine and how does it work?

A wind energy system transforms the kinetic energy of the wind into mechanical or electrical energy that can be harnessed for practical use. Mechanical energy is most commonly used for pumping water in rural or remote locations. Wind electric turbines generate electricity for homes and businesses and for sale to utilities.

There are two basic designs of wind electric turbines: vertical-axis, or "egg-beater" style, and horizontal-axis machines. Horizontal-axis wind turbines are most common, comprising more than 95% of the "utility-scale" (100 kilowatts (kW) capacity and larger) turbine market.



Wind Turbine Configurations

Turbine subsystems include:

- a rotor, or blades, which convert the wind's energy into rotational shaft energy;
- a nacelle containing a drive train, usually including a gearbox* and a generator;
- a tower, to support the rotor and drive train; and
- electronic equipment such as controls, electrical cables, ground support equipment, and interconnection equipment.

*Some turbines operate without a gearbox.

Wind turbines vary in size and the corresponding amount of electricity they are capable of generating (the turbine's capacity, or power rating, explained below). For example, a 10kW turbine typically has a 7m rotor diameter; a utility-scale turbine with a 750 kW generating capacity operates with a rotor diameter of 24 meters, mounted on a tower that is 63 meters high; and a 1.5 MW turbine operates with a 70 m rotor diameter.

How much electricity can one wind turbine generate?

The ability to generate electricity is measured in watts. Watts are very small units, so the terms *kilowatt* (1,000 watts), *megawatt* (1 million watts), and *gigawatt* (1 billion watts) are most commonly used to describe the capacity of generating units like wind turbines or other power plants.

Electricity production and consumption are most commonly measured in *kilowatt-hours (kWh)*. A kilowatt-hour means 1,000 watts of electricity produced or consumed for one hour. One 50-watt light bulb left on for 20 hours consumes one kilowatt-hour of electricity (50 watts x 20 hours = 1,000 watt-hours = 1 kilowatt-hour).

The output of a wind turbine depends on the turbine's size and the wind's speed through the rotor. Wind turbines being manufactured now have power ratings ranging from 250 watts to 1.65 megawatts (MW).

> Example: A 10-kW wind turbine can generate about 16,000 kWh annually, more than enough to power a typical household. A 1.65-MW turbine can produce more than 4.7 million kWh in a year--enough to power more than 470 households. The average U.S. household consumes about 10,000 kWh of electricity each year.

> Example: A 250-kW turbine installed at the elementary school in Spirit Lake, Iowa, provides an average of 350,000 kWh of electricity per year, more than is necessary for the 53,000-square-foot school. Excess electricity fed into the local utility system has earned the school $25,000 over five years. The school uses electricity from the utility at times when the wind does not blow.

Spirit Lake Community Schools, Spirit Lake, Iowa

Wind speed is a crucial element in projecting turbine performance, and a site's wind speed is measured through wind resource assessment prior to a wind system's construction. Generally, annual average wind speeds greater than four meters per second (m/s) (9 mph) are required for small wind electric turbines (less wind is required for water-pumping operations). Utility-scale wind power plants require minimum average wind speeds of 6 m/s (13 mph).

The power available in the wind is proportional to the cube of its speed, which means that doubling the wind speed increases the available power by a factor of eight. Thus, a turbine operating at a site with an average wind speed of 12 mph will generate about 29% more electricity than one at an 11-mph site.

How many turbines does it take to make one megawatt (MW)?

Most manufacturers of utility-scale turbines offer machines in the 700-kW to 1.65-MW range. Ten 700-kW units would make a 7-MW wind plant, while 10 1.65-MW machines would make a 16.5-MW facility. In the future, machines of larger size will be available.

What is a wind power plant?

The most economical application of wind electric turbines is in groups of large machines (700 kW and up), called "wind power plants" or "wind farms." For example, a 107-MW wind farm near the community of Lake Benton, Minn., consists of turbines sited far apart on farmland along windy Buffalo Ridge. The wind farm generates electricity while agricultural use continues undisturbed.

Wind turbines on farmland in Lake Benton, Minn. (Enron)

Wind plants can range in size from a few megawatts to hundreds of megawatts in capacity. Wind power plants are "modular," which means they consist of small individual modules (the turbines) and can easily be made larger or smaller as needed. Turbines can be added as electricity demand grows. Today, a 50-MW wind farm can be completed in 18 months (including resource assessment).

What is "capacity factor"?

Capacity factor is one element in measuring the productivity of a wind turbine or any other power production facility. It compares the plant's actual production over a given period of time with the amount of power the plant would have produced if it had run at full capacity for the same amount of time.

$$\text{Capacity Factor} = \frac{\text{Actual amount of power produced over time}}{\text{Power that would have been produced if turbine operated at maximum output 100\% of the time}}$$

A conventional utility power plant uses fuel, so it will normally run much of the time unless it is idled by equipment problems or for maintenance. A capacity factor of 40% to 80% is typical for conventional plants.

A wind plant is "fueled" by the wind, which blows steadily at times and not at all at other times. Most modern utility-scale wind turbines operate with a capacity factor of 25% to 40%, although they may achieve higher capacity factors during windy weeks or months. It is possible to achieve much higher capacity factors by combining wind with a storage technology such as pumped hydro or compressed-air energy storage (CAES).

What is "availability factor"?

Availability factor (or just "availability) is a measurement of the reliability of a wind turbine or other power plant. It refers to the percentage of time that a plant is ready to generate (that is, not out of service for maintenance or repairs). Modern wind turbines have an availability of more than 98%--higher than most other types of power plant. After two decades of constant engineering refinement, today's wind machines are highly reliable.

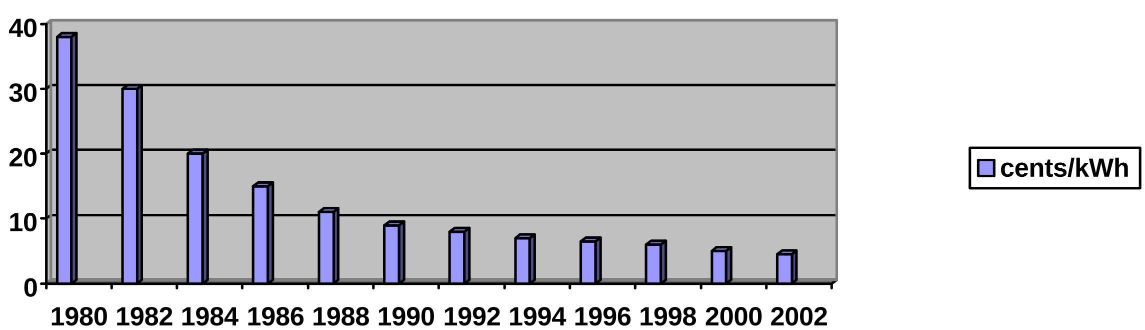
Wind Energy Costs

How much does wind energy cost?

Over the last 20 years, the cost of electricity from utility-scale wind systems has dropped by more than 80%.

In the early 1980s, when the first utility-scale turbines were installed, wind-generated electricity cost as much as 30 cents per kilowatt-hour. Now, state-of-the-art wind power plants are generating power at costs as low as 4 cents/kWh, a price that is competitive with many conventional energy technologies.

Cost of Wind-Generated Energy in Levelized Cents/kWh

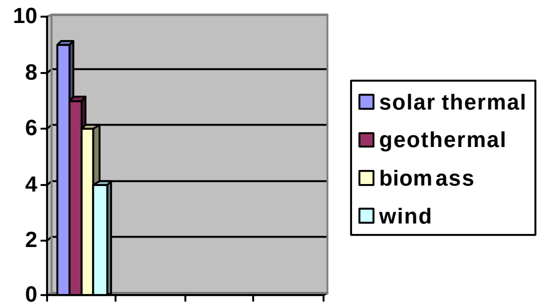


Assumptions: levelized cost at excellent wind sites, large project size, not including PTC

The National Renewable Energy Laboratory (NREL) is working with the wind industry to develop a next generation of wind turbine technology. The products from this program are expected to generate electricity at prices competitive with natural gas turbines, the least expensive conventional power source.

How do utility-scale wind power plants compare in cost to other renewable energy sources?

Wind is the low-cost emerging renewable energy resource.



Wind Costs Compared With Other Renewable Energy Technologies (in cents/kWh)

What is the "production tax credit" for wind energy?

A 1.5-cent per kilowatt-hour* production tax credit (PTC) for wind energy was included in the Energy Policy Act of 1992. Passage of the PTC reflected a recognition of the important role that wind energy can and should play in our nation's energy mix. It also was intended to partially correct the existing tilt of the federal energy tax code, which has historically favored conventional energy technologies such as oil and coal.

Generally, the credit is a business credit that applies to electricity generated from wind plants for sale at wholesale (i.e., to a utility or other electricity supplier). It applies to electricity produced during the first 10 years of a wind plant's operation.

The wind PTC expired June 30, 1999, and an effort is currently underway to extend it for five years. For information on the status of that effort, contact the American Wind Energy Association (AWEA), phone (202) 383-2500, e-mail <windmail@awea.org>.

Wind Energy's Potential

The wind doesn't blow all the time. How much can it really contribute to a utility's generating capacity?

Utilities must maintain enough power plant capacity to meet expected customer electricity demand at all times, plus an additional reserve margin. All other things being equal, utilities generally prefer plants that can generate as needed (that is, conventional plants) to plants that cannot (such as wind plants).

However, in two separate studies, researchers have found that despite its intermittent nature, wind can provide capacity value for utilities.

The studies, by the Tellus Institute of Boston, Mass., and the Prince Edward Island (Canada) Energy Corp., concluded that when wind turbines are added to a utility system, they increase the overall statistical probability that the system will be able to meet demand requirements. They noted that while wind is an intermittent resource, conventional generating systems also experience periodic outages for maintenance and repair.

The exact amount of capacity value that a given wind project provides depends on a number of factors, including average wind speeds at the site and the match between wind patterns and utility load requirements.

How much energy can wind realistically supply to the U.S.?

Wind energy could supply about 20% of the nation's electricity, or 600 billion kilowatt-hours annually, according to Battelle Pacific Northwest Laboratory, a federal research lab. Wind energy resources useful for generating electricity can be found in nearly every state.

U.S. wind resources are even greater, however. North Dakota alone is theoretically capable (if there were enough transmission capacity, storage capability, etc.) of producing enough wind-generated power to meet more than one-third of U.S. electricity demand. The theoretical potentials of the windiest states are shown in the following table.

1	North Dakota	1,210	11	Colorado	481
2	Texas	1,190	12	New Mexico	435
3	Kansas	1,070	13	Idaho	73
4	South Dakota	1,030	14	Michigan	65
5	Montana	1,020	15	New York	62
6	Nebraska	868	16	Illinois	61
7	Wyoming	747	17	California	59
8	Oklahoma	725	18	Wisconsin	58
9	Minnesota	657	19	Maine	56
10	Iowa	551	20	Missouri	52

THE TOP TWENTY STATES for wind energy potential, as measured by annual energy potential in the billions of kWhs, factoring in environmental and land use exclusions for wind class of 3 and higher.

Source: An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States, Pacific Northwest Laboratory, 1991.

Experience also shows that wind power can provide at least up to a fifth of a system's electricity, and the figure could probably be higher. Wind power currently provides more than

20% of the electricity distributed by Energia Hidroelectrica de Navarra, the regional electric utility of the industrial state of Navarra in northern Spain. In western Denmark, wind supplies more than 25% of the electricity that is used during windy winter nights.

How much energy can wind supply worldwide?

Today, there are approximately 35,000 wind turbines generating power worldwide, totaling 12,000 megawatts of generating capacity and producing more than 20 billion kilowatt-hours each year. Yet this is but a tiny fraction of wind's potential.

According to the U.S. Department of Energy, the world's winds could theoretically supply the equivalent of 5,800 quadrillion BTUs (quads) of energy each year--more than 15 times current world energy demand. (A quad is equal to about 172 million barrels of oil or 45 million tons of coal.)

A recent study performed by Denmark's BTM Consult for the European Wind Energy Association and Greenpeace found that by the year 2017, wind could provide 10% of world electricity supplies, meeting the needs of 500 million average European households.

The potential of wind to improve the quality of life in the world's developing countries, where more than two billion people live with no electricity or prospect of utility service in the foreseeable future, is vast.

What is the "energy payback time" for a wind turbine?

The "energy payback time" is a term used to measure the net energy value of a wind turbine or other power plant--i.e., how long does the plant have to operate to generate the amount of electricity that was required for its manufacture and construction? Several studies have looked at this question over the years and have concluded that wind energy has one of the shortest energy payback times of any energy technology. A wind turbine typically takes only a few months (3-8, depending on the average wind speed at its site) to "pay back" the energy needed for its fabrication, installation, operation and retirement.

Wind Energy and the Economy

What does the U.S. wind industry contribute to the economy?

Wind power supplies affordable, inexhaustible energy to the economy. It also provides jobs and other sources of income. Best of all, wind powers the economy without causing pollution, generating hazardous wastes, or depleting natural resources.

What are America's current sources of electricity?

Coal, the most polluting fuel and the largest source of the leading greenhouse gas, carbon dioxide (CO2), is currently used to generate more than half of all of the electricity (52%)

used in the United States. Other sources of electricity are: natural gas (15%), oil (4%), nuclear (19%), and hydropower (9%).

How many people work in the U.S. wind industry?

The U.S. wind industry currently directly employs more than 2,000 people. The wind industry contributes directly to the economies of 46 states, with power plants and manufacturing facilities that produce wind turbines, blades, electronic components, gearboxes, generators, and a wide range of other equipment.

The European Wind Energy Association (EWEA) estimates that every megawatt of installed wind capacity creates about 60 person-years of employment and 15-19 jobs, directly and indirectly. A typical 50-MW wind farm, therefore, creates some 3,000 person-years of employment. The rate of job creation will decline as the industry grows and becomes able to make more use of efficiencies of volume, but wind and solar energy are still likely to furnish one of the largest sources of new manufacturing jobs worldwide during the 21st Century.

What is the value of export markets for wind?

Export markets are growing rapidly. Overseas markets account for about half of the business of U.S. manufacturers of small wind turbines and wind energy developers. Small wind turbine markets are diverse and include many applications, both on-grid (connected to a utility system) and off-grid (stand-alone). A recent market study predicts that small wind turbine sales will increase fivefold by 2005.

The potential economic benefits from wind are enormous. At a time when U.S. manufacturing employment is generally on the decline, the production of wind equipment is one of the few potentially large sources of new manufacturing jobs on the horizon.

In 1997, AWEA estimated that wind installations worldwide would total more than 48,000 megawatts over the next decade, or more than $45 billion worth of business. The 40% annual growth in installed new capacity in the global market over the last 5 years has, if anything, made that projection look conservative. If the U.S. industry could capture a 25% share of the global wind market through the year 2010, more than 150,000 new jobs would be created.

In what other ways does wind energy benefit the economy?

Wind farms can revitalize the economy of rural communities, providing steady income through lease or royalty payments to farmers and other landowners. Although leasing arrangements can vary widely, a reasonable estimate for income to a landowner from a single utility-scale turbine is about $2,000 a year. For a 250-acre farm, with income from wind at about $55 an acre, the annual income from a wind lease would be $14,000, with no more than 2-3 acres removed from production. Farmers can grow crops or raise cattle next to the towers. Wind farms may extend over a large geographical area, but their actual "footprint" covers only a very small portion of the land, making wind development an ideal way for farmers to earn additional income.   In west Texas, for example, farmers are welcoming wind, as lease payments from this new clean energy source replace declining payments from oil wells that have been depleted.

Farmers are not the only ones in rural communities to find that wind power can bring in income. In Spirit Lake, Iowa, the local school is earning savings and income from the electricity generated by a turbine. In the district of Forest City, Iowa, a turbine recently erected as a school project is expected to save $1.6 million in electricity costs over its lifetime.

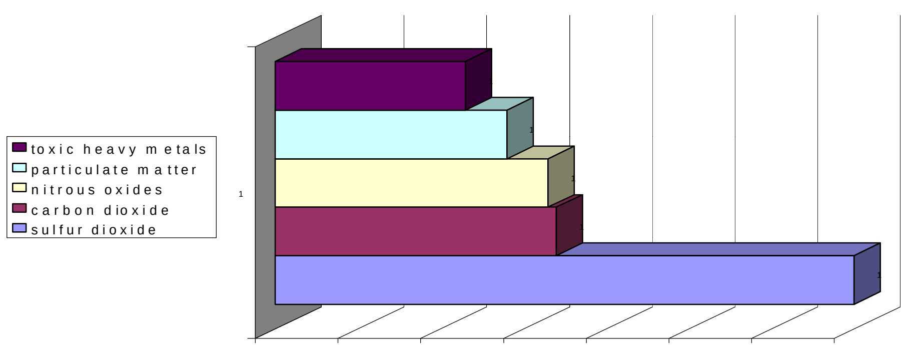
Additional income is generated from one-time payments to construction contractors during installation, and from payments to turbine maintenance personnel on a long-term basis. Wind farms also expand the local tax base, and keep energy dollars in the local community instead of spending them to pay for coal or gas produced elsewhere. Alameda (Calif.) County, for example, collected $725,000 in property taxes during 1998 from wind turbine installations valued at $66 million.

Wind Energy and The Environment

What are the environmental benefits of wind power?

Wind energy system operations do not generate air or water emissions and do not produce hazardous waste. Nor do they deplete natural resources such as coal, oil, or gas, or cause environmental damage through resource extraction and transportation. Wind's pollution-free electricity can help reduce the environmental damage caused by power generation in the U.S. and worldwide.

In 1997, U.S. power plants emitted 70% of the sulfur dioxide, 34% of carbon dioxide, 33% of nitrogen oxides, 28% of particulate matter and 23% of toxic heavy metals released into our nation's environment, mostly the air. These figures are currently increasing in spite of efforts to roll back air pollution through the federal Clean Air Act.



U.S. Power Plants Are a Major Source of Air Pollutants
Source: Northwest Foundation, 12/97

Sulfur dioxide and nitrogen oxides cause acid rain. Acid rain harms forests and the wildlife they support. Many lakes in the U.S. Northeast have become biologically dead because of this form of pollution. Acid rain also corrodes buildings and economic infrastructure such as bridges.

Carbon dioxide (CO2) is a greenhouse gas--its buildup in the atmosphere contributes to global warming by trapping the sun's rays on the earth as in a greenhouse. The U.S., with 5% of the world's population, emits 23% of the world's CO2. The build-up of greenhouse gases is not only causing a gradual rise in average temperatures, but also seems to be increasing fluctuations in weather patterns and causing more severe droughts.

Particulate matter is of growing concern because of its impacts on health. Its presence in the air along with other pollutants has contributed to make asthma one of the fastest growing childhood ailments in industrial and developing countries alike. Toxic heavy metals accumulate in the environment and up the biological food chain.

Development of 10% of the wind potential in the 10 windiest U.S. states would provide more than enough energy to displace emissions from the nation's coal-fired power plants and eliminate the nation's major source of acid rain; reduce total U.S. emissions of CO2 by almost a third and world emissions of CO2 by 4 %; and help contain the spread of asthma and other respiratory diseases aggravated or caused by air pollution in this country.

If wind energy were to provide 20% of the nation's electricity--a very realistic and achievable goal with the current technology--it could displace more than a third of the emissions from coal-fired power plants, or all of radioactive waste and water pollution from nuclear power plants.

The 6 billion kilowatt-hours currently generated by wind plants in the U.S. each year displaced some 9 billion pounds (4.5 million tons) of carbon dioxide, 23,500 tons of sulfur dioxide (64 tons per day), and 15,500 tons of nitrogen oxides (42 tons per day).

What are wind power's other environmental impacts?

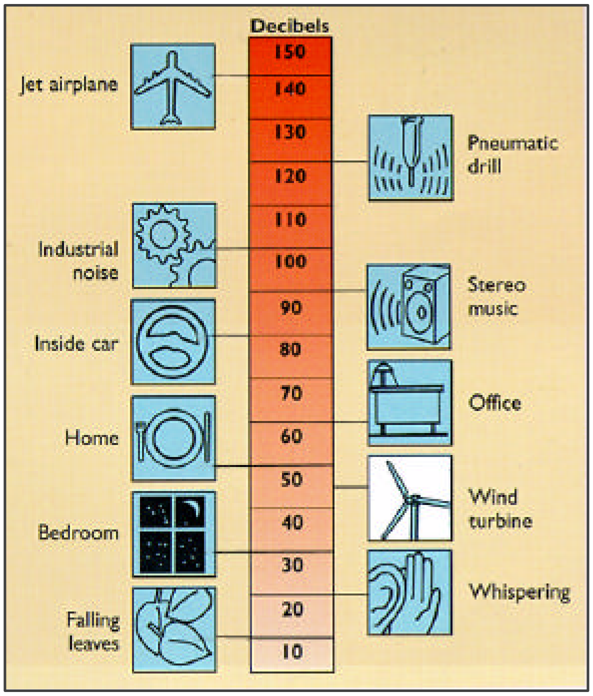
Wind power plants, like all other energy technologies, have some environmental impacts. However, unlike most conventional technologies (which have regional and even global impacts due to their emissions), the impacts of wind energy systems are local. This makes them easier for local communities to monitor and, if necessary, mitigate.

The local environmental impacts that can result from wind power development include:

* **Erosion**, which can be prevented through proper installation and landscaping techniques. Erosion can be a concern in certain habitats such as the desert, where a hard-packed soil surface must be disturbed to install wind turbines.
* **Bird kills and other effects.** Birds occasionally collide with wind turbines, as they do with other tall structures such as buildings. Avian deaths have become a concern at Altamont Pass in California, which is an area of extensive wind development and also high year-round raptor use. Detailed studies at other wind development areas indicate that this is a site-specific issue that will not be a problem at most potential wind sites. However, areas that are commonly used by threatened or endangered species should be regarded as unsuitable for wind development. The wind industry is working with environmental groups, federal regulators, and other interested parties to develop methods of measuring and mitigating wind energy's effect on birds.

* **Visual impacts**, which can be minimized through careful design of a wind power plant. Using turbines of the same size and type and spacing them uniformly generally results in a wind plant that satisfies most aesthetic concerns. Computer simulation is helpful in evaluating visual impacts before construction begins. Public opinion polls show that the vast majority of people favor wind energy, and support for wind plants often increases after they are actually installed and operating.

* **Noise** was an issue with some early wind turbine designs, but it has been largely eliminated as a problem through improved engineering and through appropriate use of setbacks from nearby residences. Aerodynamic noise has been reduced by adjusting the thickness of the blades' trailing edges and by orienting blades upwind of the turbine tower. A small amount of noise is generated by the mechanical components of the turbine. To put this into perspective, a wind turbine 250 meters from a residence is no noisier than a kitchen refrigerator.



How much land is needed for a utility-scale wind plant?

In open, flat terrain, a utility-scale wind plant will require about 50 acres per megawatt of installed capacity. However, only 5% (2.5 acres) or less of this area is actually occupied by turbines, access roads, and other equipment--95% remains free for other compatible uses such as farming or ranching. In California, Minnesota, Texas, and elsewhere, wind energy provides rural landowners and farmers with a supplementary source of income through leasing and royalty arrangements with wind power developers.

A wind plant located on a ridgeline in hilly terrain will require much less space, as little as two acres per megawatt.

How much water do wind turbines use compared with conventional power plants?

Water use can be a significant issue in energy production, particularly in areas where water is scarce, as conventional power plants use large amounts of water for the condensing portion of the thermodynamic cycle. For coal plants, water is also used to clean and process fuel.

According to the California Energy Commission, conventional power plants consume the following amounts of water (through evaporative loss, not including water that is recaptured and treated for further use):

WATER CONSUMPTION--CONVENTIONAL POWER PLANTS		
Technology	gallons/kWh	liters/kWh
Nuclear	0.62	2.30
Coal	0.49	1.90
Oil	0.43	1.60
Combined Cycle	0.25	0.95

Small amounts of water are used to clean wind turbine rotor blades in arid climates (where rainfall does not keep the blades clean). The purpose of blade cleaning is to eliminate dust and insect buildup, which otherwise deforms the shape of the airfoil and degrades performance.

Similarly, small amounts of water are used to clean photovoltaics (solar) panels. Water use numbers for these two technologies are as follows:

WATER CONSUMPTION--WIND AND SOLAR		
Technology	gallons/kWh	liters/kWh
Wind [1]	0.001	0.004
Solar [2]	0.030	0.110

Wind therefore uses less than 1/600 as much water per unit of electricity produced as does nuclear, and approximately 1/500 as much as coal.

NOTES

[1] American Wind Energy Association estimate, based on data obtained in personal communication with Brian Roach, Fluidyne Corp., December 13, 1996. Assumes 250-kW turbine operating at .25 capacity factor, with blades washed four times annually.

[2] Meridian Corp., "Energy System Emissions and Materials Requirements," U.S. Department of Energy, Washington, DC. 1989, p. 23.

Wind Industry Statistics

How much wind generating capacity currently exists in the U.S.? How much will be added over the next several years?

At the end of June, 1999, U.S. capacity reached almost 2,500 MW, after 12 months of record growth. Utility wind power projects now under construction or under negotiation will add some 2,000 megawatts of wind capacity in the U.S. over the next 10 years.

The U.S. Department of Energy has announced a goal of obtaining 5% of U.S. electricity from wind by 2020--a goal that is consistent with the current rate of growth of wind energy nationwide. As public demand for clean energy grows, and as the cost of producing energy from the wind continues to decline, it is likely that wind energy will provide a growing portion of the nation's energy supply.

In what states is there significant wind power development?

California is the state in which most wind power development has occurred up to now. The state, as of June, 1999, had a total of 1,615 MW of wind generating capacity. However, more than half of the new projects built in the U.S. between June, 1998, and June, 1999, were built in **Iowa** (240 MW) and **Minnesota** (247 MW), where state laws have required the development of renewable energy and where wind is the most cost-competitive option.

Other states with sizable wind plants include **Colorado, Oregon, Texas, Wisconsin, and Wyoming**.

Today, wind plants are operating in many regions of the country. For information on wind projects in individual states, visit the AWEA Web site at <**http://www.awea.org**> and click on Wind Projects.

How much wind generating capacity currently exists worldwide? How fast is it growing and where?

In 1999, world wind capacity soared past the 12,000 MW mark. Of that amount, about 2,590 MW was installed during 1998 alone. The Danish industry consulting firm BTM Consult predicts that global wind energy capacity will more than triple from its current level to 31,000 MW by the year 2003. During the 1990s, wind was the fastest-growing power source worldwide, with an annual average growth rate of 22.6%. Since 1994, wind energy's growth in new capacity has accelerated to a rate of more than 40% annually.

Wind power plants are heavily concentrated in Europe and the United States, with the exception of India and China. The "top 10" nations listed below accounted for over 95% of the total wind energy produced in 1998.

World Leaders in Wind Capacity, December 1998

Country	Capacity (MW)	
Germany	2,874	
United States	1,884	(increased to 2,500 by July, 1999)
Denmark	1,450	
India	968	
Spain	834	
Netherlands	363	
United Kingdom	334	
China	224	
Sweden	150	
Canada	83	

Elsewhere, wind is catching on slowly but steadily, with new plants having been built recently in Costa Rica, Australia, New Zealand, and many other countries.

How much is currently invested in the U.S. wind industry?

Wind plants typically cost approximately $1,000 per kilowatt of installed capacity. Thus, today's installed base of 2,500 megawatts in the U.S. amounts to about $2.5 billion in investment.

The U.S. wind energy industry is composed of many small- to medium-sized companies with a growing range of capabilities, plus a few large firms that are divisions of Fortune 500 companies. U.S. wind companies can provide vertically integrated services ranging from wind turbine manufacturing to financing, project development, and operation and maintenance.

How much electricity does wind generate in the U.S. today?

About 2,500 megawatts of wind power capacity are currently installed in the U.S., generating about 6 billion kilowatt-hours annually.

What U.S. utilities are participating in wind power development?

- Alaska Village Electric Cooperative
- Alliant Energy (Iowa-Wisconsin)
- Austin Energy (Texas)
- Bonneville Power Administration
- Cedar Falls Utilities (Iowa)
- Central & South West (Texas-Oklahoma)
- Dairyland Electric Cooperative (Wisconsin)
- Eugene Water & Electric Board (Oregon)
- Fort Collins Light & Power (Colorado)
- Great River Energy (Minnesota)
- Green Mountain Power Co. (Vermont)
- Kotzebue Electric Association (Alaska)
- Holy Cross Electric Association (Colorado)

- Lincoln Electric System (Nebraska)
- Lower Colorado River Authority (Texas)
- Madison Gas & Electric Co. (Wisconsin)
- Marshall Public Utilities (Minnesota)
- Mid-American Energy (Iowa)
- Moorhead Public Service (Minnesota)
- Nebraska Public Power District
- Northern States Power Co. (Minnesota)
- PacifiCorp
- Pacific Gas & Electric Co. (California)
- Platte River Power Authority (Colorado)
- Portland General Electric Co. (Oregon)
- Princeton Municipal Light Dept. (Massachusetts)
- Public Service Co. of Colorado
- Reliant Energy HL&P (Texas)
- Sacramento Municipal Utility District (California)
- SCANA (South Carolina)
- Southern California Edison Co.
- Southwestern Public Service Co. (Texas-New Mexico)
- Traverse City Power & Light Co. (Michigan)
- Tri-State Generation & Transmission (Colorado)
- TXU Corp. (Texas)
- Waverly Light & Power (Iowa)
- Western Resources (Kansas)
- Wisconsin Electric Power Co.
- Wisconsin Power & Light Co.
- Wisconsin Public Power
- Wisconsin Public Service Corp.

In what states is there significant wind power development activity?

Wind power plant development is occurring in many regions of the country. States in which utility wind power projects are operating or being developed include Alaska, California, Colorado, Hawaii, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Nebraska, New Mexico, New York, Oregon, Pennsylvania, Texas, Vermont, Wisconsin, and Wyoming.

Small Wind Energy Systems

How many turbines are needed to power a household or farm?

For a home or farm, one turbine is normally installed. The turbine's size is chosen to meet the energy requirements given the available wind resource. Turbines with power ratings from 1 kW to 25 kW are typically used.

For village electrification applications, both single and multiple turbine installations are common, and turbines up to 100 kW in capacity may be used.

How much land is needed for a small wind system?

The actual space required for a small wind turbine tower is quite small. It can be as small as one square yard, but as a general rule, at least one-half acre is recommended for a single small turbine installation.

What size tower is used for a small-scale wind turbine?

Usually a tower between 80 and 120 feet in height is supplied with the wind turbine. Towers of this height raise the turbine above turbulence generated by obstacles (such as buildings and trees) on the ground. Also, wind velocity increases with greater altitude, so wind turbine performance improves with height.

How do small turbine costs compare to the costs of other alternatives?

Small wind turbines (ranging in size from 250 watts to 50 kW) are often the least expensive source of power for remote sites that are not connected to the utility system.

The Congressional Office of Technology Assessment has found wind to be cheaper for meeting remote loads than diesel generators, photovoltaics, or utility transmission line extensions. (Micro-hydro also was found to be less expensive in many locations.)

Hybrid systems--wind/photovoltaic, wind/diesel, and other combinations--can often provide the most efficient and cost-effective option for rural electrification. Photovoltaics (PV)--the direct conversion of sunlight into electricity--are often used to supplement wind power since PV tends to operate best in low wind months. Diesel generators or batteries can be used for backup power and to maintain power production during low wind seasons.

A recent study of an Arctic community with annual average wind speeds of 15 mph compared the cost of a 500-kW diesel system to that of a 200-kW diesel generator and four mid-sized wind turbines. If found that the wind/diesel combination cost considerably more to install ($378,000 versus $125,000), but would deliver fuel savings of $90,000 per year, paying for itself in less than three years.*

*For more information, see Proceedings of the Seventh Wind-Diesel Workshop, 1993.

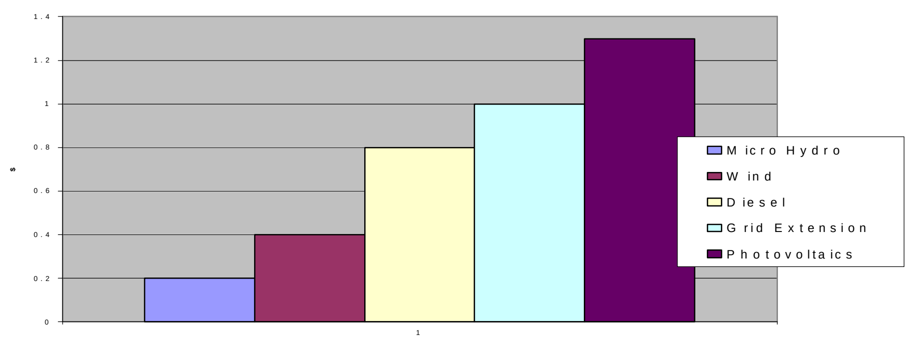
Why are small wind turbines better than diesel generators or extension of utility lines in developing countries?

Small wind turbines are better because they are more sustainable and offer a number of other socioeconomic benefits. Wind systems come in smaller sizes than diesel generators and have a shorter leadtime than extending the utility lines ("grid"). For grid extension distances as short as one kilometer, a wind system can be a lower cost alternative for small loads. While wind turbines cost more initially than diesels, they are often much better from the user's point of view because of typical foreign aid practices. Donor agencies, for example, typically supply diesels at no cost, but leave operational costs (fuel, maintenance and replacement) to be supplied by the local people. These expenses (in particular, fuel and parts) require scare hard currency. This usually leads to limited utilization and a shortened diesel lifetime due to inadequate maintenance. Many countries must also import their fossil fuels, further magnifying the burden imposed by diesels.

How do small wind turbines compare with other renewable energy technologies suitable for decentralized rural electrification?

Wind power is very competitive with photovoltaics (solar), biomass, and diesel generators, but is usually more expensive than micro-hydro. Wind is also very attractive for the ease with which the technology can be transferred to developing countries. Generally speaking, wind power complements these other power sources by providing a least cost approach under certain conditions. This expands the range of potential projects, pointing to the day when decentralized electrification projects will be implemented on the same scale as current utility line extension projects. In many situations, the lowest-cost centralized system will be a hybrid system that combines wind, photovoltaics and diesel.

Cost of Energy for Remote Village Power (producing 50kWh/day)



Source: Renewable Energy for Agriculture & Health, U.S. Agency for International Development

Aren't wind turbines too "high-tech" for rural people?

The high technology of a wind turbine is in just a few manufactured components such as the blades. A wind turbine can actually be much simpler than a diesel engine, and also require substantially less attention and maintenance. Some types of small turbines can operate for extended periods, five years or more, without any attention. With training and spare parts, local users can support the wind turbine equipment they use.

What companies make small wind electric systems?

The following AWEA members manufacture small wind electric systems:

- Atlantic Orient Corp.
- Bergey Windpower Co.
- Northern Power Systems
- Southwest Wind Power Co.
- Synergy Power Corp. (Hong Kong)
- Wind Turbine Industries Corp.
- World Power Technologies, Inc.

What companies make water pumping wind turbines?

The following AWEA members manufacture water pumping wind turbines:

- Bergey Windpower Co.
- Synergy Power Corp. (Hong Kong)
- WindTech International
- World Power Technologies, Inc.

Wind Energy Policy Issues

I've heard that the U.S. utility industry is being "restructured." How will that affect wind energy?

Where wind energy is concerned, utility restructuring will have both positive and negative impacts.

On the positive side, as with long-distance telephone service, restructuring will offer consumers a chance to choose to buy their electricity from among a number of different service providers. Since electricity generation, unlike phone service, has major environmental impacts, it seems likely that some of these service providers will choose to offer "green" (environmentally-friendly) products from clean power sources like wind. Indeed, many electric utilities are already offering wind-generated electricity as an option today.

On the negative side, the primary purpose of restructuring is to allow large industrial companies to shop among power suppliers for the cheapest price. It will do this regardless of the environmental impacts of the sources that are used. Already, this appears to be leading to increasing generation from older, dirtier coal-fired plants that were "grandfathered" (exempted from having to install new pollution controls) under the Clean Air Act. To the degree that restructuring encourages cheap generation regardless of environmental costs, it will be harmful to wind energy.

One solution that has been suggested to some of the problems posed by restructuring is the Renewables Portfolio Standard (RPS).

What is the Renewables Portfolio Standard and how does it work?

The Renewables Portfolio Standard (RPS) would require each company that generates electricity in the U.S., or in a given state, to obtain part of the electricity it supplies from renewable energy sources such as wind. To meet this requirement, the company could either generate electricity from renewables itself or buy credits or electricity from a renewable generator such as a wind farm. This "credit trading" system has been used effectively by the federal Clean Air Act to require utilities to reduce pollutant emissions.

Aside from the "minimum renewable content" requirement, the RPS imposes very few other requirements on companies--they are free to buy, trade, or generate electricity from renewables in whatever fashion is most efficient and economical for them. The RPS is therefore often described by its supporters as being "market-friendly."

Several federal restructuring bills have included an RPS, and at least eight states have also adopted RPS laws. Typically, the RPS gradually increases over time, by 1% per year or some such number, in order to encourage the sustained, orderly development of renewable energy industries.

What exactly is "green power"?

Green power is a term applied to electricity that is generated from wind and other renewable energy sources, such as solar, geothermal, biomass, and small hydropower. Typically, the environmental impacts of these sources are quite modest compared to those of coal and other conventional sources.

Utility green power programs vary, but one common approach is for a utility to offer its customers the option of buying electricity generated from wind at a premium price. For example, a customer might be able to sign up to receive a certain number of 100-kilowatt-hour "blocks" of electricity from wind each month for an extra $2 each (that is, for 2 cents to 4 cents per kilowatt-hour). A customer signing up for 2 blocks at $2 would pay $4 more for electricity each month and receive 200 kilowatt-hours of wind-generated electricity. The utility would then add enough wind capacity to its generating mix to provide the additional electricity required. (The utility cannot deliver specific electrons from any of its plants to a specific customer. Instead, its generating mix should be thought of as a pool. Power plants add electricity to the pool and customers take it out. With green power, the utility adds more wind energy to the pool based on the amount customers have said they will purchase.)

No one knows yet how successful green programs and products will be in the electricity marketplace. If consumers learn more about the air pollution, strip mining, and other harmful environmental impacts of electricity generation and decide to "vote with their dollars" for clean energy, green power could be come a large and growing business over the next decade and beyond.

Customers in parts or all of the states of California, Colorado, Idaho, Kansas, Michigan, Minnesota, Nebraska, New Mexico, Ohio, Oregon, Pennsylvania, Texas, Washington, and Wisconsin have the option today to sign up for green power.

What about government purchases? Do federal and state governments use their purchasing power to encourage clean energy?

Governments--federal, state, and local--are jointly the largest consumer of energy and electricity in the United States.

In 1998, the federal government alone consumed 1,077 trillion British thermal units (Btu) of energy, or 1.14% of total energy use. Within that total, it consumed approximately 54 billion kilowatt-hours of electricity, or about 1.6% of total national electricity use. The federal government's total energy bill was $8 billion, or 2% of the federal consumption of goods and services. Its electricity bill was approximately $3.5 billion. Perhaps more important, in 1998 the federal government used more than twice as much electricity as was generated by all the solar, wind, and geothermal facilities owned by utilities and the industrial sector nationwide. Federal energy dollars could have a great impact on renewable energy markets.

By and large, the potential of government purchases to encourage clean energy industries has not been realized. In early 1999, President Clinton issued an Executive Order that urges government agencies to consider the federal government's policy of supporting renewable energy in making energy purchases. More recently, the federal Environmental Protection Agency (EPA) has announced that one of its facilities in California will be entirely supplied by green power, and the U.S. Army has announced plans to develop wind energy at Fort Bliss, New Mexico. More commonly, though, government agencies, like industrial companies, look for the cheapest electricity source, regardless of environmental consequences.

Is wind energy heavily subsidized? More than other forms of energy?

Wind energy received a direct subsidy, the Production Tax Credit (PTC), from December 31, 1993, to June 30, 1999. The PTC provided a tax credit of 1.5 cents per kilowatt-hour (adjusted for inflation) to the producer of electricity from wind energy. The PTC was an acknowledgement that wind energy can play an important role in the nation's energy mix. It was also a recognition that the federal energy tax code favors established, conventional energy technologies. The wind industry is currently seeking to have the PTC extended for another five years, to June 30, 2004.

All energy technologies are subsidized by the U.S. taxpayer. Subsidies come in various forms, including payment for production, tax deductions, guarantees, and leasing of public lands at below-market prices. Subsidies can also be provided indirectly, for example through federal research and development programs, and provisions in federal legislation and regulations. For example, loopholes in the Clean Air Act currently exempt older power plants from compliance with federal pollution standards and become, in effect, a kind of subsidy that lowers the price of electricity from coal-fired power plants.

Here are some conclusions from a detailed 1993 study of energy subsidies by the Alliance to Save Energy (*Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts*):

> "Energy subsidies in 1989 favored mature, conventional energy supply resources by $32.3 billion to $3.8 billion over non-conventional energy resources: $21 billion went to fossil fuels, $11 billion to nuclear, and $900 million to all renewable energy sources including wind.
>
> "There is currently no free market in energy. Given the size of federal energy subsidies, now and in the past, it is erroneous to speak of a 'free market' in energy. . . It may be appropriate to subsidize emerging energy resources, but mature resources should stand the test of the market. When this test is applied to subsidies in 1989, the pattern appears to be almost completely backward. In other words, the mature, conventional technologies received almost 90% of the subsidies."

The pattern of subsidies that the Alliance found is also flatly opposed to the views of the American public. In numerous public opinion surveys over the past several years, those surveyed have favored providing government assistance to clean energy sources and not to nuclear or fossil fuels. For example, in one national poll conducted in mid-1999, 80% of respondents said they favor the use of tax incentives to increase the use of renewable energy for the production of electricity.

What is "net metering" ("net billing") and how does it work?

Net metering or net billing is a term applied to laws and programs under which a utility allows the meter of a customer with a residential power system (such as a small wind turbine) to turn backward, thereby in effect allowing the customer to deliver any excess electricity he produces to the utility and be credited on a one-for-one basis against any electricity the utility supplies to him.

This 20kW wind turbine generates power and savings
(Wind Turbine Industries Corp.)

Example: During a one-month period, John Doe's wind turbine generates 300 kilowatt-hours (kWh) of electricity. Most of the electricity is generated at a time when equipment in John's household (refrigerator, lights, etc.) is drawing electricity and is used on site. However, some is generated at night when most equipment is turned off. At the end of the month, the turbine has generated 100 kWh in excess of John's instantaneous needs and has been transmitted to the utility system. The utility has also supplied John with a total of 500 kWh for his use at times when the wind turbine has not been generating or has been insufficient for his needs. Since the meter ran backward while 100 kWh was being transmitted to the utility, the utility will only bill John for 400 kWh, rather than 500 kWh.

Net metering can dramatically improve the economics of a residential wind turbine by allowing the turbine's owner to use her excess electricity to offset utility-supplied power at the full retail rate, rather than having to sell the power to the utility at the price the utility pays for the wholesale electricity it buys or generates itself. Many utilities have argued against net metering laws, saying that they are being required, in effect, to buy power from wind turbine owners at full retail rates, and are therefore being deprived of a profit on part of their electricity sales. However, wind energy advocates have successfully argued that what is going on is a power swap, and that it is standard practice in the utility industry for utilities to trade power among themselves without accounting for differences in the cost of generating the various kilowatt-hours involved.

Today, net metering's popularity is growing. Twenty-nine states have enacted it in some form, and others are considering it.

Wind Energy Resource Guide

Where can I go for more information?

Trade Associations

American Wind Energy Association
122 C Street, N.W.
Washington, D.C. 20001
(202) 383-2500, fax (202) 383-2505
windmail@awea.org
http://www.awea.org

Kern Wind Energy Association
P.O. Box 277
Tehachapi, CA 93581-0277
http://www.kwea.org

Technical Assistance

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401
Technical Inquiries (303) 275-4099
National Wind Technology Center (303) 384-6900
http://www.nrel.gov

General Information (The following publications can be purchased from AWEA. To order, call the AWEA publications department at (202) 383-2500.)

**Introduction to Small Wind Systems*
Evaluating Residential Wind System Economics
Understanding Your Wind Resource
published by AWEA
Booklets outlining the basics of small wind systems. The books provide information on siting, determining energy needs, assessing wind resources, financing, and other crucial elements in designing a small wind system.

**Wind Power for Home & Business*
by Paul Gipe
A comprehensive guide for those who want to learn how wind energy systems work and how they can tap wind resources.

**Wind Energy Resource Atlas*
published by Battelle Pacific Northwest Laboratories
A good source for general wind data for each state. Includes an explanation of wind resource assessment methods.

**AWEA Membership Directory*
Provides a listing of wind turbine manufacturers, project developers and others, including contact information. (The directory is available only on the World Wide Web, at http://www.awea.org.)

Wind Energy Publications

AWEA Publications Catalog (available at http://www.awea.org)

Online Information

AWEA Web site
http://www.awea.org
Contains the AWEA Membership Directory and Publications Catalog plus a wide variety of other information about wind energy systems and the wind industry.

References

The Wind Energy Production Tax Credit: A User's Guide
published by AWEA

International Wind Power Markets
by Arthur D. Little

Renewable Energy for New York State--Policy Options for a Clean Energy Future
published by AWEA

Workshop Report: Seventh International Wind-Diesel Workshop, August 22-25, 1993
published by AWEA and the Canadian Wind Energy Association

Electricity Transmission Pricing Report
by Dr. Richard Rosen and Dr. Stephen Bernow
The Tellus Institute, Boston, Mass.

The Most Frequently Asked Questions About Wind Energy was produced by the American Wind Energy Association in cooperation with the U.S. Department of Energy and the National Renewable Energy Laboratory.