The Most Frequently Asked Questions About Wind Energy

American Wind Energy Association

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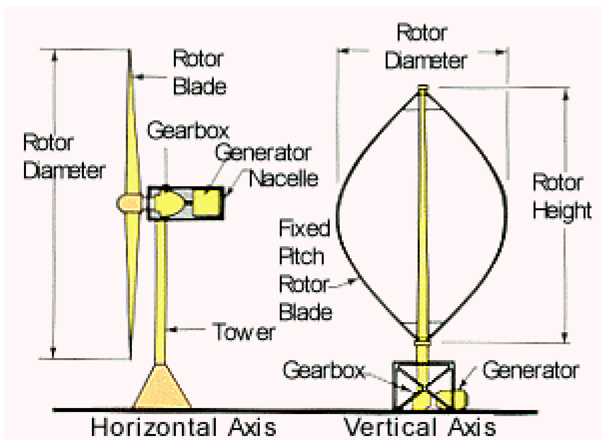
Contents

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 today, constituting nearly all of the "utility-scale" (100 kilowatts, kW, capacity and larger) turbines in the global market.



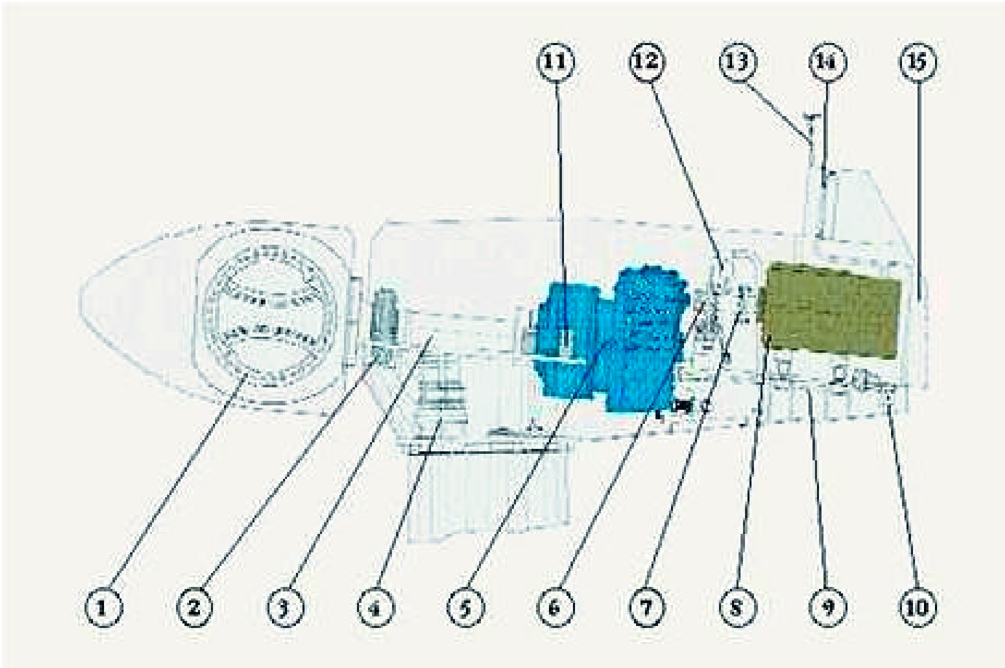
Wind Turbine Configurations

Turbine subsystems include:

- a **rotor**, or **blades**, which convert the wind's energy into rotational shaft energy;
- a **nacelle** (enclosure) 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.

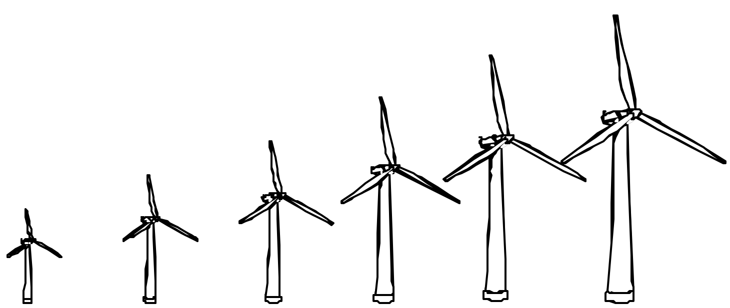
*Some turbines operate without a gearbox.

The following illustration shows the inside of a nacelle:



1. Spherical hub	5. Gearbox	9. Frame	13. Anemometer and wind vane
2. Main bearing	6. Fail safe hydraulic disc brake unit	10. Heat exchanger for cooling of the gearbox oil	14. Radiator
			15. Cover
3. Main shaft	7. Flexible coupling	11. Gearbox suspension	
4. Yaw gear	8. Liquid-cooled generator	12. Crane for maintenance work	

Wind turbines vary in size. The following chart depicts a variety of turbine sizes and the amount of electricity they are each capable of generating (the turbine's capacity, or power rating).



	1981	1985	1990	1996	1999	2000
Rotor (meters)	10	17	27	40	50	71
KW	25	100	225	550	750	1,650
MWh	45	220	550	1,480	2,200	5,600

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* (kW, 1,000 watts), *megawatt* (MW, 1 million watts), and *gigawatt* (pronounced "jig-a-watt," GW, 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 one kilowatt (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 1.8 megawatts (MW).

Example: A 10-kW wind turbine can generate about 16,000 kWh annually, more than enough to power a typical household. A 1.8-MW turbine can produce more than 5.2 million kWh in a year--enough to power more than 500 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, (pictured at left) 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. This project has been so successful that the Spirit Lake school district has since installed a second turbine with a capacity of 750 kW.

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 could in theory generate about 33% more electricity than one at an 11-mph site, because the cube of 12 (1,768) is 33% larger than the cube of 11 (1,331). (In the real world, the turbine will not produce quite that much more electricity, but it will still generate much more than the 9% difference in wind speed. The important thing to understand is that what seems like a small difference in wind speed can mean a large difference in available energy and in electricity produced, and therefore, a large difference in the cost of the electricity generated.

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

Most manufacturers of utility-scale turbines offer machines in the 700-kW to 1.8-MW range. Ten 700-kW units would make a 7-MW wind plant, while 10 1.65-MW machines would make a 18-MW facility. In the future, machines of larger size will be available, although they will probably be installed offshore, where larger transportation and construction equipment can be used.

How many homes can one megawatt of wind energy supply?

An average U.S. household uses about 10,000 kilowatt-hours (kWh) of electricity each year. One megawatt of wind energy can generate between 2.4 million and 3 million kWh annually. Therefore, a megawatt of wind generates about as much electricity as 240 to 300 households use. It is important to note that since the wind does not blow all of the time, it cannot be the only power source for that many households without some form of storage system. The "number of homes served" is just a convenient way to translate a quantity of electricity into a familiar term that people can understand.

What is a wind power plant?

The most economical application of wind electric turbines is in groups of large machines (660 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 (below). The wind farm generates electricity while agricultural use continues undisturbed.

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 to two years (including resource assessment and permitting).

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).

It is important to note that while capacity factor is almost entirely a matter of reliability for a fueled power plant, it is not for a wind plant—for a wind plant, it is a matter of economical turbine design. With a very large rotor and a very small generator, a wind turbine would run at full capacity whenever the wind blew and would have a 60-80% capacity factor—but it would produce very little electricity. The most electricity per dollar of investment is gained by using a larger generator and accepting the fact that the capacity factor will be lower as a result. Wind turbines are fundamentally different from fueled power plants in this respect.

If a wind turbine's capacity factor is 33%, doesn't that mean it is only running one-third of the time?

No. A wind turbine at a typical location in the Midwestern U.S. should run about 65-80% of the time. However, much of the time it will be generating at less than full capacity (see previous answer), making its capacity factor lower.

What is "availability factor"?

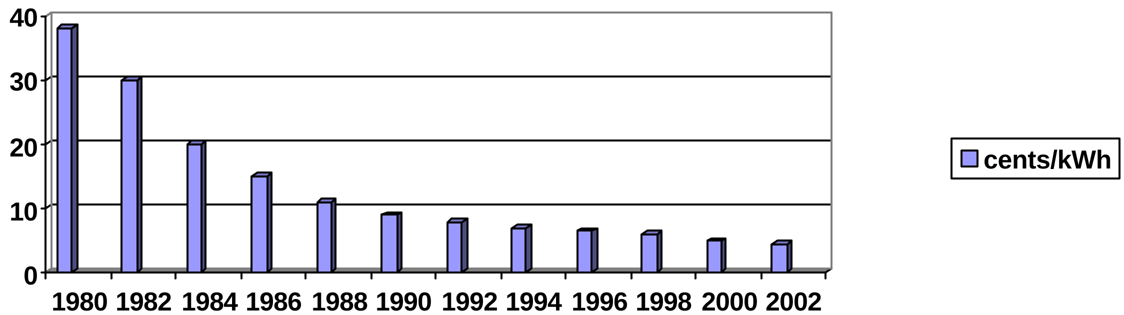
Availability factor (or just "availability") is a measurement of the reliability of a wind turbine or other power plant. It refers to the percentage of time that a plant is ready to generate (that is, not out of service for maintenance or repairs). Modern wind turbines have an availability of more than 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 can generate electricity for less than 5 cents/kWh in many parts of the U.S., a price that is in a competitive range with many conventional energy technologies.

Cost of Wind-Generated Energy in Levelized Cents/kWh

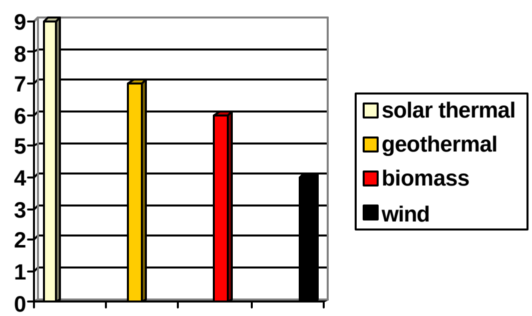


Assumptions: levelized cost at excellent wind sites, large project size, not including PTC

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)
Assumptions for wind energy cost: levelized cost at excellent wind sites, large project size

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 is currently scheduled to expire on December 31, 2003. An effort is underway to extend it through December 31, 2006, to provide a stable financial environment for the wind energy industry. For information on the status of that effort, contact the American Wind Energy Association (AWEA), phone (202) 383-2500, e-mail <windmail@awea.org>.

*The PTC is adjusted annually for inflation, and currently stands at 1.7 cents/kWh.

If wind energy is competitive, why does it need a tax credit subsidy from the government? Isn't this government interference in the free market?

The energy market has never been free—large energy producers such as coal and oil have always been able to win government subsidies of various kinds. To take just one example, the federal government has paid out $35 billion over the past 30 years to cover the medical expenses of coal miners who suffer from "black lung disease." These subsidies mean that the true cost of coal is not reflected in its market price.

As the previous answer indicates, the wind PTC was passed by Congress to give wind a "level playing field" compared with other subsidized energy sources. More information on energy subsidies is available at
http://www.repp.org/repp_pubs/articles/resRpt11/preleasesubsidies.pdf .

More generally, coal receives a huge hidden subsidy resulting from the fact that its full environmental and health costs are not accounted for. A recent article in *Science* magazine reported that coal-fired electricity would cost 50-100% more if these costs were taken into account ("Exploiting Wind Versus Coal," Mark Z. Jacobson and Gilbert M. Masters, *Science*, 24 August 2001, Vol. 293, p. 1438).

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 (demand) requirements.

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

Wind energy could supply about 20% of the nation's electricity, 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 nearly 25% of electricity demand in the north German state of Schleswig Holstein. In western Denmark, wind supplies more than 50% of the electricity that is used during windy winter nights.

What is needed for wind to reach its full potential in the U.S.?

First, new transmission lines. The entire transmission system of the Missouri River Basin, which covers the central one-third of the U.S., needs to be extensively redesigned and redeveloped. At present, this system consists mostly of small distribution lines—instead, a series of new high-voltage transmission lines is needed to transmit electricity from wind plants to population centers. Such a redevelopment will be expensive, but it will also benefit consumers and national security, through increased system reliability.

Second, nondiscriminatory access to transmission lines. Transmission line operators typically charge generators large penalty fees if they fail to deliver electricity when it is scheduled to be transmitted. The purpose of these penalty fees is to punish generators and deter them from using transmission scheduling as a "gaming" technique gain advantage against competitors, and the fees are therefore not related to whether the system operator actually loses money as a result of the generator's action. But because the wind is variable, wind plant owners cannot guarantee delivery of electricity for transmission at a scheduled time. Wind energy needs a new penalty system that recognizes the different nature of wind plants and allows them to compete on an equitable basis.

Transmission will be a key issue for the wind industry's future development over the next few decades.

How much energy can wind supply worldwide?

Today, there are approximately 50,000 wind turbines generating power worldwide, totalling 24,000 megawatts of generating capacity and producing more than 50 billion kilowatt-hours each year—as much as five million average American households use, or as much as eight large nuclear power plants could generate. 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 study ("Wind Force 10") 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.

I've heard that Denmark is pulling back on wind development. Does that mean wind is a failure?

No. As this is being written (early 2002), Denmark is revisiting its current wind policy. The degree to which that means the U.S. should reexamine its own policy revolves around the degree to which our situation is similar to Denmark's. In fact, a brief analysis of some major differences suggests that there are strong reasons for continuing to support wind development in the U.S. rather than back away from it:

--*Denmark is small, the U.S. is not*:

(1) Wind supplies 15% of national electricity demand in Denmark. Although the U.S. has nearly twice as much installed wind equipment as Denmark, wind generates only 0.3% of our electricity, far below the 10% threshold identified by most analysts as the point at which wind's variability becomes a significant issue for utility system operators.

(2) Denmark is also so small geographically (half the size of Indiana) that high winds can cause many of its wind plants to shut down almost at once--in the U.S., wind plants are much more geographically dispersed and do not all experience the same wind conditions at the same time.

--*Denmark has transformed its national power system, the U.S. has not:*
Rapid development of wind and new small-scale power plants within the past five years has brought Denmark to the point where power produced by so-called non-dispatchable resources in the country's West exceeds 100% of demand in the region. At many times, this excess generation leaves the country scrambling to increase electricity export capabilities to handle the surplus. This situation is essentially unimaginable in the U.S.

--*Danish wind plants are typically small, U.S. wind plants are not:*
Denmark's approach encourages community involvement, but places particular stress on low-capacity distribution networks (at the "end of the line" on transmission systems). In the U.S., our larger wind plants require advance transmission planning, but feed into main transmission lines and do not affect the customer distribution network.

In summary, Denmark's situation should not cause concern in the U.S. Denmark's problem is that wind has been very successful very quickly in a small country, and it must now take steps to manage that success; would that the U.S. had dealt with its energy problems so decisively.

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.

Since you can't count on the wind blowing, what does a utility gain by adding 100 megawatts (MW) of wind to its portfolio of generating plants? Does it gain anything? Or should it also add 100 MW of fueled generation capacity to allow for the times when the wind is calm?

First, it needs to be understood that the bulk of the “value” of any supply resource is in the energy the resource produces, not the capacity it adds to a utility system. Having said that, utilities use fairly complicated computer models to determine the value in added capacity that each new generating plant adds to the system. According to those models, the capacity value of a new wind plant is approximately equal to its capacity factor. Thus, adding 100-MW wind plant with an average capacity factor of 35% to the system is approximately the same as adding 35 MW of conventional fueled generating capacity. The exact answer depends on, among other factors, the correlation between the time that the wind blows and the time that the utility sees peak demand. Thus wind farms whose output is highest in the spring months or early morning hours will generally have a lower capacity value than wind farms whose output is high on hot summer evenings.

Since wind is a variable energy source, doesn't its growing use present problems for utility system managers?

At current levels of use, this issue is still some distance from being a problem on most utility systems. The rule of thumb (admittedly rough) is:

- Up to the point where wind generates about 10% of the electricity that the system is delivering in a given hour of the day, it's not an issue. There is enough flexibility built into the system for reserve backup, varying loads, etc., that there is effectively little difference between such a system and a system with 0% wind.

- At the point where wind is generating 10% to 20% of the electricity that the system is delivering in a given hour, it is an issue that needs to be addressed, but that can probably be resolved with wind forecasting (which is fairly accurate in the time frame of interest to utility system operators), system software adjustments, and other changes.

- Once wind is generating more than about 20% of the electricity that the system is delivering in a given hour, the system operator begins to incur significant additional expense because of the need to procure additional equipment that is solely related to the system's increased variability.

These figures assume that the utility system has an “average” amount of resources that are complementary to wind’s variability (e.g., hydroelectric dams) and an “average” amount of load that can vary quickly (e.g., electric arc furnace steel mills). Actual utility systems can vary quite widely in their ability to handle as-available output resources like wind farms. However, as wholesale electricity markets grow, fewer, larger utility systems are emerging. Therefore, over time, more and more utility systems will look like an “average” system.

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—it has no "hidden costs."

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 (16%), oil (3%), nuclear (20%), and hydropower (7%).

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 American Wind Energy Association estimates that every megawatt of installed wind capacity creates about 2.5 job-years of direct employment (short-term construction and long-term operations and maintenance jobs) and about 8 job-years of total employment (direct and indirect). This means that a 50-MW wind farm creates 125 job-years of direct employment and 400 job-years of total employment.

Wind and solar energy are 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.

AWEA estimates that wind installations worldwide will total more than 75,000 megawatts over the next decade, or more than $75 billion worth of business. If the U.S. industry could capture a 25% share of the global wind market through the year 2012, many thousands of 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 $3,000 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. Such a sum can significantly increase the net income from farming. 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 (picture at left). 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 and suppliers 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.

Finally, wind also benefits the economy by reducing "hidden costs" resulting from air pollution and health care. Several studies have estimated that 50,000 Americans die prematurely each year because of air pollution.

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.

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. Nitrogen oxides (which are released by otherwise clean-burning natural gas) are also a primary component of smog.

Carbon dioxide (CO_2) 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 CO_2. 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, and it has also recently been linked to lung cancer. Similarly, urban smog has been linked to low birth weight, premature births, stillbirths and infant deaths. In the United States, the research has documented ill effects on infants even in cities with modern pollution controls. Toxic heavy metals accumulate in the environment and up the biological food chain.

Development of just 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 CO_2 by almost a third and world emissions of CO_2 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 the radioactive waste and water pollution from nuclear power plants.

The 10 billion kilowatt-hours currently generated by wind plants in the U.S. each year displace some 13.5 billion pounds (6.7 million tons) of carbon dioxide, 35,000 tons of sulfur dioxide (98 tons per day), and 21,000 tons of nitrogen oxides (58 tons per day).

How does wind stack up on greenhouse gas emissions when the "total fuel cycle" (including manufacture of equipment, plant construction, etc.) is considered?

The claim is sometimes made that manufacturing wind turbines and building wind plants creates large emissions of carbon dioxide. This is false. Several studies have found that even when these operations are included, wind energy's CO2 emissions are quite small—on the order of 1% of coal or 2% of natural gas per unit of electricity generated.

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 and bat kills and other effects.** Birds and bats 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, and monitoring following construction, at other wind development areas indicate that this is a site-specific issue that will not be a problem at most potential wind sites. Also, wind's overall impact on birds is low compared with other human-related sources of avian mortality—see [Avian Perspectives Paper Web address] for more information. No matter how extensively wind is developed in the future, bird deaths from wind energy are unlikely to ever reach as high as 1% of those from other human-related sources such as hunters, house cats, buildings, and autos. Wind is, quite literally, a drop in the bucket. Still, 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.

Bat collisions at wind plants tend to be low in number and to involve common species that are quite numerous. Human disturbance of hibernating bats in caves is a far greater threat to species of concern.

* **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. For more information on public attitudes toward wind, see http://www.awea.org/faq/survpub.html .

* **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 (cited in Paul Gipe's WIND ENERGY COMES OF AGE, John Wiley & Sons, 1995), 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 Gas	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, approximately 1/500 as much as coal, and approximately 1/25 as much as natural gas, the most popular choice for new power plants

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.

I've heard that wind energy doesn't really reduce pollution, because other, fossil-fired generating units have to be kept running on a standby basis in case the wind dies down. Is this true?

No. It is true that other generating plants have to be available to the power system's operator to supply electricity when the wind is not blowing. However, the wind does not just start and stop. Typically, wind speeds increase gradually and taper off gradually, and the system operator has time to move other plants on and off line (start and stop them from generating) as needed--the fluctuations in wind plant output change more slowly than do the changes in customer demand that a utility must adjust to throughout the day. Studies indicate that for a 100-megawatt wind plant, only about 2 megawatts of conventional capacity is needed to compensate for changes in wind plant output.

What about turbines throwing blades, or ice? Is wind energy dangerous to the public?

It has been estimated by a number of reliable sources that 50,000 Americans a year die from air pollution, of which about one-third is produced by power plants. By contrast, in 20 years of operation, the wind industry (which emits no pollutants) has recorded only one death of a member of the public--a skydiver in Germany who parachuted off-course into an operating wind plant. Blade throws were common in the industry's early years, but are unheard of today because of better turbine design and engineering. Ice throw, while it can occur, is of little danger because of setbacks typically required to minimize noise (see above).

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 2001, U.S. capacity reached 4,261 MW, after a year of record-shattering growth during which 1,695 MW were added. Utility wind power projects now under construction or under negotiation will add at least 3,000 megawatts of wind capacity in the U.S. over the next five 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. As of the end of 2001, the Golden State had a total of 1,671MW of wind generating capacity. However, Texas powered into a strong second place during 2001, installing more new capacity—916 MW—than had ever before been installed in the entire U.S. during a single year. Texas' total wind capacity now amounts to 1,096 MW. Other states with sizable wind plants include Colorado, Iowa, Kansas, Minnesota, New York, Oregon, Pennsylvania, Texas, Washington, Wisconsin, and Wyoming.

Wind plants are now 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 2001, world wind capacity soared past the 24,000 MW mark, having doubled in the past two years. Of that amount, about 6,500 MW was installed during 2001 alone. Since 1990, , wind has been the fastest-growing power source worldwide on a percentage basis, with an annual average growth rate of just over 25%. During the past two years, it has tripled in Germany and quadrupled in Spain.

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 2001.

World Leaders in Wind Capacity, December 2001

Country	Capacity (MW)		
Germany	8,750	Italy	697
United States	4,261	Netherlands	483
Spain	3,337	United Kingdom	474
Denmark	2,417	China	399
India	1,407	Sweden	290

Elsewhere, wind is catching on slowly but steadily, with new plants having been built recently in Portugal, Morocco, 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 4,261 megawatts in the U.S. amounts to over $4 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 4,261 megawatts of wind power capacity are currently installed in the U.S., generating about 10 billion kilowatt-hours annually. That is as much electricity as about 1 million average American households use each year.

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, Illinois, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Montana, Nebraska, Nevada, New Mexico, New York, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Texas, Vermont, Washington, 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.

A study by the Congressional Office of Technology Assessment 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--is 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.

One 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 construction lead time 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.

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.

What companies make water pumping wind turbines?

The following AWEA members manufacture water pumping wind turbines:

- Bergey Windpower Co.
- Southwest Wind Power Co.
- Synergy Power Corp. (Hong Kong)
- WindTech International

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) (see next question).

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," because it allows market forces to decide which renewable energy sources will be developed where, and also allows price competition.

Several federal restructuring bills have included an RPS, and at least 12 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"? Can you tell me more about it? How can I buy it?

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.

Green power programs vary, but one common approach, called "green pricing," 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 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 desire to purchase.)

A second form of green power is used in states that have opened their electricity markets to competition (in much the same way as long-distance telephone service is now open to competition). In these states, electricity suppliers offer electricity "products" from renewable and other sources, and customers are free to sign up for the product and company they prefer. One company, for example, might offer a product that is called "Earth Saver" that is 50% wind-generated electricity and 50% electricity from landfill gas, and charge 1.5 cents/kWh more than "system power" (regular commodity electricity from the regional generating mix).

A third form of green power is called "green tags" and can be used by consumers anywhere to "green" their electricity supply. With this approach, when a certain amount of electricity (e.g., 1,000 kWh) is generated from a renewable source, a certificate called a "green tag" is created. The generator sells the electricity into the commodity wholesale market, but keeps the certificate (which represents the beneficial environmental attributes of the electricity) and sells it to an interested buyer for an agreed-upon price (e.g., $20, or 2 cents/kWh). By buying green tags that represent the amount of renewable generation equal to your electricity use, you can, in effect, "green" your power supply in much the same way that you would through "green pricing" or "green power"—you are paying extra, and extra renewable energy is being delivered to the utility system based upon your payment.

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 become a large and growing business over the next decade and beyond.

Customers in many states have the option today to participate in green pricing or green power programs, while of course, customers anywhere can buy green tags. To find out more about your options, check the U.S. Department of Energy's Green Power Network Web site at http://www.eren.doe.gov/greenpower/consumers.shtml .

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 and many individual consumers, look for the cheapest electricity source, regardless of environmental consequences.

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

Wind energy currently receives a direct subsidy, the Production Tax Credit (PTC). The PTC provides a tax credit of 1.5 cents per kilowatt-hour (adjusted for inflation, currently 1.7 cents) 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 three years, to December 31, 2006.

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 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.

> 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 that electricity has been transmitted to the utility system. During the month, the utility also supplied John with a total of 500 kWh for his use at times when the wind turbine was not generating or was 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 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. Thirty-four 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
(661) 822-7956, fax (661) 331-3868
kweawhite@aol.com

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, please visit AWEA's **Online Bookstore** at www.awea.org or call the AWEA publications department at (202) 383-2500.)

**Introduction to Small Wind Systems*
published by AWEA
Booklet answering many of the basic questions people have about small wind systems. Topics include: determining your energy needs, siting the turbine, energy backup options, purchasing a system, and operation and maintenance. While this publication is not intended to be a "how-to" manual, it is a useful introduction to small wind systems and their application.

**Understanding Your Wind Resource*
published by AWEA
Booklet designed to give an overview of the nature of wind and the methods of assessing the wind energy potential of a given site. The publication will help the reader understand the methods used in site evaluation and the process of determining a wind resource's viability.

**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 Handbook*
by Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi
Book providing comprehensive treatment of wind energy for electricity generation. Covers issues ranging from practical concerns about component design to the economic importance of sustainable power sources.

**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.)

Online Information

AWEA Web site
http://www.awea.org
Contains the AWEA Membership Directory (http://www.awea.org/directory/), free AWEA publications (http://www.awea.org/pubs/complimentary.html), and AWEA Online Bookstore, 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.