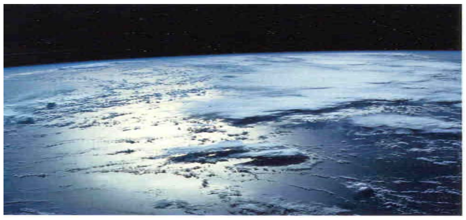

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Wind Power Basics 101

What is wind energy?

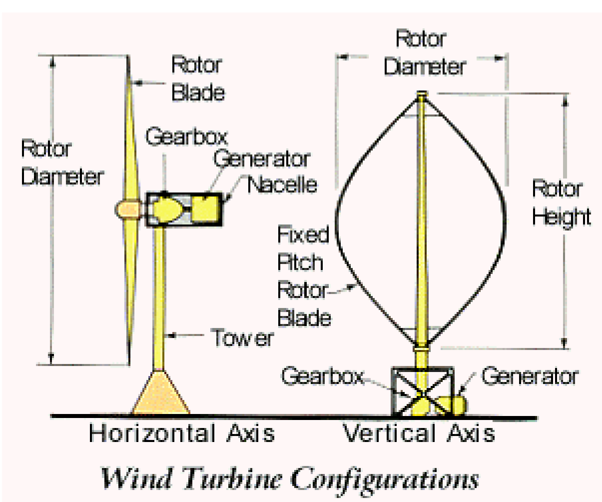
In reality, wind energy is a converted form of solar energy. The sun's radiation heats different parts of the earth at different rates—most notably during the day and night, but also when different surfaces (for example, water and land) absorb or reflect at different rates. This in turn causes portions of the atmosphere to warm differently. Hot air rises, reducing the atmospheric pressure at the earth's surface, and cooler air is drawn in to replace it. The result is wind.

Air has mass, and when it is in motion, it contains the energy of that motion --- "kinetic energy." Some portion of that energy can be converted into other forms --- mechanical force or electricity --- that we can use to perform work.

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 — the "farm windmill" still seen in many rural areas of the U.S. is a mechanical wind pumper — but it can also be used for many other purposes (grinding grain, sawing, pushing a sailboat, etc.). 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 (propeller-style) 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

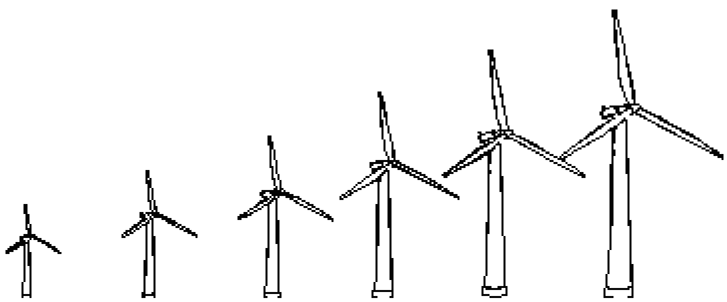
Contact Us

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 do not require a gearbox

Wind turbines vary in size. This 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
Rating (KW)	25	100	225	550	750	1,650
Annual MWh	45	220	550	1,480	2,200	5,600

The electricity generated by a utility-scale wind turbine is normally collected and fed into utility power lines, where it is mixed with electricity from other power plants and delivered to utility customers.

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 10,000 kWh annually at a site with wind speeds averaging 12 miles per hour, or about 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, 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 earned the school $25,000 in its first five years of operation. 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, an annual average wind speed greater than four meters per second (m/s) (9 mph) is 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. Also, there is little energy to be harvested at very low wind speeds (6-mph winds contain less than one-eighth the energy of 12-mph winds).

What are wind turbines made of?

The towers are mostly tubular and made of steel. The blades are made of fiberglass-reinforced polyester or wood-epoxy.

How big is a wind turbine?

Utility-scale wind turbines for land-based wind farms come in various sizes, with rotor diameters ranging from about 50 meters to about 90 meters, and with towers of roughly the same size. A 90-meter machine, definitely at the large end of the scale at this writing (2003), with a 90-meter tower would have a total height from the tower base to the tip of the rotor of approximately 135 meters (442 feet).

Offshore turbine designs now under development will have larger rotors—at the moment, the largest has a 110-meter rotor diameter—because it is easier to transport large rotor blades by ship than by land.

Small wind turbines intended for residential or small business use are much smaller. Most have rotor diameters of 8 meters or less and would be mounted on towers of 40 meters in height or less.

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 1.8-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. Units larger than 4 MW in capacity are now under development.

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. (Typically, storage is not needed, because wind generators are only part of the power plants on a utility system, and other fuel sources are used when the wind is not blowing.)

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. 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. Most of that time is needed for measuring the wind and obtaining construction permits—the wind farm itself can be built in less than six months.

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.

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

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. Although modern utility-scale wind turbines typically operate 65% to 80% of the time, they often run at less than full capacity. Therefore, a capacity factor of 25% to 40% is common, although they may achieve higher capacity factors during windy weeks or months.

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" or "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.

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 competitive with new coal- or gas-fired power plants.

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 that will be lower still.

Why does the cost of wind energy vary from place to place?

The most important factors in determining the cost of wind-generated electricity from a wind farm are: (1) the size of the wind farm; (2) the wind speed at the site; and (3) the cost of installing the turbines. Each of these factors can have a major impact. Generally speaking:

- The larger the wind farm, all other factors being equal, the lower the cost of energy;
- The higher the wind speed, the lower the cost of energy;
- The less expensive construction costs are, the lower the cost of energy.

On New England ridgelines, for example, wind farms are likely to be smaller, to experience lower wind speeds, and cost more to install than in the flat terrain of northern Plains states. While wind power may cost less than 5 cents/kWh in the northern Plains, it may cost 6-7 cents/kWh in New England.

In the case of offshore wind farms, the distance that power must be transmitted to shore is a fourth potentially significant cost element.

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

Wind is the low-cost emerging renewable energy resource.

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 which then sells the electricity to customers at "retail"). It applies to electricity produced during the first 10 years of a wind plant's operation. The company that owns the wind plant subtracts the value of the credit from the business taxes that it would otherwise pay.

The U.S. Congress recently (December 31, 2003) allowed the wind PTC to expire for the third time since it was created. An effort is underway to extend the PTC through December 31, 2008, to provide a stable financial environment for the wind energy industry.

An incentive similar to the PTC is made available to public utilities (which do not pay taxes and therefore cannot benefit from a tax credit). The incentive is called the Renewable Energy Production Incentive (REPI) and it consists of a direct payment to a public utility installing a wind plant that is equal to the PTC (1.5 cents per kilowatt-hour, adjusted for inflation). However, since the REPI involves the actual spending of federal funds, money must be "appropriated" (voted) for it annually by Congress. It is sometimes difficult to obtain full funding for REPI because of competing federal spending priorities. As with the PTC, for information on the status of REPI funding, contact AWEA.

[1] *The PTC is adjusted annually for inflation, and stood at 1.8 cents/kWh as of December 2003*

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 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). The hidden environmental and health costs of coal and other fossil fuels are also confirmed by a major 10-year study by the European Union.

Nuclear power and oil also benefit from hidden subsidies. The potential cost of damages that might result from an accident at a nuclear power plant are too large for the insurance industry to cover, so the federal government has pledged to act as "insurer of last resort" above a certain level of cost. The cost of oil does not reflect government military expenditures that are required to make sure that the shipping lanes to the Persian Gulf remain open.

If wind energy is competitive, why do "green power" or "green pricing" programs charge extra for it?

There are several reasons for the cost premium (typically 2 to 3 cents per kilowatt-hour) that most green marketers charge for wind-generated electricity. Among them:

1. If the power is being sold by a marketing company, it has to recover the cost of its marketing campaigns;

2. Whether the power is being sold by a marketing company or a utility, the sale is being done on a piecemeal basis. Often one turbine's output is sold, then another's, and another's. Also, the term of the sales to retail customers is short, typically a year or two. This is more expensive, and risky, than buying all of the power from a 50-megawatt or 100-megawatt wind farm for 10 years.

The experience of Austin Energy, the municipal utility for Austin, Tex., shows just how competitive wind can be when these obstacles are removed. When Austin Energy set up its green pricing program, it did not sell small "blocks" of power to individual customers and then base the size of its wind purchase on how much was sold. Instead, it signed a 10-year contract to buy wind power and offered its customers a fixed rate for wind power for 10 years. At this writing, late 2003, the rising cost of natural gas is swiftly closing the gap between the price for wind and the price for Austin Energy's regular electricity supply—in January, 2004, regular electricity will cost 2.80 cents per kilowatt-hour and wind-generated electricity will cost 2.85 cents per kilowatt-hour—a difference of only 1/20 of a cent, or roughly 75 cents a month for an average household.

(It is important to remember, though, that the federal production tax credit (PTC) helps to lower the cost of wind power for Austin Energy and other sellers.)

If my utility uses more wind energy, will that make my electric rates go up?

Yes, probably, but not much. Let's say that wind energy costs 2 cents more per kilowatt-hour (2 cents/kWh) than the rest of the electricity your utility is generating or buying—a conservative estimate. If your utility were to decide to use wind energy to generate 10% of its electricity (more than nearly all utilities in the U.S.), then the added cost to you would be 0.2 cents/kWh. An average U.S. home uses about 800 kWh per month, so you would pay an extra $1.60 per month, or about a nickel a day.

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, despite the fact that the wind is variable and sometimes does not blow at all, wind plants do increase the overall statistical probability that a utility system will be able to meet demand requirements. A rough rule of thumb is that the capacity value of adding a wind plant to a utility system is about the same as the wind plant's capacity factor multiplied by its capacity. Thus, a 100-megawatt wind plant with a capacity factor of 35% would be similar in capacity value to a 35-MW conventional generator. For example, in 2001 the Colorado Public Utility Commission found the capacity value of a proposed 162-MW wind plant in eastern Colorado (with a 30% capacity factor) to be approximately 48 MW.

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. It also depends on how dispersed geographically wind plants on a utility system are, and how well-connected the utility is with neighboring systems that may also have wind generators. The broader the wind plants are scattered geographically, the greater the chance that some of them will be producing power at any given time.

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) 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.

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

	B kWh/Yr		B kWh/Yr
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

Source: An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States, Pacific Northwest Laboratory, August 1991. PNL-7789

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 100% of the electricity that is used during some hours on windy winter nights.

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

A number of factors are needed, including:

Consistent policy support. Over the past five years (1999-2003), the federal production tax credit has been extended twice, but each time Congress allowed the credit to expire before acting, and then only approved short durations. The PTC expired again December 31, 2003, and as of March 2004 had still not been renewed. These expiration-and-extension cycles inflict a high cost on the industry, cause large lay-offs, and hold up investments. Long-term, consistent policy support would help unleash the industry's pent-up potential.

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 to 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 a fair basis.

New transmission lines. The entire transmission system of the wind-rich High Plains, which cover 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, by making the electrical transmission system more reliable and by reducing shortages and price volatility of natural gas.

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

How much energy can wind supply worldwide?

As of the end of 2003, there were over 39,000 megawatts of generating capacity operating worldwide, producing some 90 billion kilowatt-hours each year—as much as 9 million average American households use, or as much as a dozen 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.)

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.

A study ("Wind Force 12") performed by Denmark's BTM Consult for the European Wind Energy Association and Greenpeace found that by the year 2020, wind could provide 12% of world electricity supplies, meeting the needs of 600 million average European households.

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

No. As this is being written (mid-2003), 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 20% of national electricity demand in Denmark. Although the U.S. has nearly twice as much installed wind equipment as Denmark, wind generates only 0.4% 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 (from California to New York to Texas) 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 too successful too quickly in a small country, and it must now take steps to manage that success; it is unfortunate that the U.S. has not 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 a 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. Variations introduced by wind are much smaller than routine variations in load (customer demand).

- 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.

Since wind is a variable energy source, doesn't it cost utilities extra to accommodate on a system that mostly uses fueled power plants with predictable outputs?

Yes, but as the previous answer suggests, the added cost is modest. Three major studies of utility systems with less than 10% of their electricity supplied by wind have found the extra or "ancillary" costs of integrating it to be less than 0.2 cents per kilowatt-hour. Two major studies of systems with wind at 20% or more have found the added cost to be 0.3 to 0.6 cents per kilowatt-hour.

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." Finally, wind energy depends on a free fuel source—the wind—and so it is relatively immune to inflation.

What are America's current sources of electricity?

Coal, the most polluting fuel and the largest source of the leading greenhouse gas, carbon dioxide (CO_2), 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 Renewable Energy Policy Project (REPP) estimates that every megawatt of installed wind capacity creates about 4.8 job-years of employment, both direct (manufacturing, construction, operations) and indirect (advertising, office support, etc.). This means that a 50-MW wind farm creates 240 job-years of 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 2013, 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 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 could 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. 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.

I've heard that rising natural gas prices are hurting our economy. Is this a problem that wind energy can help to solve?

Yes. When a wind farm generates electricity in the U.S., the fuel that it is most likely to displace is natural gas. In mid-2003, when Federal Reserve Board Chairman Alan Greenspan testified before Congress that rising natural gas prices were threatening the economy's future, the American Wind Energy Association (AWEA) estimated that U.S. wind plants were already reducing the national natural gas shortage by 10-15%. AWEA has stated that enough wind plants could be built within four years to eliminate the entire gas shortage (estimated at 3-4 billion cubic feet of gas per day).

In 2001, the Colorado Public Utility Commission recognized wind's value as a hedge against volatile natural gas prices, requiring a major utility to include a wind plant in its generating mix in the state rather than relying solely on natural gas.

I own some land that is windy. How can I build a wind farm on it?

A first step is to find out more about just how windy your land is—its "wind resource."

What are the environmental benefits of wind power?

A basic and comprehensive reference on this issue is "The Environmental Imperative for Renewable Energy: An Update," by the Renewable Energy Policy Project (REPP).

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, or require significant amounts of water during operation. 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 frequent and severe droughts and floods. The World Meteorological Organization (WMO) warned in July, 2003, that extreme weather events appear to be increasing in number due to climate change.

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. A number of states have banned or limited the eating of fish from fresh-water lakes because of concerns about mercury, a toxic heavy metal, accumulating in their tissue.

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 CO2 by almost a third; 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.

In 2004, the American Wind Energy Association estimates that wind plants in the U.S. will generate 16 billion kilowatt-hours. If instead the average utility fuel mix were used to generate that much electricity, 21 billion pounds (10.6 million tons) of carbon dioxide, 56,000 tons of sulfur dioxide (150 tons per day), and 33,000 tons of nitrogen oxides (92 tons per day) would be released into the atmosphere.

The comparative environmental impacts of various options for producing electricity have been extensively studied by the European Union in a 10-year effort called the "ExternE" ("external" or non-economic costs of energy). As with every other study of non-economic costs that has been conducted, the Externe study found wind energy's costs to be among the lowest, far below those of fossil fuels. The highest non-economic cost for wind in any European country, for example, was 0.25 Euro cents per kilowatt-hour, while the lowest cost for coal was 2-4 Euro cents/kWh (eight to 16 times as much).

Will using more wind energy help to prevent global warming?

Yes! Carbon dioxide (CO_2) is the most important of the greenhouse gases which are changing our climate. According to experts, if we are to avoid dangerous levels of climate change we must cut our CO_2 emissions by 80-90 per cent by 2050. That means switching to forms of energy generation that do not produce CO_2.

Wind power is a clean, renewable form of energy, which during operation produces no carbon dioxide. While some emissions of these gases will take place during the design, manufacture, transport and erection of wind turbines, enough electricity is generated from a wind farm within a few months to totally compensate for these emissions. When wind farms are dismantled (usually after 20-25 years of operation) they leave no legacy of pollution for future generation.

Given the scale of the CO_2 cuts needed, wind power--as the least expensive, most developed renewable energy technology and the fastest to build--is the best placed renewable technology to deliver carbon cuts on a large scale, quickly.

Will using more wind energy reduce health care costs?

Yes! In 2000, the Harvard School of Public Health looked at the human health effects from two fossil-fuel-fired power plants in Massachusetts. It estimates that the air pollution from the plants causes:

- 159 premature deaths
- 1,710 emergency room visits
- 43,300 asthma attacks

each year. Replacing as much of this electricity as possible with wind energy would clearly lower associated health care costs.

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 CO_2 emissions are quite small — on the order of 1% of coal or 2% of natural gas per unit of electricity generated. Or in other words, using wind instead of coal reduces CO_2 emissions by 99%, using wind instead of gas by 98%.

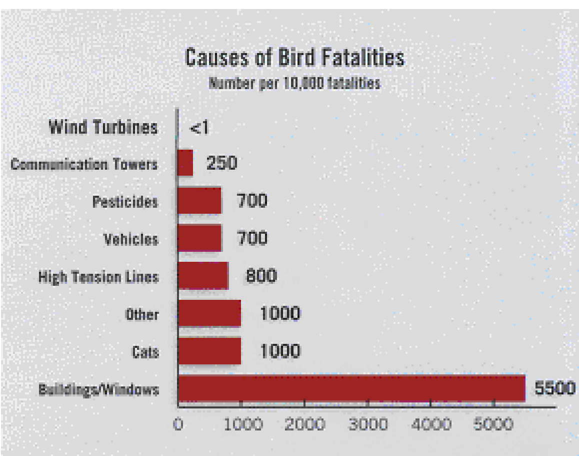
What are wind power's other environmental impacts?

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 and fuel imports), the impacts of wind energy systems are minimal and 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. Erosion has also been raised as a concern in the eastern U.S., where wind farms typically must be installed on mountain ridgelines. However, standard engineering practices used by ski areas on the same kind of terrain are adequate to deal with any erosion issues that might be raised by construction of a wind farm and its service road.

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. The following graph is based on data from the studies described in that report:



Source: Erickson, et.al, 2002. Summary of Anthropogenic Causes of Bird Mortality

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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. (House cats, for example, are believed to kill 1 billion birds annually in the U.S. alone.) Wind is, quite literally, a drop in the bucket. Still, areas that are commonly used by threatened or endangered bird 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.

Wind energy can also negatively impact birds and other wildlife by fragmenting habitat, both through installation and operation of wind turbines themselves and through the roads and power lines that may be needed. This has been raised as an issue in areas with unbroken stretches of prairie grasslands or of forests. More research is needed to better understand these impacts.

Bat collisions at wind plants generally tend to be low in number and to involve common species which are quite numerous. Human disturbance of hibernating bats in caves is a far greater threat to species of concern. At the same time, a surprisingly high number of bat kills at a new wind plant in West Virginia in the fall of 2003 has raised concerns. The problem of bat mortality at that site is currently under investigation.

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 changing the thickness of the blades' trailing edges and by making machines "upwind" rather than "downwind" so that the wind hits the rotor blades first, then the tower (on downwind designs where the wind hits the tower first, its "shadow" can cause a thumping noise each time a blade passes behind the tower). A small amount of noise is generated by the mechanical components of the turbine. To put this into perspective, a wind turbine 300 meters away is no noisier than the reading room of a library.

Shadow Flicker is occasionally raised as an issue by close neighbors of wind farm projects. A wind turbine's moving blades can cast a moving shadow on a nearby residence, depending on the time of the year (which determines how low the sun is in the sky) and time of day. It is possible to calculate very precisely whether a flickering shadow will in fact fall on a given location near a wind farm, and how many hours in a year it will do so. Therefore, it should be easy to determine whether this is a potential problem. Normally, it should not be a problem in the U.S., because at U.S. latitudes (except in Alaska) the sun's angle is not very low in the sky, and the appropriate setback for noise (see above) will be sufficient to prevent shadow flicker problems.

Will wind energy hurt tourism in my area?

People who would rather not live near wind plants (sometimes referred to as "NIMBYs," short for "Not In My Back Yard") often raise this concern with respect to new wind project proposals.

There is no evidence that wind farms reduce tourism, and considerable evidence to the contrary. For example, in late 2002, a survey of 300 tourists in the Argyll region of Scotland, noted for its scenic beauty, found that 91% said the presence of new wind farms "would make no difference in whether they would return." Similar surveys of tourists in Vermont and Australia have produced similar results. Many rural areas in the U.S. have noted increases in tourism after wind farms have been installed, as have scenic areas in Denmark, the world's leader in percentage of national electricity supplied by wind. Other telling indicators: local governments frequently decide to install information stands and signs near wind farms for tourists; wind farms are regularly featured on post cards, magazine covers, and Web pages.

How popular is wind energy?

Wind energy is one of the most popular energy technologies. Opinion surveys regularly show that just over eight out of 10 people (80%) are in favor of wind energy, and less than one in ten (around 5%) are against it. The rest are undecided.

Public opinion in support of wind power tends to become even more strongly in favor once the wind turbines are installed and operating, a finding from several surveys carried out in the UK and in Spain.

Some people who live near proposed wind projects may be apprehensive about them. But when accurate information and knowledge is made available, experience shows that initial concerns are reduced and support for wind farms increases.

Why is there sometimes opposition to wind energy projects?

Local opposition to proposed wind farms usually arises because some people perceive that the development will spoil the view that they are used to. It is true that a large wind farm can be a significant change, but while some people express concern about the effect wind turbines have on the beauty of our landscape, others see them as elegant and beautiful, or symbols of a better, less polluted future.

The visual effect of wind farms is a subjective issue, but most of the other criticisms made about wind energy today are exaggerated or untrue, and simply reflect attempts by particular groups to discredit the technology, worry local communities, and turn them against proposed projects. In the electronic age, myths and misinformation about wind power spread at lightning speed.

There are three major environmental groups — the World Wildlife Fund, Greenpeace, and Friends of the Earth — who believe that wind's benefits in reducing greenhouse gas emissions and air pollution far outweigh its negative impacts.

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

In open, flat terrain, a utility-scale wind plant will require about 60 acres per megawatt of installed capacity. However, only 5% (3 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]T	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.

Also, whenever the wind is blowing, it displaces the most expensive conventional power plant that is generating. Typically, this tends to be the oldest and dirtiest gas plants on a utility system, but in some parts of the country (notably the mid-Atlantic states such as Maryland, West Virginia, or Virginia), wind power may displace coal.

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 German skydiver 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 setbacks typically required to minimize noise (see above) are sufficient to protect against danger to the public, and because ice buildup slows a turbine's rotation and will be sensed by a turbine's control system, causing the turbine to shut down. One European group that has investigated the ice throw question recommends a setback of 1.5 times the sum of a turbine's hub height and its rotor diameter.

Why not develop wind farms on mountains that are already being used for ski resorts?

Because of the potential danger from ice throw. As the above answer indicates, ice throw does not present a danger except for the area close to turbines (that is, within a few hundred meters). At ski areas, however, turbines would typically have to be sited very close to operating lifts and trailheads, making ice throw a safety concern.

I've heard that stray voltage from wind power plants can be transmitted through the ground, disturbing or harming livestock. Is this true?

No. There is nothing different or unusual about managing the electricity flow from an operating wind plant. Standard electric wiring practices are adequate to prevent stray voltage from occurring.

Will a wind project interfere with electromagnetic transmissions such as radio, television, or cell-phone signals?

First, this is not a problem for modern small (residential) wind turbines. The materials used to make such machines are non-metallic (composites, plastic, wood) and small turbines are too small to create electromagnetic interference (EMI) by "chopping up" a signal.

Large wind turbines, such as those typically installed at wind farms, can interfere with radio or TV signals if a turbine is in the "line of sight" between a receiver and the signal source, but this problem can usually be easily dealt with improving the receiver's antenna or installing relays to transmit the signal around the wind farm. Use of satellite or cable television is also an option.

Will a wind project interfere with radar?

Yes. Radar is basically designed to filter out stationary objects and display moving ones, and moving wind turbine blades create radar echoes. It is possible to modify a radar installation to eliminate this problem, according to a consulting firm that has studied it for the British government. According to the study: "This study concludes that radars can be modified to ensure that air safety is maintained in the presence of wind turbine farms. Individual circumstances will dictate the degree and cost of modification required, some installations may require no change at all whilst others may require significant modification."

If a wind project is proposed near an airport or military airfield, this issue will likely require further technical investigation. The interference is generally limited to objects (airplanes) that are physically shadowed by the turbines (that is, very low-flying aircraft), so the further the turbines are from an airfield and the lower their altitude, the less interference should occur.

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 has both positive and negative impacts.

On the positive side, as with long-distance telephone service, restructuring offers 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 does this regardless of the environmental impacts of the sources that are used. This has led 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 is 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," 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. One federal proposal, for example, would require 20% of U.S. electricity to come from non-hydro renewable energy sources (wind, solar, biomass, geothermal) by the year 2020. Typically, the RPS gradually increases over time, by 1% per year or some such number, in order to provide a foundation for the sustained, orderly development of renewable energy industries.

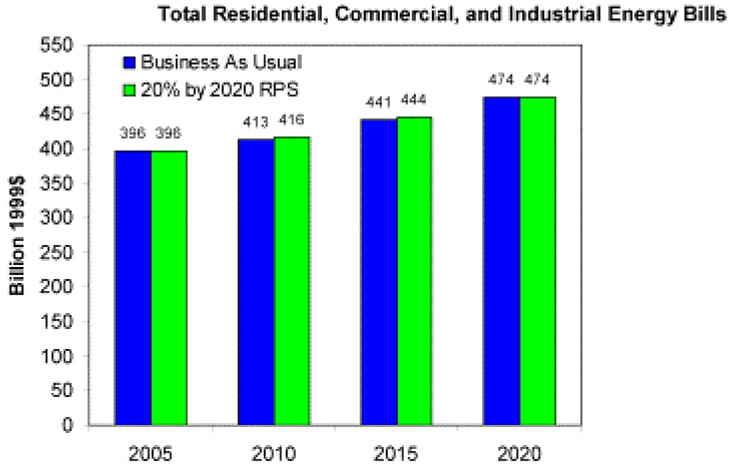
Is it feasible to supply 20% of US electricity from non-hydro renewable sources by 2020?

Yes. The United States is blessed by an abundance of renewable energy resources from the sun, wind, and earth. Good wind areas, covering only 6% of the land area of the "lower 48" states, could theoretically supply more than one and a third times the total current national demand for electricity. A 12,000-square-mile area in Nevada could produce enough electricity from the sun to meet annual national demand. There are large untapped geothermal and biomass (energy crops and plant waste) resources. Of course, there are limits to how much of this potential can be used economically, because of competing land uses, competing costs from other energy sources, and limits to the transmission system. The important question is how much it would cost to supply 20% of our electricity from renewable energy sources other than hydroelectric power.

How much would it cost to supply 20% of our electricity from renewable energy sources other than hydroelectric power?

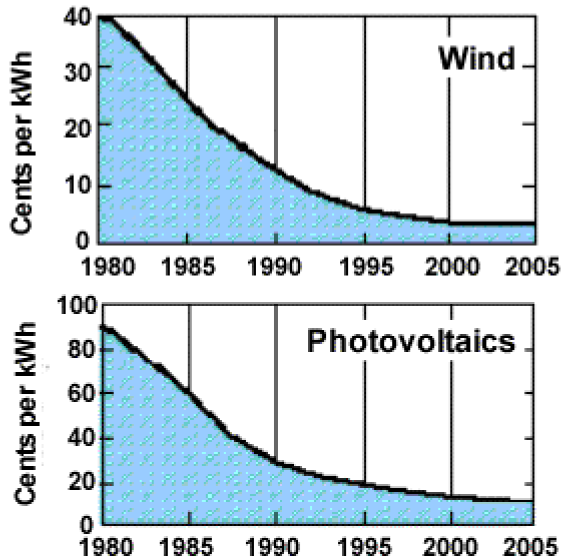
Not very much. A major study in 2002 by the U.S. Energy Information Administration (EIA)—using very high estimates of renewable energy costs—found that an RPS of 20% by 2020 would raise electricity costs by about 0.2 cents per kilowatt-hour (kWh), from 6.6 cents/kWh to 6.8 cents/kWh (See Figure 1). Further, most of the increase would be offset by reductions in the price of natural gas for home heating. Other studies, using more realistic assumptions developed by the U.S. Department of Energy's Interlaboratory Working Group, consisting of the five national energy research labs, have found that a 20% RPS, when combined with energy efficiency programs, could save consumers billions of dollars.

Figure 1. National RPS Cost - 20% by 2020



Source: EIA,[1] Appendix E, Table E3.

Figure 2. Renewable Energy Cost Reductions
Source: U.S. DOE[3]



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 (for example, 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 (for example, $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.

Why should I buy green power?

Some of the most common reasons why people buy green power are to:

- Improve human health
- Preserve the earth for their children and grandchildren
- Reduce environmental impacts
- Conserve finite fossil resources

Green power can also offer protection against rising electricity prices or price volatility. We have seen the devastating effects of volatile wholesale electricity prices in California in 2000 and early 2001. In addition, natural gas prices, which influence electricity prices, have "spiked" twice in the last three years, rising sharply above historic ranges.

When I pay extra for green power, does it really come directly to my home?

Probably not--the flow of electricity usually follows the path of least resistance to the nearest demand, so you probably don't get "green" electrons flowing directly from a wind farm to your home. The electricity system operates like a large pool of water, with many pumps (power plants) adding water and many outlets (customers) withdrawing it. When you buy green power, instead of actually getting it at your home or business, you are helping to change the mix of generating plants that put electricity into the "pool." Each green power provider either generates, or purchases from a generator, enough wind or other renewable energy to supply the amount of electricity that green power customers are purchasing. By selecting wind energy over conventional electricity generation, consumers indicate support for the growth of America's wind energy industry and encourage utilities to add and expand green power programs. As the popularity of green power grows, power producers have to build additional wind plants to meet growing demand.

If I buy green power, will my electricity supply be reliable when the wind isn't blowing?

Yes. Remember that the wind energy is not delivered directly to your home. Instead, the wind energy goes into a "pool" along with all other types of energy generation. It is this "pool" that serves all electricity users. This is true whether or not the wind blows. Therefore, if one plant, say a wind turbine (but also any other power plant), isn't generating, then another plant will be asked to generate more electricity to meet demand. (The green power provider does not have to guarantee a steady supply of green electricity, but rather only to generate or buy as much green electricity over the course of a year or month as you pay for.)

Most power outages or interruptions in your service are not caused by whether or not a particular generator is operating. Instead, the problem is usually in the distribution system--for example, power lines downed from a storm. So you'll still call your local distribution utility when you have a problem.

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 the nation's 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 1.8 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.

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