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Wind Web Tutorial

WIND ENERGY and the ENVIRONMENT

- What are the environmental benefits of wind power?
- Will using more wind energy help to prevent global warming?
- Will using more wind energy reduce 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?
- What are wind power's other environmental impacts?
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- Why not develop wind farms on mountains that are already being used for ski resorts?
- Will a wind project interfere with electromagnetic transmissions such as radio, television, or cell-phone signals?
- Will wind energy hurt tourism in my area?
- How popular is wind energy?
- Why is there sometimes opposition to wind energy projects?
- How much land is needed for a utility-scale wind plant?
- How much water do wind turbines use compared with conventional power plants?
- What about turbines throwing blades, or ice? Is wind energy dangerous to the public?
- I've heard that stray voltage from wind power plants can be transmitted through the ground, disturbing or harming livestock. Is this true?
- Will a wind project interfere with radar?

FAQ / wind web tutorial

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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), available on the Web at http://www.repp.org/repp_pubs/repp_publications.html

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 global warming pollutant --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 global warming pollution 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.

In 2006, the American Wind Energy Association estimates that wind plants in the U.S. will generate 24 billion kilowatt-hours. If instead the average utility fuel mix were used to generate that much electricity, 30 billion pounds (15 million tons) of carbon dioxide, 76,000 tons of sulfur dioxide (208 tons per day), and 36,000 tons of nitrogen oxides (100 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). The results of that study are available at http://www.externe.info/externpr.pdf and http://www.externe.info. 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).

More reading:
Comparative Air Emissions of Wind and Other Fuels

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Will using more wind energy help to prevent global warming?

Yes! Carbon dioxide (CO_2) is the most important of the global warming pollutants which are changing our climate. According to experts, if we are to avoid dangerous levels of warming, 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 emissions reductions 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.

More reading:
Estimated Public Health Impacts of Criteria Air Pollutant Emissions from the Salem Harbor and Brayton Point Power Plants

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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. 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?

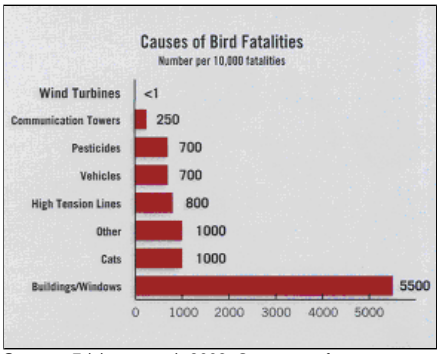
Wind power plants, like all other energy technologies, have some environmental impacts. However, unlike most conventional technologies (which have regional and even global impacts due to their emissions and fuel imports), the impacts of wind energy systems are minimal and local. This makes them easier 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 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 Collisions With Wind Turbines," for more information. 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. Still, a surprisingly high number of bat kills at a new wind plant in West Virginia in the fall of 2003 has raised concerns, and research at that plant and another in Pennsylvania in 2004 suggests that the problem may be a regional one. The wind industry has joined with the U.S. Fish and Wildlife Service, the U.S. Department of Energy's National Renewable Energy Laboratory, and Bat Conservation International to form the Bats and Wind Energy Cooperative (BWEC), which funded the 2004 research program and is continuing to explore ways to avoid or reduce bat kills.

More reading:
Comparative Impacts of Wind and Other Energy Sources on Wildlife

Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States

Wind Turbine Interactions With Birds and Bats: A Summary of Research Results and Remaining Questions, National Wind Coordinating Committee

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

More reading:
A Summary of Opinion Surveys on Wind Power,
European Wind Energy Association .

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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.

More reading:
Wind Energy and Noise.
Noise from Wind Turbines: The Facts.

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.

More reading:
Shadow Casting from Wind Turbines

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.

More reading:
Wind Farms and Tourism*:* The Facts

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.

More reading:

Public Attitudes to Wind Energy

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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.

More reading:
An excellent resource for debunking myths about wind power is the *"Yes2Wind"* Web site at http://www.yes2wind.com It has been created by 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:

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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 1/250 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.

The U.S. Department of Energy puts it quite simply in its fact sheet *Wind Energy Myths*: "When wind is added to a utility system, no new backup is required to maintain system reliability." See http://www.nrel.gov/docs/fy05osti/37657.pdf

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-see http://www.bwea.com/aviation/ams_report.html. 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.

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