Small-Scale Wind Energy on the Farm

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Contents

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Wind-generated electricity is attracting the interest of farmers, ranchers, and other landowners across the country. People find wind energy attractive for a variety of reasons, including its potential economic benefits and its lower impact on the environment when compared to coal and other electric power generation fuels. Wind-generated electricity can help farmers and ranchers reduce their energy costs, an important consideration in these days of continually increasing utility rates.

This publication will introduce you to small-scale wind energy to help you decide if wind energy is an economical option for your farm or ranch.

This publication draws heavily on Small Wind Electric Systems: A U.S. Consumer's Guide *(DOE/GO-102005-2095), produced by the National Renewable Energy Laboratory (NREL). Material from this publication is reprinted and adapted here with permission from NREL.*

Farms and ranches, such as this one in southwest Minnesota, can use wind-generated electricity to reduce utility bills. Photo courtesy of NREL.

Introduction

Wind energy systems use the wind to generate electricity with a wind turbine. More and more people are considering wind energy as they look for affordable and reliable sources of electricity. Small wind electric systems can make an important contribution to our nation's energy needs. In 2005, the United States installed more new wind energy capacity than any other country in the world. The new capacity, totaling 2,431 megawatts (MW), was worth more than $3 billion in generating equipment, and it brought the total national wind energy capacity to 9,149 MW. That's enough electricity to power 2.3 million average American households. In 2006, an additional 2,454 MW was installed, bringing the nation's total installed capacity to 11,603 MW.

Many rural areas have sufficient wind speeds to make wind an attractive alternative, and farms and ranches can often install a small-scale wind energy system without impacting their ability to plant crops and graze livestock. Most farms and ranches have enough open land (generally an acre or more) to provide a significant portion of their electricity from wind power.

Why Should I Choose Wind?

Wind energy can be a cost-effective small-scale renewable energy system. Depending on your wind resource and the electric consumption on your farm, a small wind energy system can lower electricity bills, help avoid the high costs of extending utility power lines to remote locations, prevent power interruptions, and provide a non-polluting source of electricity.

How Do Wind Turbines Work?

Wind is created by the unequal heating of the Earth's surface by the sun. Wind turbines convert the kinetic energy in wind

Wind turbines operate in harmony with farming and ranching. Photo courtesy of NREL.

into mechanical power that runs a generator to produce clean electricity. Today's turbines are versatile sources of electricity. Their blades are aerodynamically designed to capture the maximum energy from the wind. The wind turns the blades, which spin a shaft connected to a generator that makes electricity.

Is Wind Energy Practical for Me?

A small wind energy system can provide you with a practical and economical source of electricity if:

- your property has a good wind resource
- you have at least one acre of land in a rural area
- your local zoning codes or covenants allow wind turbines
- you have high electric costs
- your property is in a remote location that does not have easy access to utility lines
- you are comfortable with long-term investments

It's important to examine your reasons for wanting to purchase a wind energy system. If your reasons are purely economic, you could end up disappointed, since wind energy systems can have long payback periods. If you are also interested in benefits such as environmental protection, independence, or energy security, you may find the cost and payback period to be perfectly acceptable. Make sure you fully understand the results you can expect, as well as potential obstacles, such as zoning laws, generation capacity, maintenance requirements, and warranty coverage.

Related ATTRA Publications

Renewable Energy Opportunities on the Farm

Wind-Powered Electric Systems for Homes, Farms, and Ranches: Resources

Efficient Agricultural Buildings: An Overview

First Things First: Make Your Farm Buildings as Energy-Efficient as Possible

Before choosing a wind system for your farm or ranch, you should reduce your energy consumption as much as possible. This topic is discussed in greater detail in the ATTRA publication *Efficient Agricultural Buildings: An Overview*. Energy conservation is almost always more cost-effective than renewable energy systems, and could reduce the size of your wind energy system. From wall insulation to light bulbs, there are many ways to make your farm buildings more efficient.

- Reduce your heating and cooling needs by up to 30% by investing just a few hundred dollars in proper insulation and weatherization products.
- Save money and increase comfort by properly maintaining and upgrading your heating, ventilation, and air-conditioning systems.
- Install double-paned, gas-filled windows with low-emissivity (low-e) coatings to reduce heat loss in cold climates and spectrally selective coatings to reduce heat gain in warm climates.
- Replace your lights in high-use areas with fluorescents. Replacing 25% of your lights can save about 50% of your lighting energy bill.
- When shopping for products such as lighting, windows, and heating and cooling systems, look for the ENERGY STAR® label. ENERGY STAR® products have been identified by the U.S. Environmental Protection Agency and U.S. Department of Energy as being the most energy-efficient products in their classes.

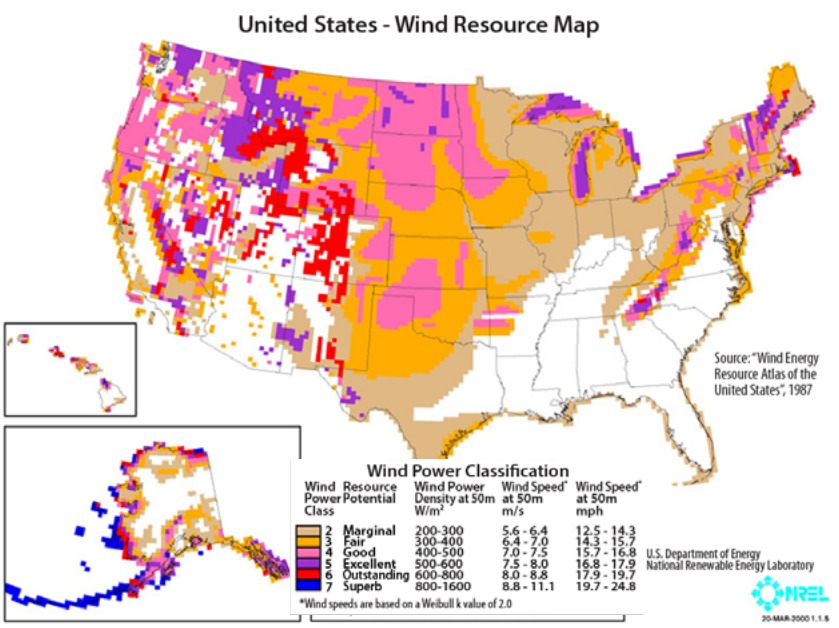
Is There Enough Wind at My Site?

Does the wind blow hard and consistently enough at your site to make a small wind turbine system economically worthwhile? That is a key question and not always easily answered. The wind resource can vary significantly over an area of just a few miles because of local terrain influences on the wind flow. Yet, there are steps you can take that can help answer this question.

As a first step, a wind resource map can help you estimate the wind resource in your region. State wind resource maps, such as those found on the Wind Powering America website (*www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp*) will help you understand the resources in your specific region. Note that maps for some states show wind speed estimates at 50 meters above the ground and depict the resource that could be used for utility-scale wind development. DOE's future plans include providing wind speed estimates at 30 meters, which are useful for identifying small wind turbine opportunities.

You can find additional wind resource maps, showing region-specific data, in NREL's Wind Energy Resource Atlas of the United States, available online at *http://rredc.nrel.gov/wind/pubs/atlas*. For western regions, consult windpowermaps.org and The Renewable Energy Atlas of the West, available at *www.energyatlas.org*. For California only, consult California Wind Resource Maps at *www.energy.ca.gov/maps/wind.html*. Note that wind maps provide only broad estimates—the wind speed for any particular site is often a prediction based on terrain, rather than an actual measurement. The actual wind resource at a specific site may differ considerably from these estimates. For site-specific wind resource data, consult a turbine dealer or install an anemometer (a device that measures wind speed) on your property.

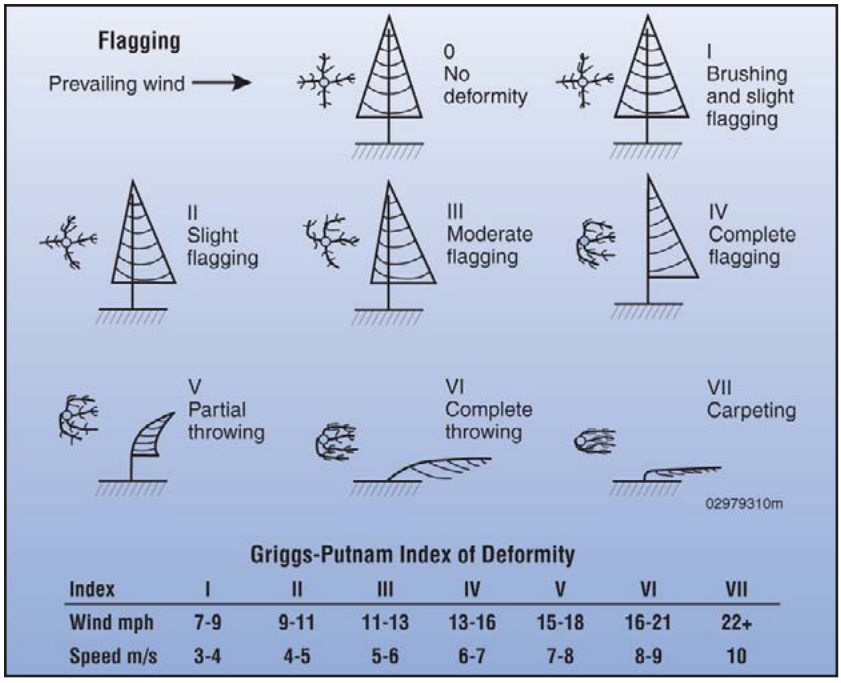
In general, the highest average wind speeds in the United States are found along seacoasts, on ridgelines, and in the Great Plains; however, many areas have wind resources strong enough to power a small wind turbine economically. The wind resource estimates on the map above generally apply to terrain features that are well-exposed to the wind, such as plains, hilltops, and ridge crests.



Source: U.S. Department of Energy.

Another way to estimate the wind resource is to get average wind speed information from a nearby airport. Use caution, however, because local terrain and other factors may cause the wind speed recorded at an airport to be different from your particular location. Also, airport wind speeds are generally measured at heights of only about 20-33 feet (6–10 meters) above ground.

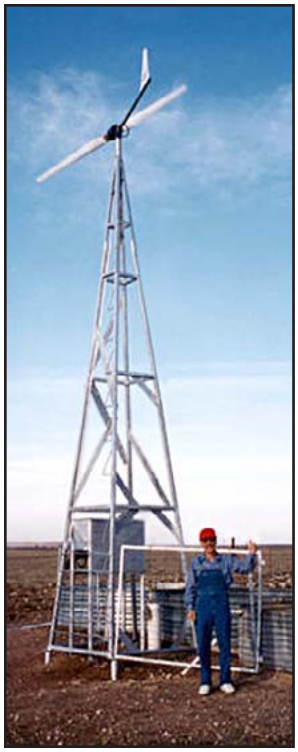
Average wind speeds increase with height and may be 15–25% greater at a typical small wind turbine hub-height of 80 feet (24 meters) than those measured at airport anemometer heights. The National Climatic Data Center collects data from airports in the United States and makes wind data summaries available for purchase. Summaries of wind data from almost 1,000 U.S. airports also are included in Wind Energy Resource Atlas of the United States, available online at *http://rredc.nrel.gov/wind/pubs/atlas*.



Griggs-Putnam Index of Deformity

Index	I	II	III	IV	V	VI	VII
Wind mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
Speed m/s	3-4	4-5	5-6	6-7	7-8	8-9	10

Flagging, the effect of strong winds on area vegetation, can help determine area wind speeds. Source: Windustry.



This 1-kW wind turbine from World Power Technology, Inc. is used for pumping water for 120 head of cattle at a ranch in Texas. Source: World Power Technology.

Another useful, indirect way to measure the wind resource is by observing vegetation. Trees, especially conifers or evergreens, can be permanently deformed by strong winds. This deformity, known as "flagging," has been used to estimate the average wind speed for an area. For more information on flagging, you may want to obtain A Siting Handbook for Small Wind Energy Conversion Systems, by H. Wegley, J. Ramsdell, M. Orgill & R. Drake, Report No. PNL-2521, available from National Technical Information Service at *www.ntis.gov* or (703) 605-6585.

Direct monitoring by a wind resource measurement system at a site provides the clearest picture of the available resource. A good overall guide on this subject is the *Wind Resource Assessment Handbook*, available online at *www.nrel.gov/docs/legosti/fy97/22223.pdf*. Wind measurement systems are available for as little as $600 to $1,200. This expense may or may not be justified, depending on the exact nature of your proposed small wind system. The measuring equipment must be set high enough to avoid turbulence created by trees, buildings, and other obstructions. The most useful readings are those taken at hub-height. If there is a small wind turbine system in your area, you may be able to obtain information on the annual output of the system or wind speeds at its location.

Zoning Issues

Before you invest in a wind energy system, you should research potential obstacles. Some jurisdictions, for example, restrict the height of the structures permitted in residentially zoned areas, although variances might be allowed. Most zoning ordinances have a height limit of 35 feet. You can find out about the zoning restrictions in your area by calling the local building inspector, board of supervisors, or planning board. As a minimum, contact the county commission to ask what, if any, county requirements exist. They can tell you if you will need to obtain a building permit and provide you with a list of requirements. In addition to zoning issues, your neighbors might object to a wind machine that blocks their view, or they might be concerned about noise. Most zoning and aesthetic concerns can be addressed by supplying objective data.

For more information about permitting, see AWEA's *Small Wind Toolbox: Getting a Building Permit* at *www.awea.org/smallwind/toolbox2/INSTALL/building_permits.html*

What Size Wind Turbine Do I Need?

The size of the wind turbine you need depends on your application. Most turbines are rated according to peak wattage. Small turbines are rated from 100 watts to 100 kilowatts (one kilowatt equals 1,000 watts). One- to 10-kW turbines can be used in applications such as pumping water.

A wind turbine manufacturer can provide you with the expected annual energy output of the turbine as a function of annual average wind speed. The manufacturer will also provide information on the maximum wind speed for safe operation. Most turbines have automatic overspeed-governing systems to keep the rotor from spinning out of control in very high winds. This information, along

with your local wind speed and your energy budget, will help you decide what size of turbine will best meet your electric needs.

What are the Basic Parts of a Small Wind Electric System?

Home-scale wind energy systems are generally comprised of a rotor, a generator or alternator mounted on a frame, a tail, a tower, wiring, and the "balance of system" components: controllers, inverters, and/or batteries. Through the spinning blades, the rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator.

To find wind equipment suppliers and installers in your area, as well as sources of technical support, see ATTRA's *Farm Energy Search Tool* at *http://attra.ncat.org/energy.php*

Wind Turbine

Most turbines manufactured today are horizontal-axis, upwind machines (the rotor faces the wind) with two or three blades, which are usually made of a composite material such as fiberglass. These machines are designed so that turbines rotate around a horizontal axis, and the rotor is placed on the windward side of the support tower.

The amount of power a turbine will produce is determined primarily by the diameter of its rotor. The diameter of the rotor defines its "swept area," or the quantity of wind intercepted by the turbine. The turbine's frame is the structure onto which the rotor, generator, and tail are attached. The tail keeps the turbine facing into the wind.

Bergey XL-1 horizontal-axis upwind machine. Source: Bergey Windpower.

Tower

Because wind speeds increase with height, the turbine is mounted on a tower. In general, the higher the tower, the more energy the wind system can produce. The tower also raises the turbine above the air turbulence caused by obstructions such as hills, buildings, and trees. As a general rule of thumb, the bottom of the rotor blades should be at least 30 feet (9 meters) above any obstacle that is within 300 feet (90 meters) of the tower. Relatively small investments in increased tower height can yield very high rates of return in energy production. For instance, raising a 10-kW generator from a 60-foot tower height to a 100-foot tower increases system cost by about 10%, but can increase energy production by 29%.

Mounting turbines on rooftops is not recommended. All wind turbines vibrate and transmit the vibration to the structure on which they are mounted. This can lead to noise and structural problems with the building, and the roofline can cause excessive turbulence that will shorten the life of the turbine.

Balance of System

The parts that you need in addition to the turbine and the tower, or the balance of system parts, will depend on your application. Most manufacturers can provide you with a system package that includes all the parts you need for your application. For example, the parts required for a water pumping system will be much different than what you need for a residential application. The balance of system required will also depend on whether the system is grid-connected (connected to the utility grid), stand-alone (independent of the utility grid), or part of a hybrid system (a power system that uses more than one source of energy—wind and

Types of Towers

There are three basic types of towers suitable for farm-sized turbines:

Monopole

This type of tower is generally the least expensive. The tower is a tilt-up style tower and is generally installed using a gin-pole and winch. Monopoles generally have four guy wires for support. Maintenance on the turbine is performed by tilting the tower down. The height of this type of tower is limited by the weight of the machine and generally 10-kW machines are the largest that can be placed on such towers. Tilt-up towers require space for guy wires and for tipping up and down of the tower.

Monopole tower.

Guyed lattice

Guyed lattice towers are generally more expensive than monopole designs but can support larger turbines at higher heights. Towers are generally installed using gin-pole and winch. Guyed lattice towers also come with the advantage of either being able to tip the tower down or relatively easy climb-ability for regular maintenance (climbing, if done with appropriate safety precautions, gear and training, is much safer than tilting a tower up and down every time maintenance is required). Guyed lattice towers require much space for tipping up and down of tower and guy wires. Again, check with turbine manufactures to see what tower options they recommend with various turbine models.

Guyed lattice tower .

Lattice

Lattice towers, in most cases, are required for machines larger than 20 kW in size. The installation of these towers is generally more complicated than that of a guyed lattice tower because a crane is needed to lift the tower and turbine into place. Maintenance is performed by climbing the tower. If major work is required on a machine a crane may be required to remove the turbine from the tower. Check with manufacturers to determine what tower options they recommend with different turbine models.

Lattice tower.

Source: Windustry.org.

photovoltaics, for example). For a residential grid-connected application, the balance of system parts may include a controller, storage batteries, a power conditioning unit (inverter), and wiring.

Stand-Alone Systems

Stand-alone systems (systems not connected to the utility grid) often require batteries to store excess power for use when the wind is calm. They also need a charge controller to keep the batteries from overcharging. Deep-cycle batteries, such as those used for golf carts, can discharge and recharge 80% of their capacity hundreds of times, which makes them a good option for remote renewable energy systems. Automotive batteries are shallow-cycle batteries and should not be used in renewable energy systems because of their short life in deep-cycling operations.

Small wind turbines generate direct current (DC) electricity. In very small systems, DC appliances operate directly off the batteries. If you want to use standard appliances that use conventional household alternating current (AC), you must install an inverter to convert DC electricity from the batteries to AC. Although the inverter slightly lowers the overall efficiency of the system, it allows

Can I Install a Wind Energy System Myself?

"Most dealers offer either complete turnkey (ready-to-operate) installations or the option to purchase direct from the factory and install the system yourself. The first option offers more customer support from the company. Self-installation offers significant savings and a hands-on understanding of the turbine. Prospective owners can discuss the options available with manufacturers to decide which method best suits their budget and technical skills."

–American Wind Energy Association

the home to be wired for AC, a definite plus with lenders, electrical code officials, and future homebuyers.

For safety, batteries should be isolated from living areas and electronics because they contain corrosive and explosive substances. Lead-acid batteries also require protection from temperature extremes. Batteries should be enclosed in a box, which should be vented to the outside.

What Do Wind Systems Cost?

According to the American Wind Energy Association (AWEA), small wind energy systems cost from $6,000 to $8,000 for every kilowatt of generating capacity, depending on size. Smaller wind systems are more costly per kilowatt of installed capacity. Wind energy becomes more cost-effective as the size of the turbine increases. Although small turbines cost less in initial outlay, they are proportionally more expensive.

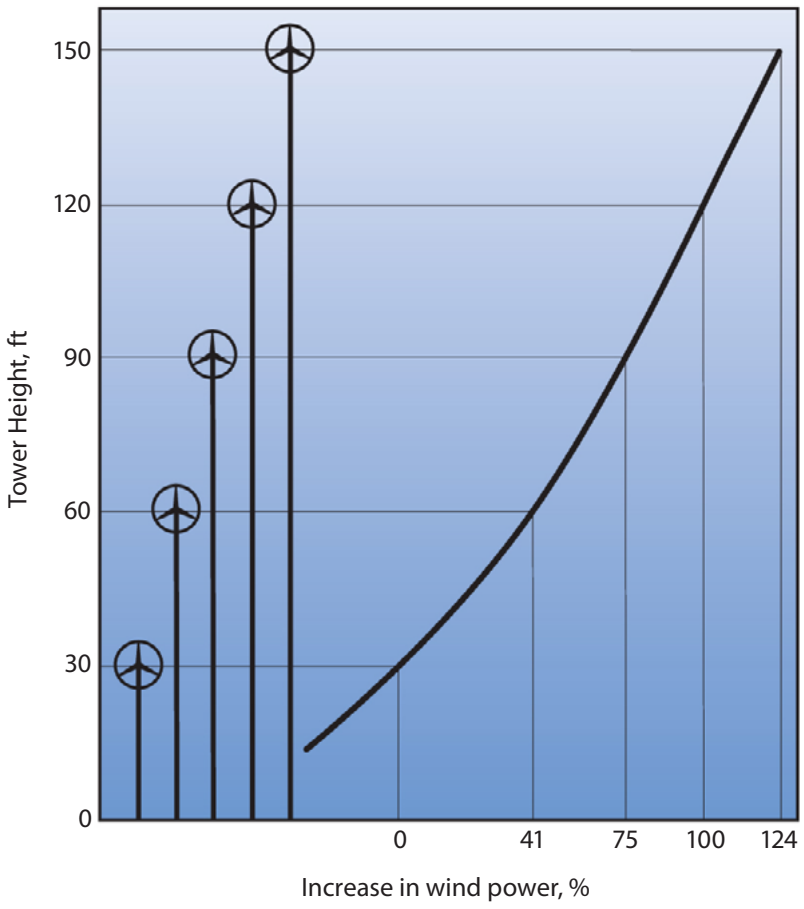
A 10-kW system, for example, can cost $47,000 to $60,000 installed. Rebates, tax credits, and other incentives can reduce these costs. Well-sited small wind turbines can usually pay for themselves within 15 years, about half their serviceable lifetimes, if the right incentives are applied, says AWEA.

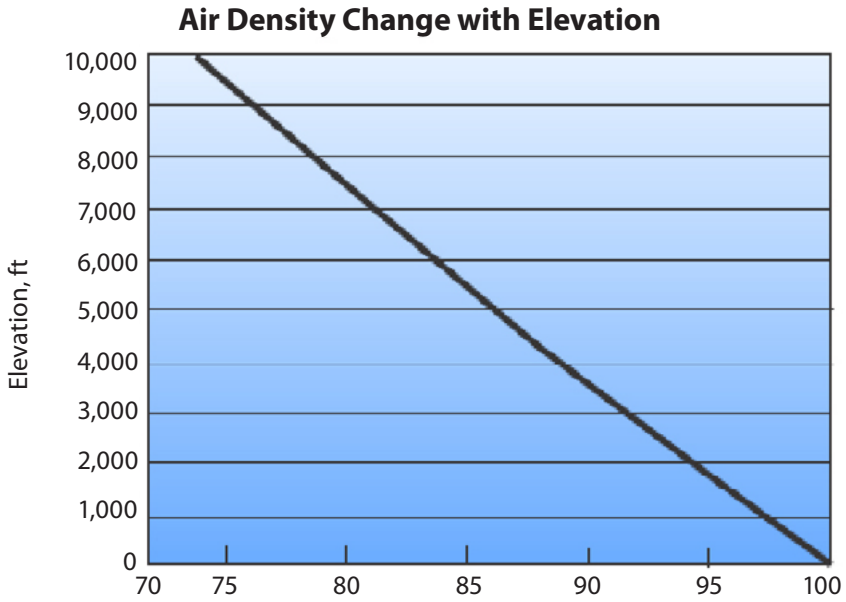
Although wind energy systems involve a significant initial investment, they can be competitive with conventional energy sources when you account for a lifetime of reduced or avoided utility costs. The length of the payback period—the time before the savings resulting from your system equal the cost of the system itself—depends on the system you choose, the wind resource on your site, electric costs in your area, and how you use your wind system.

How Much Energy Will My System Generate?

As mentioned above, most U.S. manufacturers rate their turbines by the amount of power they can safely produce at a particular wind speed. Even a small increase in wind speed results in a large increase in power. That is why a taller tower will increase the productivity of any wind turbine by giving it access to higher wind speeds, as shown in the graph below.

Wind Speeds Increase with Height





The larger the rotor, the more energy it can capture. The air density changes slightly with air temperature and with elevation. The ratings for wind turbines are based on standard conditions of 59° F (15° C) at sea level. A density correction should be made for higher elevations as shown in the graph above. A correction for temperature is typically not needed for predicting the long-term performance of a wind turbine.

The best measure of wind turbine performance is annual energy output. The difference between power and energy is that power (kilowatts [kW]) is the rate at which electric energy is consumed, while energy (kilowatt-hours [kWh]) is the quantity consumed. An estimate of the annual energy output from your wind turbine, kWh/year, is the best way to determine whether a particular wind turbine and tower will produce enough electric energy to meet your needs.

A wind turbine manufacturer or dealer can help you estimate the energy production you can expect. They will use a calculation based on the particular wind turbine power curve, the average annual wind speed at your site, the height of the tower that you plan to use, the elevation, and (if available) the frequency distribution of the wind–an estimate of the number of hours that the wind will blow at each speed during an average year. Contact a wind turbine manufacturer or dealer for assistance with this calculation.

To get a preliminary estimate of the performance of a particular wind turbine, use the formula below.

$AEO = 0.01328\ D^2\ V^3$

Where:

AEO = Annual energy output, kWh/year

D = Rotor diameter, feet

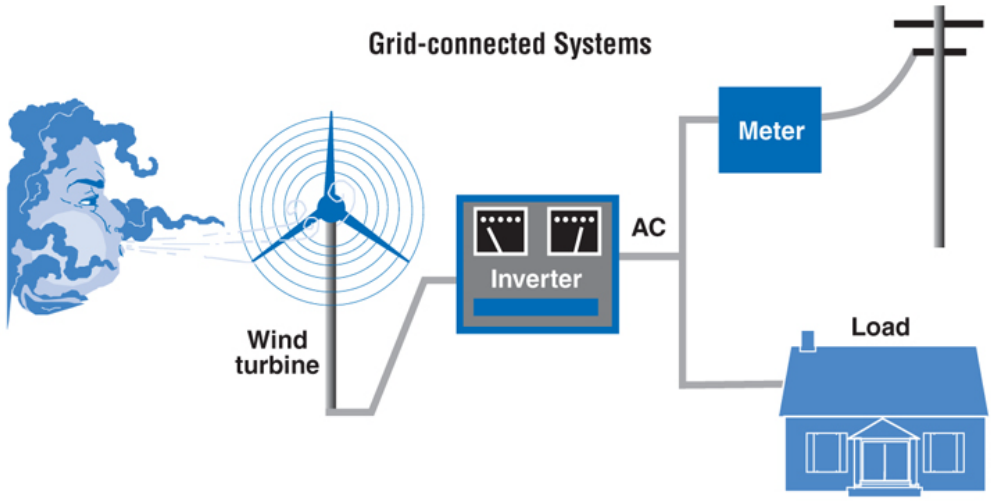
V = Annual average wind speed, mph

Wind Powering America's Wind Energy Payback Period Workbook is a spreadsheet tool that can help you analyze the economics of a small wind electric system and decide whether wind energy will work for you. The spreadsheet can be found online at *www.eere.energy.gov/windandhydro/windpoweringamerica/docs/wind_payback.xls*. The tool asks you to provide information about how you're going to finance the system, the characteristics of your site, and the properties of the system you're considering. It then provides you with a simple payback estimate in years.

Grid-Connected Systems

Small wind energy systems can be connected to the electric distribution system and are then called grid-connected systems. Grid-connected systems require a power conditioning unit (inverter), which makes the turbine output electrically compatible with the utility grid. Usually, batteries are not needed. A grid-connected wind turbine can reduce your consumption of utility-supplied electricity for lighting, appliances, and electric heat. If the turbine cannot deliver the amount of energy you need, the utility makes up the difference. When the wind system produces more electricity than the household requires, the excess is sent or sold to the utility. Grid-connected systems can be practical if the following conditions exist:

- You live in an area with average annual wind speed of at least 10 mph (4.5 m/s).



A grid-connected wind turbine can reduce your consumption of utility-supplied electricity.

Source: U.S. Department of Energy.

- Utility-supplied electricity is expensive in your area (about 10 to 15 cents per kilowatt-hour).
- The utility's requirements for connecting your system to its grid are not prohibitively expensive.
- There are good incentives for the sale of excess electricity or for the purchase of wind turbines.

Can I Sell My Excess Electricity to the Utility?

Federal regulations (specifically, the Public Utility Regulatory Policies Act of 1978, or PURPA) require utilities to connect with and purchase power from small wind energy systems. However, you must contact your utility before connecting to its distribution lines to address any power quality and safety concerns. Be aware that some utilities are more welcoming to interconnection than others. It is important that, early on in your planning process, you contact your utility to learn about its interconnection policies and expected costs. The American Wind Energy Association is another good source for information on utility interconnection requirements.

Small wind turbines can provide supplemental power for farms and ranches, such as this farm in western Kansas. Excess power is fed back into the utility grid. Source: Warren Gretz, NREL.

Financial Incentives

Financial incentives can make wind energy more affordable for farmers and ranchers. You can find out what incentives exist at both state and federal levels at the Database of State Incentives for Renewable Energy (DSIRE) at *www.dsireusa.org*.

Wind energy can be an attractive alternative for farms and ranches across the country, offering numerous benefits, including reduced energy costs, reduced environmental impact, and increased energy independence. However, as with all renewable energy systems, there also are challenges to these systems. Conduct a careful analysis of your energy needs and wind resource potential, as well as system economics, benefits, and potential obstacles, to see if wind is a good choice for your farm or ranch.

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Resources

American Wind Energy Association
www.awea.org

Farm Energy Search Tool
http://attra.ncat.org/energy.php

National Renewable Energy Laboratory
www.nrel.gov/wind

National Wind Coordinating Collaborative
www.nationalwind.org

Union of Concerned Scientists
www.ucsusa.org

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Notes

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