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ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE

Small Wind Energy Systems for the Homeowner

In the 1920s and '30s, farm families throughout the Midwest used wind to generate enough electricity to power their lights and electric motors. The use of wind power declined with the government-subsidized construction of utility lines and fossil fuel power plants. However, the energy crisis in the 1970s and a growing concern for the environment generated an interest in alternative, environmentally friendly energy resources. Today, homeowners in rural and remote locations across the nation are once again examining the possibility of using wind power to provide electricity for their domestic needs.

This publication will help you decide whether a wind system is practical for you. It will explain the benefits, help you assess your wind resource and possible sites, discuss legal and environmental obstacles, and analyze economic considerations such as pricing.

Benefits of Wind Power

A wind energy system can provide you with a cushion against electric power price increases. Wind energy systems help reduce U.S. dependence on fossil fuels, and they are nonpolluting. If you live in a remote location, a small wind energy system can help you avoid the high costs of having the utility power lines extended to your site.

Although wind energy systems involve a significant initial investment, they can be

Warren Gretz, PIX 00042

Unlike yesteryear's windmill, today's wind turbines use technological innovations that have substantially reduced the cost of electricity generated from wind power.

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Wind turbines for domestic or rural applications range in size from a few watts to thousands of watts and can be applied economically for a variety of power demands.

competitive with conventional energy sources when you account for a lifetime of reduced or altogether 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, electricity costs in your area, and how you use your wind system.

Is Wind Power Practical for You?

Small wind energy systems can be used in connection with an electricity transmission and distribution system (called *grid-connected* systems), or in *stand-alone* applications that are not connected to the utility grid. 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 can be sold to the utility. With the interconnections available today, switching takes place automatically. Stand-alone wind energy systems can be appropriate for homes, farms, or even entire communities (a co-housing project, for example) that are far from the nearest utility lines. Either type of system can be practical if the following conditions exist.

Conditions for Stand-Alone Systems

- You live in an area with average annual wind speeds of *at least* 9 miles per hour (4.0 meters per second).
- A grid connection is not available or can only be made through an expensive extension. The cost of running a power line to a remote site to connect with the utility grid can be prohibitive, ranging from $15,000 to more than $50,000 per mile, depending on terrain.
- You have an interest in gaining energy independence from the utility.
- You would like to reduce the environmental impact of electricity production.
- You acknowledge the intermittent nature of wind power and have a strategy for using intermittent resources to meet your power needs.

Conditions for Grid-Connected Systems

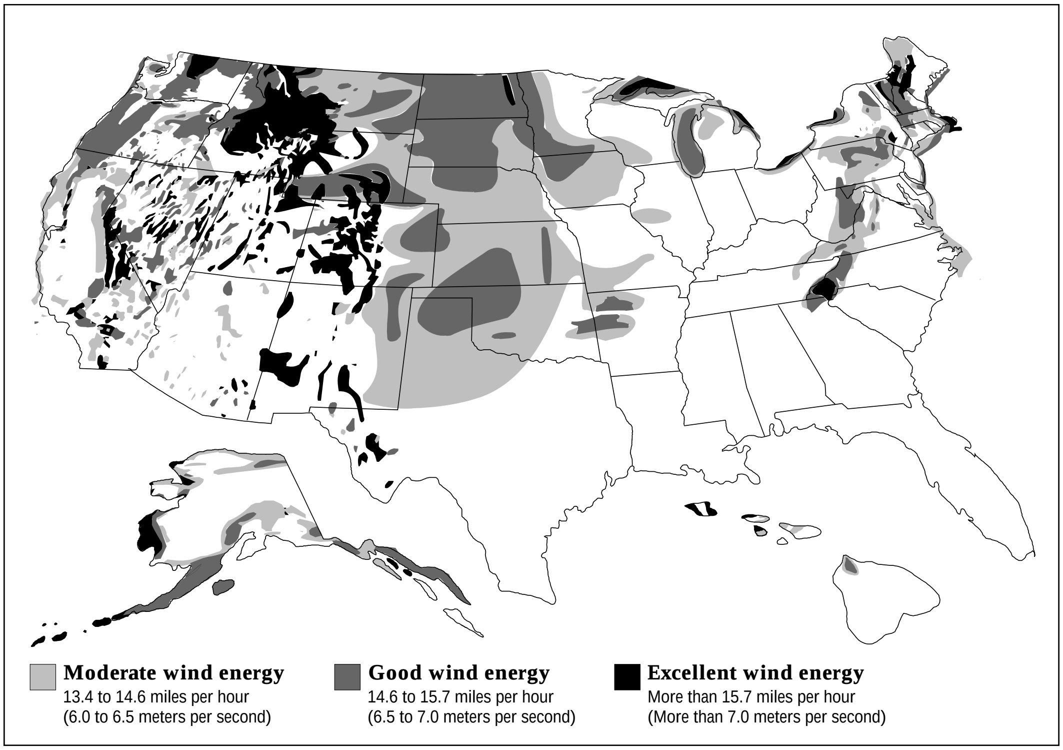
- You live in an area with average annual wind speeds of *at least* 10 miles per hour (4.5 meters per second).
- Utility-supplied electricity is expensive in your area (about 10 to 15 cents per kilowatt hour).
- The utility's requirements for connecting your system to its grid are not prohibitively expensive.
- Local building codes or covenants allow you to legally erect a wind turbine on your property.
- You are comfortable with long-term investments.

Is Your Site Right?

The U.S. Department of Energy (DOE) has compiled wind resource maps that are available from the American Wind Energy Association and the National Technical Information Service (see *Source List*). The DOE maps are good sources for regional information and can show whether wind speeds in your area are generally strong enough to justify investing in a wind system.

Wind-turbine manufacturers can use computer models to predict their machines' performance at a specific location. They can also help you size a system based on your electricity needs and the specifics of local wind patterns. However, you will need site-specific data to determine the wind resource of your exact location. If you do not have on-site data and want to obtain a clearer, more predictable picture of your wind resource, you may wish to measure wind speeds at your site for a year. You can do this with a recording anemometer, which generally costs $500 to $1500. The most accurate readings are taken at "hub height" (i.e., the elevation at the top of the tower where you will install the wind turbine—see the section on "Wind System Basics" that follows). This requires placing the anemometer high enough to avoid turbulence created by trees, buildings, and other obstructions. The standard wind sensor height used to obtain data for the DOE maps is 33 feet (10 meters).

In favorable locations, a wind turbine can reduce your consumption of utility-supplied electricity.



This map gives general information on the average wind resources available across the country. Of course, the actual wind resource on your site will vary depending on such factors as typography and structure interference.

You can have varied wind resources within the same property. If you live in complex terrain, take care in selecting the installation site. If you site your wind turbine on the top or on the windy side of a hill, for example, you will have more access to prevailing winds than in a gully or on the leeward (sheltered) side of a hill on the same property. Consider existing obstacles and plan for future obstructions, including trees and buildings, which could block the wind. Also realize that the power available in the wind increases proportionally to its speed (velocity) cubed (v^3). This means that the amount of power you get from your generator goes up exponentially as the wind speed increases. For example, if your site has an annual average wind speed of about 12.6 miles per hour (5.6 meters per second), it has twice the energy available as a site with a 10 mile per hour (4.5 meter per second) average.

Additional Considerations

In addition to the factors listed previously, you should also:

- research potential legal and environmental obstacles,
- obtain cost and performance information from manufacturers,
- perform a complete economic analysis that accounts for a multitude of factors (see the case study),
- understand the basics of a small wind system, and
- review possibilities for combining your system with other energy sources, backups, and energy efficiency improvements.

You should establish an energy budget to help define the size of turbine that will be needed. Since energy efficiency is usually less expensive than energy production, making your house more energy efficient first will likely result in being able to spend less money since you may need a smaller wind turbine to meet your needs.

Wind is derived from solar energy. When the sun heats the earth's surface unevenly, it creates differences in air temperature and atmospheric pressure, which causes wind.

Potential Legal and Environmental Obstacles

Before you invest any time and money, research potential legal and environmental obstacles to installing a wind system. Some jurisdictions, for example, restrict the height of the structures permitted in residentially zoned areas, although variances are often obtainable (see "Wind System Basics," which follows). Your neighbors might object to a wind machine that blocks their view, or they might be concerned about noise. Consider obstacles that might block the wind in the future (large planned developments or saplings, for example). If you plan to connect the wind generator to your local utility company's grid, find out its requirements for interconnections and buying electricity from small independent power producers.

Pricing a System

When you are confident that you can install a wind machine legally and without alienating your neighbors, you can begin pricing systems and components.

Approach buying a wind system as you would any major purchase. Obtain and review the product literature from several manufacturers. Lists of manufacturers are available from the American Wind Energy Association (AWEA, see *Source List*); however, not all small turbine manufacturers are members of AWEA. Manufacturer information can also be found at times in the periodicals listed in the *Reading List*. Once you have narrowed the field, research a few companies to be sure they are recognized wind energy businesses and that parts and service will be available when you need them. Also, find out how long the warranty lasts and what it includes.

Ask for references of customers with installations similar to the one you are considering. Ask system owners about performance, reliability, and maintenance and repair requirements, and whether the system is meeting their expectations.

The Economics of Wind Power for Home Use

A residential wind energy system can be a good long-term investment. However, because circumstances such as electricity rates and interest rates vary, you need to decide whether purchasing a wind system is a smart financial move for you. The case study that follows illustrates the many factors and calculations you will need to consider. Be sure you or your financial adviser conduct a thorough analysis before you buy a wind energy system.

Grid-connected-system owners may be eligible to receive a small tax credit for the electricity they sell back to the utility. For 1996, it was 1.6 cents per kilowatt hour. The National Energy Policy Act of 1992 and the 1978 Public Utilities Regulatory Policy Act (PURPA) are two programs that apply to small independent power producers. PURPA also requires that the utility sell you power when you need it. Be sure you check with your local utility or state energy office before you assume any buy-back rate. Some Midwestern rates are very low (less than $.02/kWh), but some states have state-supported buy-back rates that encourage renewable energy generation. In addition, some states have "net billing," where utilities purchase excess electricity for the same rate at which they sell it. (The Energy Efficiency and Renewable Energy Clearinghouse—see *Source List*—has more information on net billing.)

Also, some states offer tax credits and some utilities offer rebates or other incentives that can offset the cost of purchasing and installing wind systems. Check with your state's department of revenue, your local utility, public utility commission, or your local energy office for information.

Wind System Basics

All wind systems consist of a wind turbine, a tower, wiring, and the "balance of system" components: controllers, inverters, and/or batteries.

Wind Turbines

Home wind turbines consist of a *rotor*, a *generator* mounted on a frame, and (usually) a *tail*. Through the spinning blades, the rotor captures the kinetic energy of the

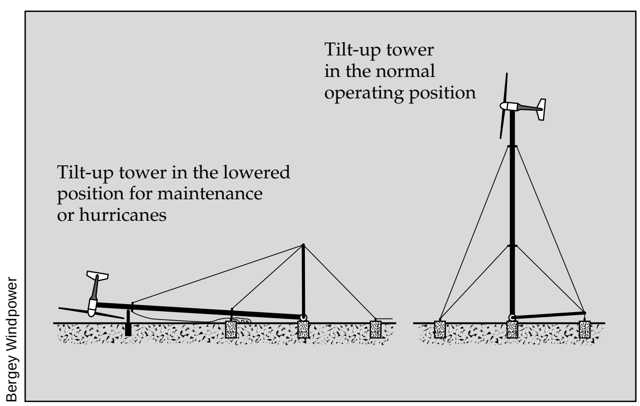
The highest average wind speeds in the United States are generally found along sea coasts, on ridge lines, and on the Great Plains, but many areas have wind resources strong enough to power a wind generator economically.

wind and converts it into rotary motion to drive the generator. Rotors can have two or three blades, with three being more common. The best indication of how much energy a turbine will produce is the diameter of the rotor, which determines its "swept area," or the quantity of wind intercepted by the turbine. The frame is the strong central axis bar onto which the rotor, generator, and tail are attached. The tail keeps the turbine facing into the wind.

A 1.5-kilowatt (kW) wind turbine will meet the needs of a home requiring 300 kilowatt-hours (kWh) per month, for a location with a 14-mile-per-hour (6.26-meters-per-second) annual average wind speed. The manufacturer will 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 in which the turbine is designed to operate safely. Most turbines have automatic speed-governing systems to keep the rotor from spinning out of control in very high winds. This information, along with your local wind speed distribution and your energy budget, is sufficient to allow you to specify turbine size.

Towers

To paraphrase a noted author on wind energy, "the good winds are up high." Because wind speeds increase with height in flat terrain, the turbine is mounted on a tower. Generally speaking, the higher the tower, the more power the wind system can produce. The tower also raises the turbine above the air turbulence that can exist close to the ground. A general rule of thumb is to install a wind turbine on a tower with the bottom of the rotor blades at least 30 feet (9 meters) above any obstacle that is within 300 feet (90 meters) of the tower.



Towers can be hinged so they can be lowered to the ground for maintenance or during very high winds.

Experiments have shown that relatively small investments in increased tower height can yield very high rates of return in power production. For instance, to raise a 10-kW generator from a 60-foot tower height to a 100-foot tower involves a 10% increase in overall system cost, but it can produce 25% more power.

There are two basic types of towers: *self-supporting* (free standing) and *guyed.* Most home wind power systems use a guyed tower. Guyed-lattice towers are the least expensive option. They consist of a simple, inexpensive framework of metal strips supported by guy cables and earth anchors.

However, because the guy radius must be one-half to three-quarters of the tower height, guyed-lattice towers require enough space to accommodate them. Guyed towers can be hinged at the base so that they can be lowered to the ground for maintenance, repairs, or during hazardous weather such as hurricanes. Aluminum towers are prone to cracking and should be avoided.

Balance of System

Stand-alone systems require batteries to store excess power generated 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 to power 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.

In very small systems, direct current (DC) appliances operate directly off the batteries. If you want to use standard appliances that require conventional household alternating current (AC), however, you must install an inverter to convert DC electricity to AC. Although the inverter slightly lowers the overall efficiency of the system, it allows the home to be wired for AC, a definite plus with lenders, electrical code officials, and future home buyers.

The power available in the wind increases proportionally to the cube of its velocity (v^3).

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.

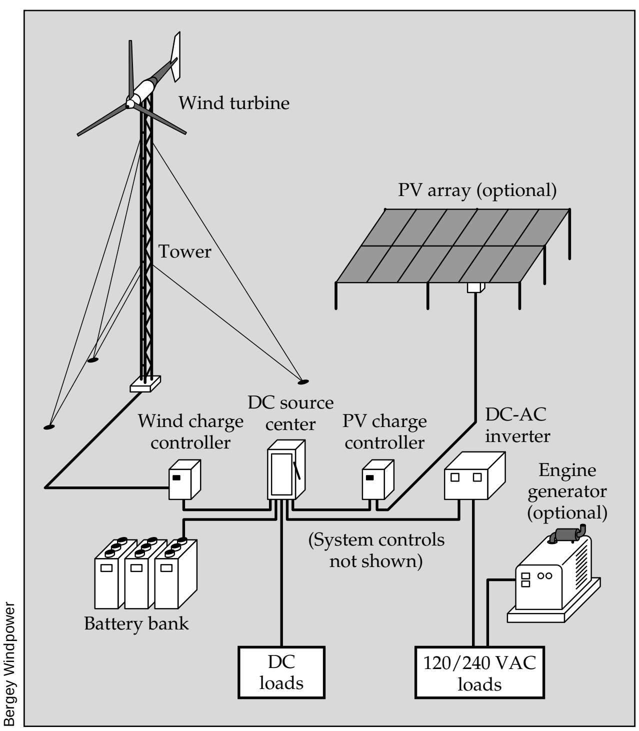
In grid-connected systems, the only additional equipment is a power conditioning unit (inverter) that makes the turbine output electrically compatible with the utility grid. No batteries are needed. Work with the manufacturer and your local utility on this.

Hybrid Wind Systems

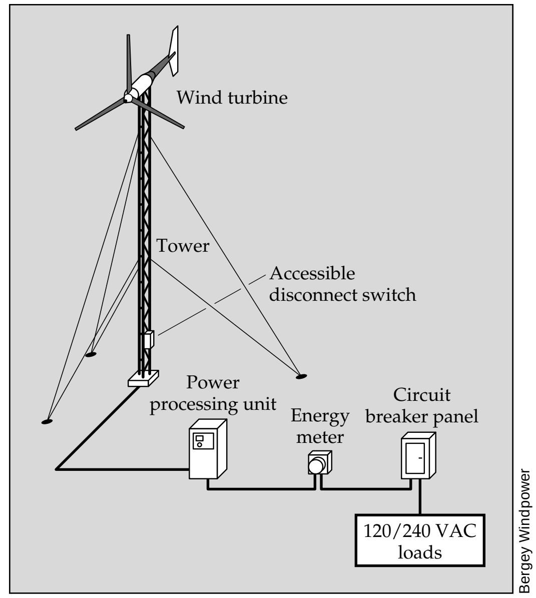
According to many renewable energy experts, a stand-alone “hybrid” system that combines wind and photovoltaic (PV) technologies offers several advantages over either single system. (For more information on solar electric—or photovoltaic—systems, contact the Energy Efficiency and Renewable Energy Clearinghouse—see *Source List*.)

In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when there is less sunlight available. Because the peak operating times for wind and PV occur at different times of the day and year, hybrid systems are more likely to produce power when you need it.

For the times when neither the wind generator nor the PV modules are producing electricity (for example, at night when the wind is not blowing), most stand-alone systems provide power through batteries and/or an engine-generator powered by fossil fuels.



Hybrid systems, which use both wind and photovoltaic components to capitalize on the strengths of each technology, can offer more reliability than either system alone.



A wind system that hooks into the existing power grid makes economic sense if electricity is expensive and the electrical load coincides with windy weather.

If the batteries run low, the engine-generator can be run at full power until the batteries are charged. Adding a fossil-fuel-powered generator makes the system more complex, but modern electronic controllers can operate these complex systems automatically. Adding an engine-generator can also reduce the number of PV modules and batteries in the system. Keep in mind that the storage capability must be large enough to supply electrical needs during noncharging periods. Battery banks are typically sized for one to three days of windless operation.

The Future of Wind Power

By investing in a small wind system, you can reduce your exposure to future fuel shortages and price increases and reduce pollution. Deciding whether to purchase a wind system, however, is complicated; there are many factors to consider. But if you have the right set of circumstances, a well-designed wind energy system can provide you with many years of cost-effective, clean, and reliable electricity.

Today's wind power systems are durable, reliable, and efficient, capable of producing clean, cost-effective power.

Case Study: Wind Power Economics of a Home System

Note: In this analysis, we have assumed a certain set of conditions, such as wind regime, maintenance costs, etc. Your analysis will differ for your set of circumstances. This case study is for illustration purposes only.

A New England homeowner is considering taking out a 20-year loan to purchase a $10,000 wind system (turbine, tower, inverter, and battery storage) for generating her own electricity, instead of paying her full electricity bills for the next 20 years.

Assume that the wind turbine she has chosen is rated at 3 kilowatts with the turbine 80 feet (24 meters) above the ground, and that she lives in a Class 4 wind regime (average wind speed of 12.5 to 13.4 miles per hour [5.6 to 6 meters per second] measured at 33 feet [10 meters] above the ground). Given these assumptions, the turbine can produce an estimated 9000 kilowatt hours (kWh) per year, or 750 kWh per month. Also assume, for the sake of simplicity, that she will use all of the electricity herself and will not sell any back to the utility. Therefore, the value of the electricity to her is equal to the retail price she pays the utility; in this case, 12 cents per kWh.

Continuing to Pay Electricity Bills
If she continues to pay her electricity bills without the wind turbine, the retail value of the electricity is $1,080 the first year. In later years, the price of electricity increases. For this analysis, we assume that the cost of electricity increases at the same rate as inflation—3% a year. Thus, the 9000 kWh will cost $1,112 in the second year, $1,146 the third year, and so forth, until the total inflation-adjusted cost of electricity for 20 years is $29,020.

Purchasing a Wind System
She can obtain the least-expensive loan by taking out a second mortgage on her home. She can borrow $10,000 at 8%, and make payments of $1,019 for 20 years. But she can deduct the portion of her payments that go toward interest at her 30% combined federal and state tax rate. Thus, after taxes, her annual payment is $779 for the first year, and increases to $996 as the interest deduction decreases in later years.

However, there are other costs to owning a wind turbine. Her property taxes will be higher because the wind turbine increases the value of her property. She will pay additional insurance since her standard homeowner's policy does not cover liability from the wind tower. And she will hire a local mechanic to climb the tower and grease the bearings every year. Altogether, she figures these operations and maintenance (O&M) costs will be about 1 cent/kWh or $100 per year in today's dollars. Let us assume for this analysis that taxes, insurance, and labor rates increase at the same rate as inflation. Thus, annual O&M costs increase to $175 in the 20th year. So, over 20 years, her total inflation-adjusted cost for buying a wind system is $19,678.

Net Present Value of Both Options
However, our example is still not complete. Economists tell us that future dollars are worth less than present dollars. It is better to have money now, rather than in the future, so we can use it to invest and earn more money. Even though inflation increases her annual electricity payments after 20 years to $1,894, those are *future* dollars, so they are worth less than today's dollars. Economists refer to this devaluation as the net present value factor, the rate at which future dollars are discounted compared to present dollars. This discount rate is equal to the rate of return that she could make on an investment of equivalent risk and liquidity to a wind turbine. In this evaluation, assume her opportunity for return on investment with today's dollars (i.e., the discount rate for her future dollars) is 10% a year.

Therefore, projecting her electric utility payments into the future to, say, the end of the first year, the dollars are worth 90% of what they were at the beginning of the year. At the end of the second year, the dollars are worth 90% of what they were at end of the previous year. (Notice the value of her future dollars depreciates at a compounded rate.) Considering these adjustments, her annual electricity payment in the 20th year is actually worth only $156 in today's dollars. Thus, her total cost of buying electricity for 20 years, adjusted for inflation and present value factors, is only $8,927 in today's dollars.

Another way to think of it is that her payment in the 20th year is really a *deferred* payment. She does not have to pay $29,020 today. Since the utility company allows her to pay her bills *as she uses the electricity*, she does not have to make any large capital expenditures. So she has more of her money to invest for 20 years. This would not be true if she had to pay for 20 years of electricity up front.

But net present value factors also apply to purchasing a wind system, because she is making deferred payments on her loan. Her payments of $1,154 in year 20 are really worth only $95 in today's dollars, for instance. Therefore, her total cost for buying a wind system, adjusted for inflation and net present value, is only $6,426 in today's dollars.

The Final Analysis
So in real terms, she saves $2,501 over 20 years by purchasing a wind system, as opposed to continuing to pay her electricity bills. An added benefit is that she would avoid the release of 40 tons (40 metric tons) of carbon dioxide, 800 pounds (363 kilograms) of nitrogen oxide, and 280 pounds (127 kilograms) of sulfur dioxide into the atmosphere—the amount of pollution that a utility company in the Northeast would emit to supply her electric load for 20 years, on average.

Source List

The following organizations can provide you with information to help decide whether a wind energy system is right for you.

Alternative Energy Institute (AEI)
West Texas A&M University
Box 248
Canyon, TX 79016
(806) 656-2296
Fax (806) 656-2733

AEI conducts field trials at its Wind Turbine Test Center and is a source of information on small wind turbines.

American Wind Energy Association (AWEA)
122 C Street, NW, 4th Floor
Washington, DC 20001
(202) 383-2500
Fax (202) 383-2505

AWEA is a source for DOE wind maps, lists of manufacturers and dealers, information on wind power tax credits, and other wind energy information.

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650
http://www.ntis.gov

NTIS has over 3 million publications that are available to the public. They offer a free catalog that lists a selection of these documents.

For free information about many kinds of energy efficiency and renewable energy topics, contact:

The Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
(800) 363-3732
Fax: (703) 893-0400
E-mail: doe.erec@nciinc.com

EREC provides free general and technical information to the public on the many topics and technologies pertaining to energy efficiency and renewable energy.

You may also contact your state and local energy offices for information on region-specific information on small wind energy systems.

Reading List

Periodicals

Backwoods Home
1257 Siskiyou Boulevard, #213
Ashland, OR 97520
(916) 459-3300

This publication is devoted to independent living, including independent energy systems.

Home Energy
2124 Kittredge Street, No. 95
Berkeley, CA 94704-9942
(510) 524-5405

This source provides information on reducing energy consumption.

Home Power
P.O. Box 520
Ashland, OR 97520-0520
(916) 475-3179

This periodical provides practical information, case studies, and advice on designing, installing, and living with small power systems.

Books

A Siting Handbook for Small Wind Energy Conversion Systems, Battelle Pacific Northwest Laboratory, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, 1980.

The Wind Power Book, J. Park, Chesire Books, Palo Alto, CA, 1981. This book is currently out of print, so check your local library for availability.

Wind Power for Home & Business: Renewable Energy for the 1990s and Beyond, P. Gipe, Chelsea Green Publishing Company, P.O. Box 130, Route 113, Post Mills, VT 05058-0130, 1993.

Wind Energy Resource Atlas of the U.S., Battelle Pacific Northwest Laboratories. Available from the American Wind Energy Association or the National Technical Information Service (see *Source List*).