The Montana Consumer Guide to Small Wind Generation Systems

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The Montana Consumer Guide to Small Wind Generation Systems

Incorporating Wind Electricity Generation for Residential and Small Business Consumers

Thank you for your interest in wind power, and for taking the time to read this publication. It has been developed as a basic resource and practical guide for consumers who are considering a small wind system.

The publication is focused on small wind systems and provides consumers basic information to begin researching and evaluating the purchase of a wind generation system. It is not intended to be a technical manual, but instead is a representation of the factors, options, and knowledge important to the purchase and installation of a safe and productive wind power system.

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Wind Power Basics

Introduction

Wind is created by the sun and is a kinetic or "motion" form of energy that has the ability to "do work". Wind energy is caused by the displacement of warm air masses that rise and allow cooler air to take their place, and is augmented by the rotation of the earth. This formula creates the planet's wind currents.

Local winds are created by similar temperature-based interactions- especially near water and mountains, where the elements facilitate the additional exchange of warm and cool air. Montana residents are familiar with the winds that originate on the mountain slopes, especially in the spring with extreme temperature changes and the presence of snow. Wind will accelerate as it blows up the side of a hill or through a narrowing valley, and much of Montana's topography supports this occurrence.

As a state, Montana is rated fifth in the United States relative to wind power potential. Commercial wind farms are located in Montana, with the emphasis on the north central plains near Great Falls, Judith Gap, and Harlowtown.

Up until several years ago, the number of residential wind turbine installations in Montana was on par with solar photovoltaics (PV). Two factors have changed that trend in favor of more solar PV: the reduction in price of PV and its mechanical reliability advantages (i.e. fewer moving parts and maintenance issues).

That being said, residential wind turbines are still popular in some areas of Montana, and there are now turbines being manufactured and installed for both the residential (2kW-10 kW) and light commercial and agricultural markets (10 kW – 50 kW). A small number of turbines in the 10kW and above range cost less than solar PV systems capable of providing the same amount of energy production.

How Wind Generators Work - An Overview

For simplicity purposes, the best way to understand how a wind turbine produces electricity is to consider a common household fan, but operating in the opposite sequence.

In a modern wind energy system, the turbine blades are designed and placed to capture the motion (i.e. kinetic energy) of the wind through a mechanism termed a rotor. The rotor is composed of blades and a hub and works by converting the energy caused by moving air into rotary mechanical energy. This is accomplished by designs that take advantage of both the drag (as in a conventional windmill) and lift (similar to airplane lift) provided by the wind source. The blades turn at a very high speed, low torque power that is ideal for electricity generation.

As the rotor turns it spins a drive shaft, which leads from the hub of the turbine to an electromagnetic alternator (also called a generator) that is located in the turbine housing (termed the nacelle). The alternator produces either "wild" AC or DC electricity (depending on the specific configuration). The electrical current is then conditioned and is usable by either the home, utility, or for battery storage. For the majority of systems, the end-use current of the wind system is AC that matches grid-produced electricity.

The Difference Between Windmills and Wind Turbines

Electricity producing wind turbines are quite different than traditional "windmills" and the terms are not interchangeable (i.e. converting a windmill to produce electricity would be a costly, ineffective endeavor).

Windmills convert kinetic wind energy directly into mechanical energy for tasks such as pumping water or grinding grain. They utilize a camshaft, which is connected by gears and rods directly to a specific, end use work task. This is usually accomplished at a slow rotational rate.

Wind turbines create electricity using a high rotational value. There is no direct connection to any mechanical process other than turning the drive shaft to the generator. As a general rule, wind turbine blades and components are precisely engineered and utilize state-of-the art materials and components, while windmills can be constructed using off-the-shelf materials and rudimentary design.

Consumers should be aware of sales people promoting converted (mill to turbine) systems or those who sell new systems patterned after traditional windmill "designs." There have been several out-of-state companies in the last ten years who have promoted and sold these types of turbines in Montana. The results have been dismal and the consumer is usually left with either a non-functioning system or one that has minimal energy output.

Suitable Wind Speeds and Siting

Choosing a Wind System

Researching, purchasing and installing a wind generation system can be a fairly complicated process. Understanding the basics of wind generation, available options, and the steps for making a good decision are critical. Consumer aptitude is appreciated by reputable dealers/installers, and it is also a deterrent to sales pressure from less reputable contractors.

This publication is intended to be a primer for consumers and introduce the concepts, components and variables of wind generation systems. Consumers should consider that purchasing, installing and maintaining a wind turbine is not something that should be done without considerable research and evaluation, and caution is warranted.

Wind Characteristics and Siting

Without a consistent and strong wind resource, the best equipment in the world still can't provide adequate generation. Siting of the wind generator is the most important and sometimes overlooked variable that can make the system either succeed or fail. Even factors within a one to two acre lot can have a significant impact on the system.

As previously mentioned, Montana has the fifth highest wind resource in the United States., However, due to the diverse topography of the State, some areas are more acceptable to wind applications than others. As a Montana resident, the first question to ask yourself is whether or not you live somewhere that is as windy as other locations where wind generators are being used. If so, you have a positive first indicator.

A reasonable second step in data collection would be to contact the nearest airport or weather station and ask for wind data for your particular location. Ask at what height the wind measurements are taken. The measurement is usually taken at approximately 30 feet, and a good rule of thumb is to consider that wind speed in flat, open terrain usually increases 10% for every doubling of height. For instance, a wind speed of 9 mph at 30 feet would increase to 9.9 mph at 60 feet.

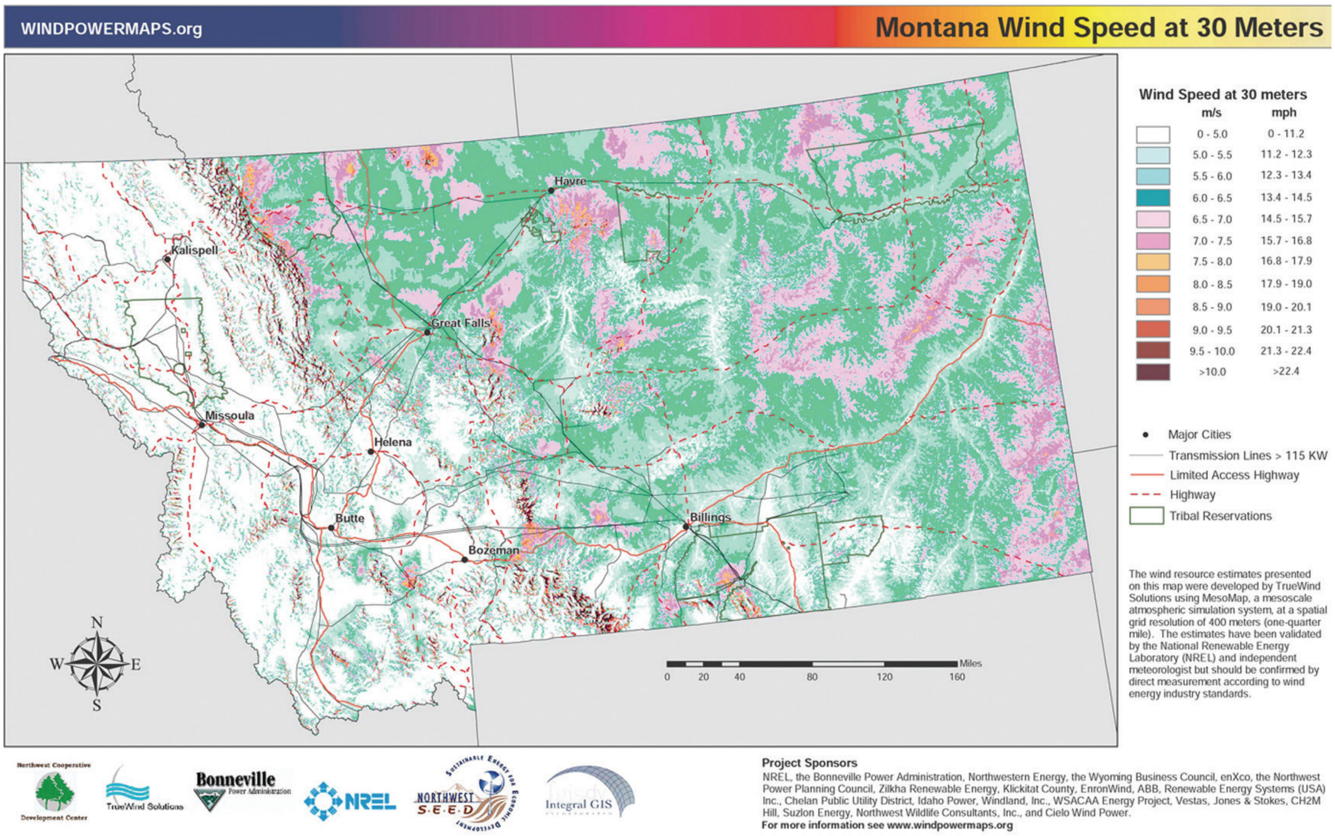
Keep in mind that some monitoring stations are adjacent to buildings or in sheltered areas, therefore the wind data might not be accurate. Measurements are also directly related to the equipment used at specific locations and how well it is maintained. Many wind professionals are hesitant to use weather station data as a trusted source and suggest that the consumer at least inquire to where and how the wind measurements are taken.

Wind Trends in Montana

There are definable classes of wind power within Montana, as estimated by the United States Department of Energy (DOE). These are available from the DOE Wind Energy Resource Atlas and define wind power class at both 33 and 164 feet for a specific location. Only sites with a wind speed average above Class 3 (11-13 mph at 33 feet) are typically recommended as suitable for small wind generation

Individuals who live in Montana and are familiar with conditions in specific geographic areas may disagree with the numbers. The DOE maps are general estimates, and the professionals at the DOE state that there can be certain sites even in regions shown as Class 1 which may be suitable for wind generator application, but are not captured in the map detail. Consider the diverse terrain even within small areas in our State, and use the Wind Atlas as one of several resources when conducting research.

Montana Wind Map



Collecting Scientific Wind Data

The advantages of collecting scientific wind data prior to system placement cannot be overstated. Under ideal conditions, this involves employing a measurement system that is close to the expected height at which your rotor hub will be located and collecting data for at least a twelve-month period.

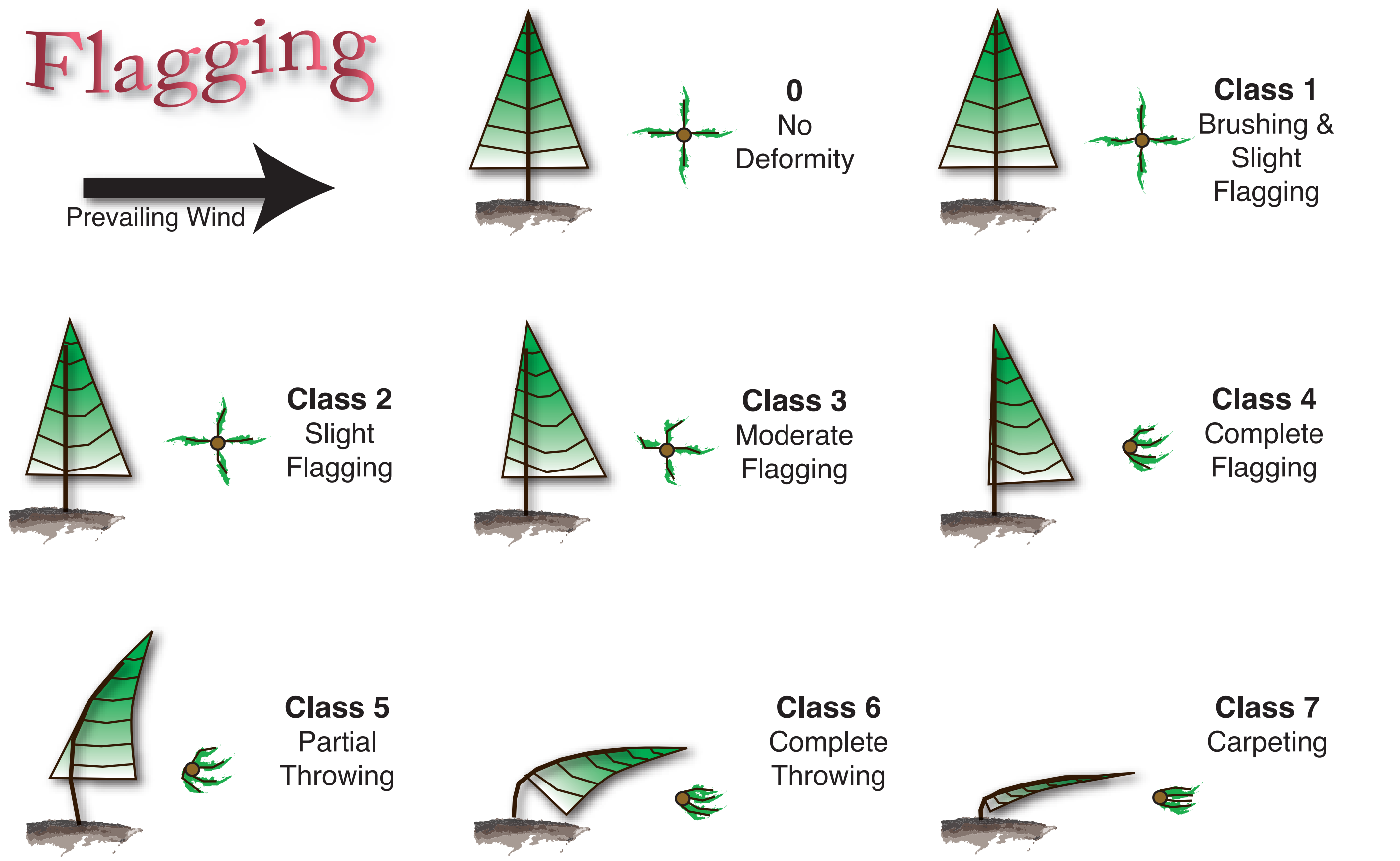
Wind measurement systems use a device called an anemometer, which measures wind velocity. There are a variety of models available for sale or lease. It is important to ensure that data recording is constant, reliable and accurate. In addition to average wind speed, wind direction and wind speed distribution are important to know and can be measured using more advanced measurement systems.

Paul Gipe, a noted expert on small wind systems, suggests that instead of purchasing an anemometer and recording system, it sometimes is more economical to install a small generation system that has data recording capabilities. This provides electricity, helps to educate the home owner, and is much easier to re-sell if the consumer decides not to pursue home generation. A number of Montana wind companies sell “micro-turbines” which can provide wind data. They can be mounted on a guyed mono-pole that is fairly easy to assemble and erect.

Consumers should feel comfortable with their wind data and combine it with information provided by research, observations, wind measurement indexes, and advice from wind contractors.

A plus or minus two miles per hour wind speed average can greatly impact the production of a turbine and having valid wind data is extremely useful for a number of reasons. One of the important factors that is often overlooked is the simple fact that a consumer who is willing to collect data prior to purchase is a deterrent to sales people or contractors who are not reputable.

Flagging



Index Class	1	2	3	4	5	6	7
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

The Griggs-Putnam Index

If the topography of your proposed site has mature trees (especially conifers), the Griggs-Putnam Index is useful for determining average wind speed. Used as a tool and a resource, it can help you to decide whether additional, scientific wind speed collection is necessary.

Class 2 - Partial Flagging

Class 3 - Moderate Flagging

Class 4 - Complete Flagging

Other Indicators of Strong Wind Resources

Some wind experts suggest that indicators such as the presence of snow fences, tattered flags, and planted windbreaks are telltale signs that a strong wind resource is available in a geographical area or community. Others suggest looking for the presence of abundant snowdrifts on a property to determine the wind resource.

These can all be supplemental, reassuring signs of a strong wind site, but don't forego the collection of scientific data and measurements based solely on visual indicators.

At Your Property...Siting Considerations

One of the most critical factors in wind energy production is providing unobstructed air flow to the turbine blades. The impact of air flow from buildings, trees, and other obstacles is sometimes overlooked, often underestimated, and can have a significant impact on system performance.

The rule of thumb is that wind turbines should have a hub height of at least 30 feet above any obstruction 300 feet or closer, based on the direction of the prevailing winds. If your house is 30 feet tall and you want the generator next to it, your tower height must be at least 60 feet at the hub. Likewise, if you have even a single tree or obstacle that interferes with prevailing wind, you must be at least 30 feet above the impediment.

Most effective small wind systems are at 50-60 feet or taller, as higher is better. Remember, increasing tower height is much harder after the generator has been placed. Also, consider in your calculations that adjacent trees may continue to grow in height and plan for any additional building construction (including that of neighbors) that might hinder the delivery of air to the unit.

Turbine Types and Wind System Components

Horizontal Axis Turbines (HAWT) versus Vertical Axis Turbines (VAWT)

In choosing between a horizontal axis turbine (HAWT) and vertical axis turbine (VAWT), be prepared for strong opinions and bias from contractors who promote and sell either of the two types. Listed below is an explanation of the differences.

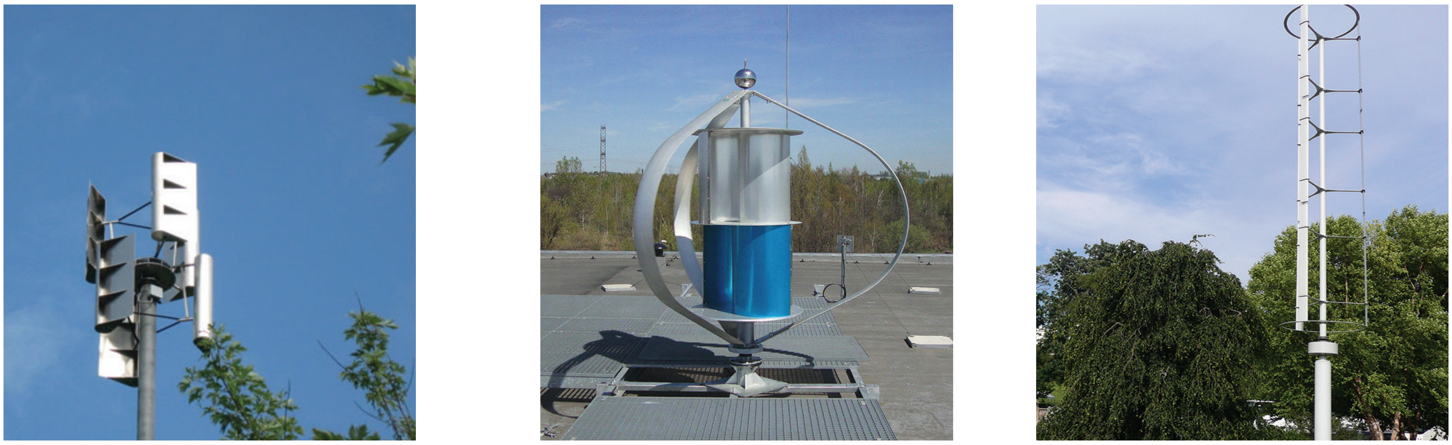
A Horizontal Axis Turbine (HAWT) is the common turbine used and proven for electricity generation. The blades spin on a horizontal shaft and are designed to access the wind from all directions. When researching the historical wind turbine market, HAWTs are the units whose manufacturers have the most longevity and credibility.

A vertical axis wind turbine (VAWT) has a main shaft that is often designed perpendicular to the ground, which the blades rotate around. Variations of VAWTs include those with “tipped” designs and a number of eccentric shapes, including helix-like profiles.

Recently there has been an increase in the number of vertical axis models available to consumers. These are sometimes quite ornamental in design and can be hard to distinguish as electricity producing machines. There are also a variety of VAWT designs that are available to do it yourself (DIY) consumers.

From a pragmatic perspective, consumers in Montana have realized significantly more success and reliability with HAWT systems. Every couple of years, a new or recycled VAWT design is brought to market, but popularity and success are often short lived.

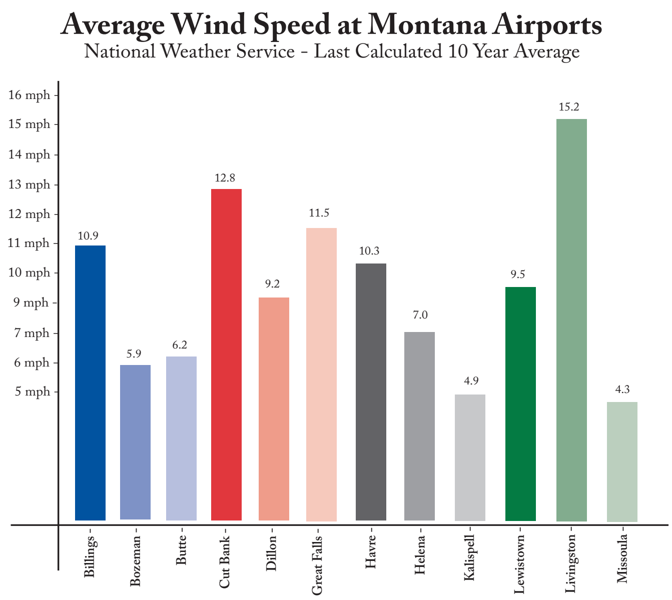
For the purposes of this manual, the focus is on HAWTs. However, the same wind principles and steps to a productive system can be applied to both designs.



Vertical Axis Wind Turbines (VAWTs)

HAWT Sizes and Characteristics

Unfortunately, the wind industry doesn't have a single method or classification for wind turbine size. This can be confusing to the consumer. Most wind contractors categorize small-scale turbines into three groups. There are micro or mini turbines (less than 2 kW of rated capacity), residential turbines (2 kW-10 kW), and agricultural or small business turbines (10 kW – 50 kW). There is some size overlap in a select number of turbines available to consumers. Also, as detailed in this publication, rated capacity or peak power can be misleading.



Generally speaking, micro-turbines in a 12 mph average wind speed produce between 2-10 kWh of electricity per day, residential turbines produce between 5-50 kWh per day at 12 mph, and agricultural turbines can produce between 50-250 kWh per day at 12 mph. This is a rough estimate only, but it provides a distinction between the different turbine classifications.

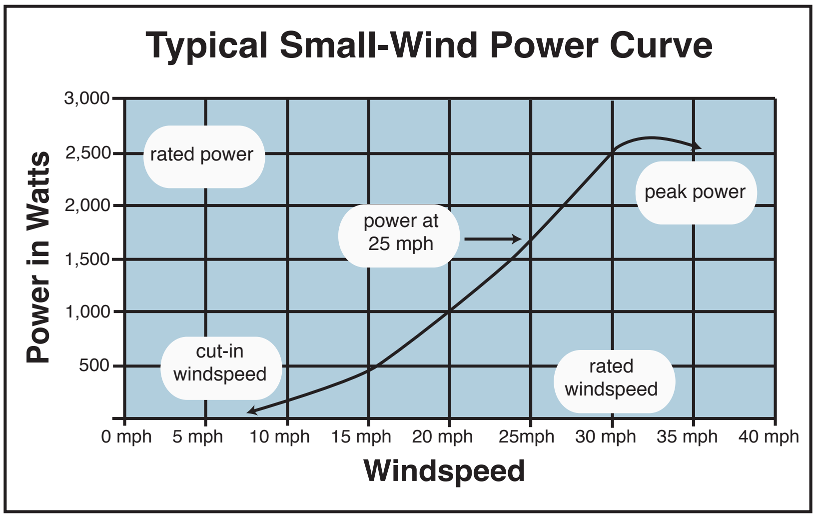
When wind generation systems were as popular as solar PV in Montana, contractors used a .15 efficiency factor related to peak output sizing to predict the kWh output of the system. This translates into approximately 3.5 kWh per day, per rated kilowatt. For example, a 5 kW wind generator was predicted to output (5kW x .15 x 24 hours) or 18 kWh per day. Unfortunately, the .15 factor was only realized in a small number of installations and fell short in most other locations.

Having a good idea about how much energy your wind system can be expected to produce is essential. Rated power, peak capacity, and estimated production percentage factors are all "indicators," but there are different methods recommended by professionals that are more accurate. The following paragraphs overview "power curves," which can be helpful, and "energy profiles", which are favored by reputable wind professionals.

Power versus Energy – Critical to Wind Generator Output

There is a difference between the terms "power" and "energy," and the distinction is important to consumers relative to wind turbine performance.

Power is an instantaneous measure of a turbine production. Turbines come with a rated power or peak watts listing, which is based on optimum wind speed but provides little information of production at either lower or higher wind speeds.



In addition to the rated power value, manufacturers also include a "power curve" for specific turbines. Power curves are somewhat more useful to consumers compared to rated power, but they are still based on "instantaneous" wind speed that has been either modeled (predicted) or physically tested.

One of the common mistakes that consumers make is to go directly to either the rated power or most productive part of the wind energy curve and assume (or convince themselves) this will be the wind speed(s) and production they will most often realize at their site.

A good example of the error in power curve "thinking" can be illustrated by reviewing a popular 5 kilowatt (rated power) turbine and the production realized at rated power (5 kilowatts at 26 mph) versus the power produced at one-half the rated wind speed or 13 mph.

Because of the "cube effect" relative to wind speed (which is detailed later in the publication), the turbine does not output at 50% of rated power at 50% of optimum wind speed (13 mph). Instead, the instantaneous power is roughly 1/8th of rated power, or .63 kilowatts.

Energy Profiles – A Much Better Estimate

The term energy in wind turbine applications is different than power because it includes a factor of time. Consumers who are on the utility grid pay for the energy used per hour (kilowatt hours or kWh). When evaluating a wind energy system, a similar measure should be used.

To develop an energy profile for your site, two estimates are needed. The first is the average wind speed at the turbine height. The second is the turbine's power curve.

An energy profile provides the production over a period of time for various average wind speeds. In the majority of Montana's geographic areas, average wind speeds differ significantly by month and season - therefore, the energy profile can be different at specific times during the year.

Understanding your site's energy profile is critical and provides the necessary data for making the best choice on turbine type, size and placement.

Upwind versus Downwind Turbines

Small-scale horizontal axis wind turbines are available in either an upwind or downwind design. Upwind and downwind denote the position of the turbine blades relative to the tower or pole.

Upwind turbines face directly into the prevailing wind. If the wind is blowing from the north, the blades face to the north and as the wind direction shifts, the turbine turns directly into the direction of the shift.

Downwind turbines have blades that are positioned on the downwind side of the tower or pole. If the wind is blowing from the south, the blades are positioned on the north.

The performance of upwind versus downwind turbines is similar – neither has a demonstrable difference in either production or reliability. Aesthetics are often the reason behind the choice.

Consumers should be aware that manufacturing companies sometimes hype advantages with a specific turbine relative to upwind versus downwind design, but most independent wind professionals believe these are negligible. Higher production is often cited as an advantage for upwind turbines. The suggestion is that available wind to downwind turbines can be impacted by the tower because of turbulence or "tower shade" due to the turbine/tower relationship.

Downwind turbine manufacturers cite the need for a tail in upwind turbines as additional cost and a possible failure point. As a counterpoint, upwind turbine proponents point to the fact that downwind turbines are slower to react to wind direction changes and can even become "stuck" in position.

Two Blade versus Three Blade Designs

Most manufactured small-scale turbines have either a two or three blade design. In Montana installations to date, three blade turbines have shown better reliability and have had fewer downtime and maintenance issues compared to two blade units.

Two blade wind turbines typically cost less because of reduced materials and easier mounting options. The major drawback for them is that the design produces what is termed "yaw chatter," which is a vibrational condition that puts stress on the entire machine. This is due to rotational imbalance when the blades are mounted at 180 degrees apart from each other. With a three blade turbine, the 120 degree position minimizes vibration.

Three blade turbines typically capture approximately 3-5% more wind energy than two blade units. Also, they are usually quieter than a two blade machine. This is because of lower rotor speed and reduced yaw chatter.

Two Blade HAWT

Three Blade HAWT

Direct Drive versus Gear Driven Turbines

Most small-scale turbines are what is termed “direct drive,” meaning the turbine blades spin at a fairly high rate of speed, which is ideal in the connection whereby the blades directly turn the alternator and produce electricity.

In situations where turbines with longer blades are used, the rotational speed of the blades is slower, which dictates the use of a gear box to increase the speed for the alternator.

Most wind experts believe that for small-scale applications, direct drive turbines are the best for two primary reasons. The first reason is that anytime energy is transferred and converted, there is a natural loss of some of that energy. Using gears, belts, pulleys and other mechanisms to alter speed results in energy losses due to friction and heat.

The second reason most experts recommend direct drive turbines is that adding components (especially ones with moving parts such as gear systems) includes extra cost and maintenance requirements. Depending on specific configurations and variables, even preventative maintenance tasks such as lubrication can be very costly.

As a general rule, small-scale turbines with gear drives are most efficient in higher wind speed areas because there is less loss in conversion. At lower wind speeds, the gear system configuration and components tend to have higher losses due to friction and conversion variables.

Too Much Wind – Over-speed Control

Beware of the sales person who tries to sell a turbine that “works best” or “produces exponentially” in extreme high winds. This is a myth, and for mechanical and safety reasons, turbines are designed to shed excess wind using varying design mechanisms. These “governors” provide over-speed control that is critical to protect the turbine and electrical system components.

“Furling” is the industry term for turning the turbine directly out of the force of high winds. This is accomplished by components that turn the entire rotor out of the wind or to the side. Some designs employ both.

Other types of over-speed control include electronic braking mechanisms, blade pitch control devices, and springs or hinges that flatten the blades as the wind increases.

Integral Equipment and Considerations

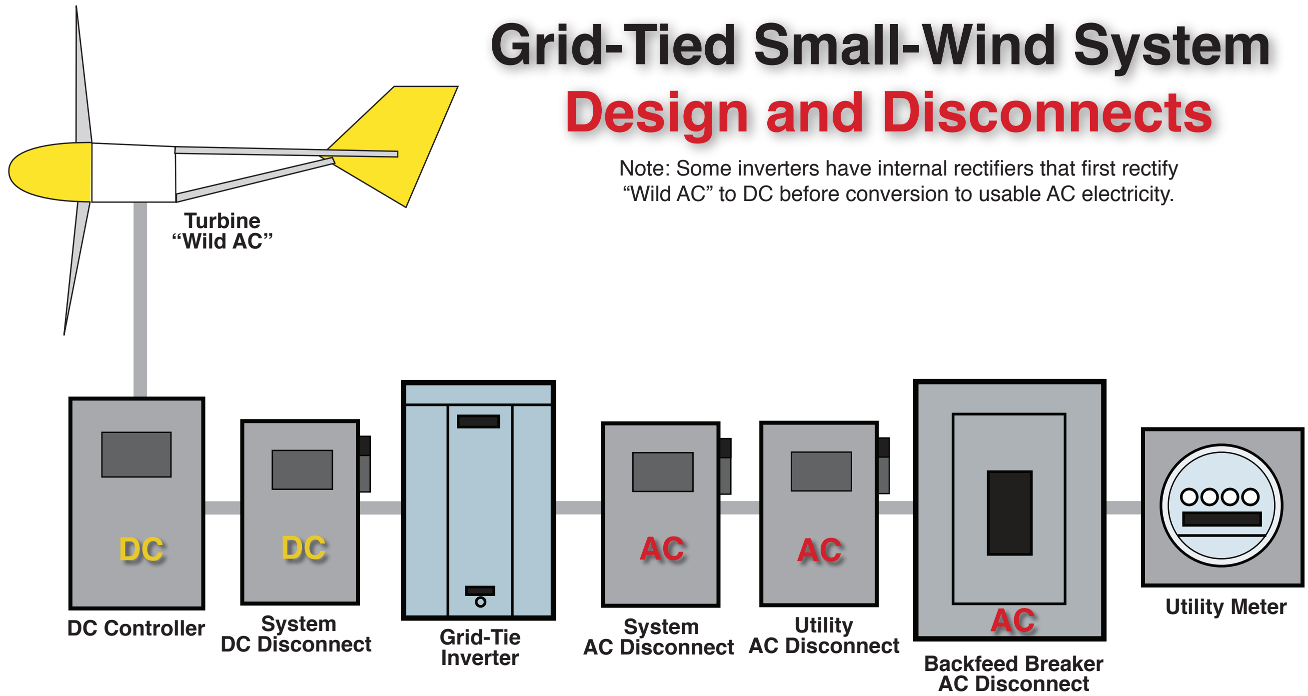
Alternators (Generators)

Creating electricity with kinetic energy originating from the wind system’s rotor is a straightforward process. Small-scale wind turbines usually employ either a permanent magnet or wound field alternator – both of which use the spinning rotor shaft to move magnetism past stationary copper wire. In doing so, an electrical current is induced in the stationary windings.

Most small wind turbines use permanent magnet alternators. These magnets are typically made of “rare earth” materials, which increase the magnetic field (and output) of the wind system when compared to systems using iron or ceramic magnets.

Wound field alternators are also used and have the ability to increase power output as wind speed increases. However, they require a small amount of source energy to realize and maintain the electromagnetic field.

Grid-Tied Small-Wind System
Design and Disconnects



Inverter and Balance of System Components

This publication is directed towards grid-connected (commonly called grid-tied) systems. The wind turbine, through a series of components and wires, is directly connected to the utility grid.

In this type of system, when the turbine produces more energy than required by the house or structure, it is directed to the utility grid. When the home or structure requires utility electricity (due to no or low wind production), the consumer receives electricity from the grid.

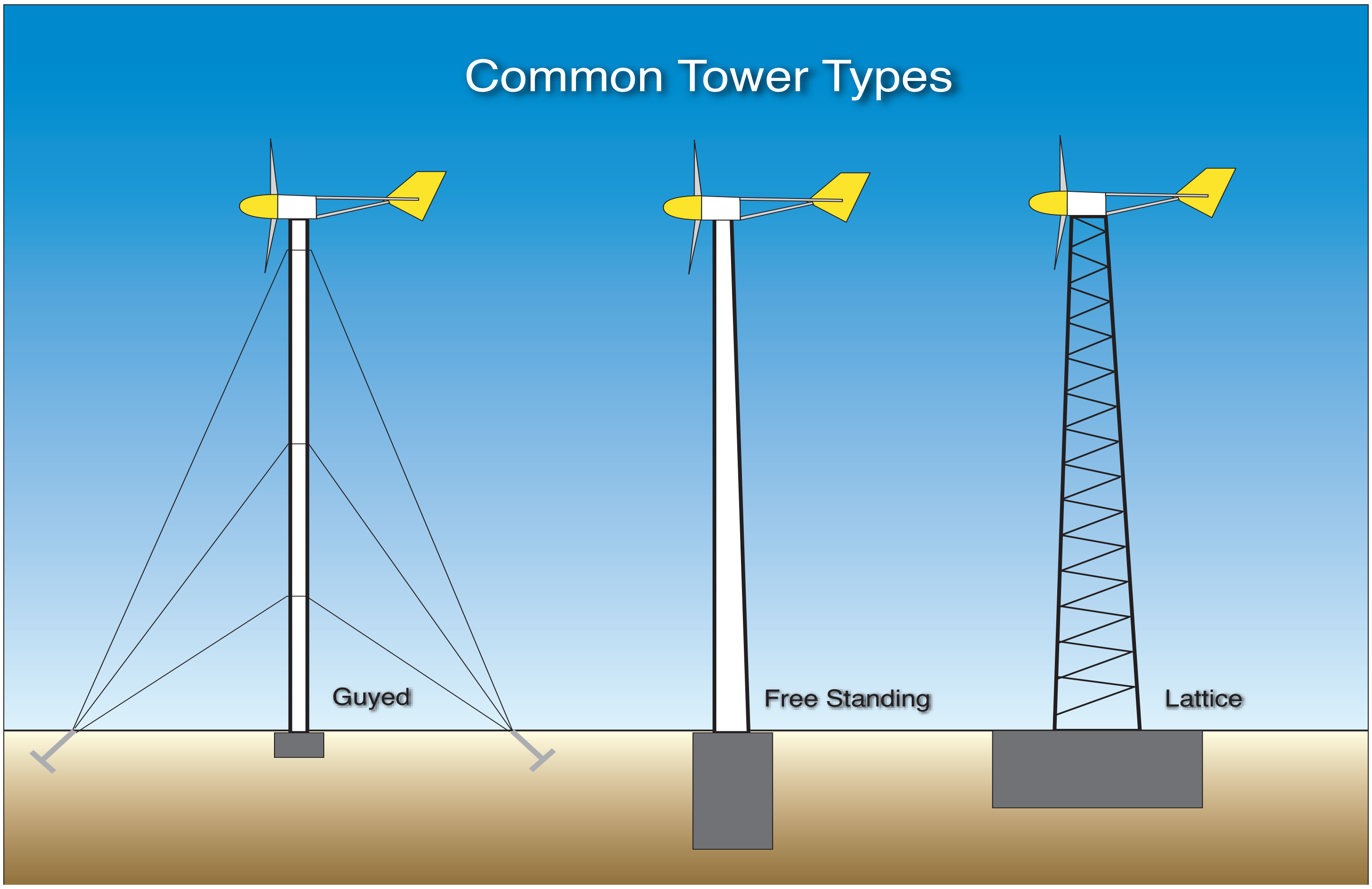
Grid-connected systems are the simplest and require the smallest number of balance of system (BOS) components. In addition to the wind turbine and tower, grid-connected systems include other components to condition and safely transfer the power from the turbine to the structure and between the structure and the utility grid.

In the majority of grid-connected systems, the turbine either produces what is called "wild AC" power or, in other cases, DC power. In both scenarios, the electricity needs to be conditioned into usable AC electricity that matches the profile of grid supplied electricity. In order to accomplish this, the power is rectified and "inverted" into 60 cycle, 120/240 AC power using the system's grid-tie inverter. The inverter works synchronously with the grid relative to both production and safety.

In addition to the inverter, there are other critical BOS components. These typically include the following:

1. **DC control panel and disconnects**
2. **AC disconnects**
3. **Breaker boxes**
4. **Electrical "net meter" supplied by the utility**
5. **Utility safety disconnect**
6. **National Electric Code (NEC) required signage**.

Consumers should understand that grid-connected systems must be compliant with both NEC requirements and the standards within the utility interconnection agreement. These regulations are meant to ensure the safety of the homeowner, the utility and the general public.



Towers

The turbine tower is a critical piece of equipment for wind turbine production and safety. It is also one of the most expensive components - in some cases, the tower is more costly than the wind turbine.

Tower construction and erection is also the place where the homeowner often attempts a do it yourself (DIY) solution or tries to cut costs. Wind turbine towers are precisely engineered with respect to materials, design and required installation parameters. Improper installation or inadequate construction can be an extreme hazard.

Fortunately, there have been significant improvements in tower design and quality over the last several years and this has made appropriate tower height requirements more practical and affordable.

There are three basic designs for towers, with sub-menus within each design. These designs are: free standing lattice towers, free standing conventional pipe towers (heavy gauge), and guyed towers that use thinner walled tubing or lattice. Caution should be used in assuring that your tower is rated to handle the specific turbine placed on it.

Your dealer should provide you with alternatives for your specific system, along with the square feet required for the tower and component and installation costs. Remember, tower erection is a technical and potentially dangerous task and in most cases should be contracted to professionals.

Tilt-Up Towers

For homeowners who have the space, mechanical aptitude and desire to maintain their own equipment, tilt-up towers provide a viable alternative. Although the initial expense is higher than conventional guyed towers, the long-term benefits of self-maintenance and extended equipment life can be worth the investment.

Tilt-up towers are not usually recommended for turbines above 5kW due to the weight and dimensions of the larger systems, and the raising and lowering of the units does involve risk to the equipment and individuals performing the task. Also, at least for the first one or two sessions of raising and lowering, assistance from the dealer or contractor that installed the system would be prudent.

Rooftop Turbines

Unless your building was specifically designed and built to support the additional load and vibrations from a rooftop turbine or one mounted on the side of the structure, it is strongly recommended that you avoid placing a turbine on the structure.

Not only is wind speed reduced and turbulence increased on towers mounted marginally above structures, but the constant vibration from the turbine can damage the structure. This includes damage to the external and internal portions of the building. In addition, the vibration from the turbine can be noticed within the structure and be very disruptive.

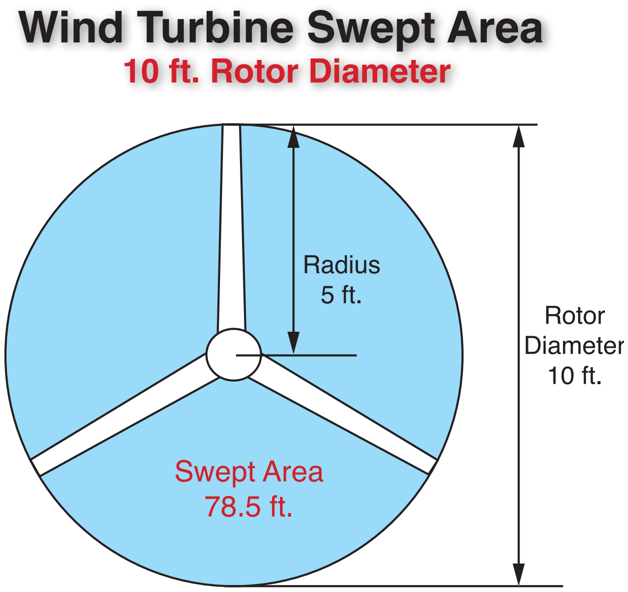
Some less than reputable contractors promote a number of “vibration proof” mounting brackets and designs for rooftop turbines. These mounts are adhered to the substructure of the building and likely will cause structural damage over the long run, regardless of how the dynamic load on the house is distributed with the design.

The Power Formula for HAWTs

There is a standard method for estimating turbine production that is applicable to the scope and scale of wind power systems. Understanding this is essential for the consumer, not only for choosing the proper wind turbine based on the turbine’s listed energy profile, but also for siting the system. Remember, this is a power formula, and the ultimate goal is to also include the “time” factor, which ensures an accurate energy production estimate.

The output of the system is termed the **Power (P)**. In a wind generation application, power is accomplished and influenced by three specific factors. These are **Wind Speed, Rotor Diameter (swept area), and Air Density**. The formula used to calculate power is **P=1/2dAV3**. Written in long hand: **Power equals one half Air Density times Swept Area times Velocity or Wind Speed Cubed.** Following is an overview of the three power factors:

Air Density is, above all else, something that cannot be controlled by the consumer. It varies with both elevation and temperature. Of importance is that cold air is denser than warm air, and the higher the elevation, the less dense the air. A good reminder is the adage “vanish into thin air” - which means ascend upward into the atmosphere.



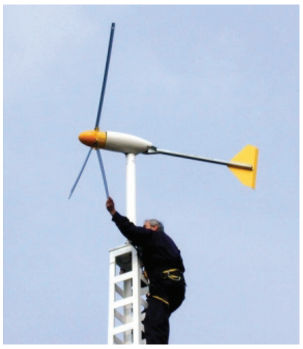
The average air density at sea level is calculated using the factor 0.6125, and it decreases approximately 4% per 1,000 feet of elevation. And with Montana’s distinct seasons, more power will be available at the same wind speed during the colder months.

Swept Area, which is a direct product of rotor diameter, is the next factor in the formula. Determining swept area is a sometimes confusing task if working with eccentric blade design (VAWTs), at which point the consumer should be guided by the dealer/manufacturer. However, there are several basics to understanding the importance of swept area.

The equation to determine swept area is **A=πD2/4** and represents the area of wind “swept” or intercepted by the rotor. Written in long hand: **Area equals Pi (3.1416) times Diameter of Blades Squared divided by Four.** An example equation using a blade diameter of 10 ft. would be A=3.14(100)/4, and the resulting calculation would result in a sum(A) or diameter of 78.5 feet.

Several key points to remember are that relatively small increases in blade length result in much larger increases in power, and the wind turbine with a bigger rotor will almost always produce more power than a turbine with a smaller rotor. For example, increasing the 10 foot diameter blade in the example above to 12 feet would lead to an increase in the swept area of 113 feet (or a gain of over 40%).

The final factor in the power equation is **Velocity** or wind speed. As a starting point, it is important to remember that velocity is cubed (v times v times v) in the power equation, so even a small increase in wind speed creates a substantial power gain. For instance, doubling wind speed from 7 to 14 mph will result in an eight fold power gain. {(7x7x7=343) as compared to (14x14x14= 2,744)}. 2,744 divided by 343 is eight.



Following are several different examples where the variables within control have minor but important changes. This illustrates the value of swept area and the absolute necessity of having favorable wind characteristics. For the examples, the air density at sea level (.6125) is a constant.

Example One: Swept area 10 ft. blade (78.5 ft.), wind speed 10 mph. The power equation would be P=(1/2 x .6125) x 78.5 x (10 x 10 x 10). The first mathematical step would be to calculate the in-parentheses sums, which would be P = .30625 x 78.5 x 1,000; then perform the multiplication, which results in a power value of 24,040 (rounded off).

Example Two: Change the rotor swept area to that of a 12 ft. blade (113 ft.) and maintain the wind speed at 10 mph. The power equation would be P= 1/2dAV3, therefore P=(1/2 x .6125) x 113 x (10x10x10), calculated to P = .30625 x 113 x 1,000, which results in a P value of 34,606.

Example Three: In this instance, use the swept area of the 10 ft. blade in example one, but raise the wind speed to 13 mph. P = (1/2 x .6125) x 78.5 x (13x13x13), calculated to P = .30625 x 78. 5 x 2197. The power value with only a 3 mph wind increase would be 52,817, or more than double the available power at 10 mph.

Maintenance and Warranties

System Maintenance

Couple Montana's diverse and often harsh weather with the turbine's constantly moving components, and a number of mechanical and performance issues can occur. However, the manufacturers of quality turbines design the systems for extreme weather, and turbine life expectancy can be greatly improved by focusing on preventative maintenance.

As a general rule, bolts and electrical connections should be checked and tightened at least twice per year, and an annual visual inspection of blades (for wear) is recommended. Rust and corrosion can lead to eventual degradation of components and should be remedied as soon as possible.

Blades and bearings should not need repair/replacement for ten years or more - excessive vibration caused by either simple issues (loose bolts) or more complex problems are often the culprit for system failure. Turbines with guyed towers should also include periodic cable inspection relative to proper tension and wear.

Safety is a major consideration when performing maintenance. Always adhere to proper mechanical and electrical lock-out procedures, fall protection and personal protective equipment, as well as appropriate lifting/hoisting work practices.

Warranties

If the consumer uses a qualified, reputable contractor, the contractor should warranty the system and its operation for a specific amount of time. This should be in addition to manufacturer component warranties. A one-two year warranty from the contractor is not too much to ask – for a set fee, a number of contractors will also include basic preventative maintenance and troubleshooting.

Warranty periods for turbine components differ with manufacturers, but five years is an approximate average. As with any warranty, reading and understanding the warranty specifics is something that should be done before purchase, rather than when components stop working.

The important consideration for consumers is the reality that if something breaks and the turbine needs to be accessed through climbing, use of mobile equipment, or tilting the tower down, there is both time and skills required. In some cases, the majority of contractor time and cost is accessing the problem.

In the small wind industry (including in Montana), there are a number of turbines with problems that have made them inoperable. In some cases, the consumer has chosen to allow them to stand idle due to projected repair costs.

Both warranties and maintenance contracts are important. Working with a reputable contractor and developing a reasonable estimate of annual maintenance costs and scheduled component replacement (i.e. bearings) is critical. From a practical perspective, the consumer can also make the “best deal” for longer term expenses at the same time as purchasing the turbine and paying for the installation.

Energy Efficiency

The complements to installing and producing wind energy are energy efficiency and conservation. Consumers who combine efficiency and conservation with renewable production typically have a greater satisfaction with their system performance and complete energy “footprint.” Both energy conservation and efficiency are directed towards minimizing the amount of loss (and waste) from the point of electricity generation to the end use application. Although the two terms are often used interchangeably, there is a difference.

Energy efficiency is the ability to provide the same level of energy service using less energy. For example, if a light bulb had an output of 10 watts, 100% efficiency would mean that 10 watts of supplied electricity would power the bulb at its rated wattage. However, in using the example of an incandescent bulb, if it would take 100 watts of power input to provide 10 watts of output (light), and the bulb would be considered 10% efficient. Both a compact fluorescent and LED bulb would provide the same level of light at a more efficient rate.

Energy conservation is focused on reducing the use or instances of use for energy services. Conservation is most often achieved through behavior changes or choices. The term “energy conservation” was popular in the late 1970’s and early 80’s and is often identified with turning down thermostats or shutting off lights. Energy conservation is still a valid control mechanism today – what has changed is the ability to mesh efficiency and conservation through the use of improved technologies.

From a “real world” economic standpoint, end use conservation and efficiency are considered to be of very high value. Professionals estimate that one dollar spent on conservation and efficiency has the same value as three to five dollars spent on production.

Consumer Resources

Zoning and Legal Restrictions

Prior to installing a wind tower and generator, consumers should ensure that zoning regulations and subdivision covenants allow for them. Most new developments have height restrictions that could very well be violated by the placement of a wind generator.

Some Montana jurisdictions have written ordinances for towers and turbines. Be aware that electrical and building codes apply to wind generation systems.

Rural and agricultural areas usually present the fewest restrictions; however, regardless of your location, the “good neighbor” policy of contacting adjacent landowners who might be affected by the visual impact and noise of your system is prudent. For grid-tied systems, the local utility should be contacted prior to installation.

Consumer Safety Considerations

Montana Statute requires a licensed electrician to perform the work on circuits that are 90 volts and above; as a result, all grid-interactive wind systems meet the Sate licensing requirements. Some established, reputable contractors in the State are not licensed electricians themselves, but employ or sub-contract the electrical portion of the installation to a licensed electrician.

Consumers should understand that they are ultimately responsible for the safety and integrity of the wind system. Prior to hiring a wind contractor, the contractor should provide the consumer proof of liability insurance, workmen’s compensation insurance (for employees), and the ability to secure necessary structural and electrical permits. Consumer groups also suggest that consumers contacted the insurance providers and make sure the proof of insurance provided by the contractor is valid.

Incentives for Wind Energy

Currently, there are a number of incentives/tax credits available for small-wind applications. The "go to" place consumers should access is the DSIRE™ (Database of State Incentives for Renewables and Efficiency) web site.

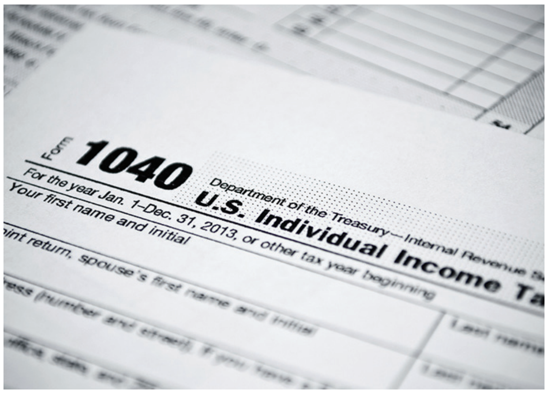
Established in 1995 and operated by North Carolina State University, DSIRE™ is the internet source for the scope of renewable energy and efficiency incentives and tax credits available to consumers. It is funded by the U.S. Department of Energy.

DSIRE™ also has resources that assist with understanding the specifics of the different types of tax credits/deductions, incentives and loans. Topics are communicated in a practical format, and links are provided to sites and providers with more detailed information.

DSIRE™ can be accessed at dsireusa.org. Consumers can access Montana incentives and tax credits by simply clicking on the "MT" segment on the site's home page. There is also a "Federal Incentive" button on the home page. This includes guidance for both residential and commercial consumers.

New IRS Rules for Small Wind Tax Credits

Effective for small wind turbines placed in service after January 26, 2015, the U.S. Internal Revenue Service (IRS) has issued a notice (Notice 2015-4), establishing performance and quality standards for turbines in order to qualify for the 30% federal investment tax credit (ITC). This includes all turbines with a nameplate capacity of up to 100 kW.



The two accepted certifications are 1) American Wind Energy Association Small Wind Turbine Performance and Safety Standard 9.1-2009 AWEA and 2) International Electrotechnical Commission 61400-1, 61400-12 and 61400-11.

Documentation stating that the turbine meets the new requirements must be provided to consumers to allow them to claim the ITC.

The new ruling is an effort by the federal government to ensure that tax benefits and public funds are directed towards safe, quality systems and provide consumer protection against untested technologies, unrealistic performance claims, and equipment failures.

Documentation establishing that the turbine meets the new requirements must be provided to taxpayers in order to claim the credit.

Consumers can access the list of accredited turbines through The Interstate Renewable Energy Council (IREC), which maintains a list of ratings of fully certified turbines for the U.S. market.

Checklist for Purchasing and Installing a Wind Generation System

1. **Determine the electrical usage of the structure being considered. Consider energy efficiency measures first.**
2. **Check zoning requirements, subdivision laws (if applicable), and determine necessary permits.**
3. **Research and learn about wind energy and available options.**
4. **Contact qualified wind turbine contractors for site assessments.**
5. **Evaluate the available wind resource and siting options.**
6. **Select a wind system based on the desired electricity needs and available wind resource.**
7. **Hire the contractor and make sure warranties, maintenance agreement, and sales/installation contract are all in place.**
8. **Contact the utility for net-metering and any available incentives. Determine other tax credits.**
9. **After the system is installed, make sure the system performance and specs are in-line with the purchase and installation agreement.**
10. **Have either a contracted or "self" maintenance plan in place for preventative maintenance.**

Notes

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The Montana Consumer Guide to Small Wind Systems