

Pipkin Electric
Renewable Energy Systems

Solar, Wind & Hydro Systems

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As more and more people recognize the need for alternate energy sources, Wind Energy has come to the forefront on many levels. A main reason for this is wind produces more power per dollar invested than any other form of renewable energy.

Unfortunately, the topic of wind energy is surrounded by a mixture myths, half-truths and outright misinformation. The reasons for this are varied. Most arise from the general lack of knowledge that the public has about wind turbines. However, some myths are created by people who have simply decided that they don't like wind turbines. These same people seem to oppose anything that does not suite them on a personal level.

We have compiled the following pages to assist the education of both you and the general public.

What is Small Wind?

For many people, the term "wind energy" conjures up an image of utility-scale wind farms, large arrays of industrial-sized 750-kW turbines with 150-foot rotors mounted on 200-foot tall towers. But wind energy systems come in small packages as well. A typical residential wind energy system includes a 10kW turbine, with rotors measuring perhaps 23 feet in diameter, mounted on an 80-foot tower. Such a system is suitable for meeting the electricity needs of a household or small business. Turbines as small as 400 watts, with rotors only 46 inches in diameter, may be employed for specific purposes, such as pumping water (for stock or irrigation) or running lights and appliances in a remote cabin or recreational vehicle. Wind energy may be used to complement a solar photovoltaic (PV) system, or by itself. It may be set up as a stand-alone system, or it may be interconnected with the utility grid.

Why Install a Small Wind System?

For over a hundred years, people have captured the wind's energy using mechanical windmills. Before rural electrification programs were instituted by the Federal government, farm families throughout the Midwestern U.S. used 200-3,000 watt wind generators to power lights, radios, and kitchen appliances. Today, small wind energy systems are still used to bring power to remote locations, but they are also increasingly being used as an independent, clean, affordable alternative to fossil- or nuclear fueled, utility-generated electricity.

How Does a Small Wind Turbine Work?

Wind energy is a form of solar energy created by the uneven heating of the Earth's surface by the sun. Most small wind turbines use a horizontal axis propeller, or rotor, to capture the kinetic energy of the wind and convert it into rotary motion to drive a generator, which usually is designed specifically for the wind turbine. The rotor consists of two or three blades, usually made from wood or fiberglass. (These materials give the turbine the needed strength and flexibility, and have the added advantage of not interfering with television signals.) The structural backbone of the wind turbine is called the mainframe, and it includes the "slip-rings" that connect the wind turbine - which rotates as it points itself into changing wind directions - and the fixed tower wiring. The tail aligns the rotor into the wind. To avoid turbulence and capture greater wind energy,

turbines are mounted on towers. As a rule of thumb, turbines should be mounted at least 30 feet above any structures or natural features within 300 feet of the installation. Smaller turbines can go on shorter towers. For example, a 250-watt turbine may be mounted on a 30-50 foot tower, while a 10 kW turbine will usually need a tower of 80-120 feet. Towers come in a variety of designs, including tubular or latticed, guyed or self-supporting. Wind turbine manufacturers also offer towers, and can ensure that the tower meets required building and safety specifications as well as being compatible with the turbine.

What size system do I need?

I am frequently asked by people, what size wind system do I need to power my house? There is no simple answer to that question, as there is no frame of reference on which to respond. If I asked a car dealer what size vehicle I need, the response would be: what do you need it for—basic commuter transportation? Got a passel of kids you transport to school every day? Need to haul a camper or a boat? Running a plumbing repair business out of it? Driving through fields? Moving cattle? Or shipping containers?

Your eyes narrow, but I'm not being a wise guy. A look at the vehicles on any highway results in the conclusion that vehicle size all depends on your use. The same holds true for what size wind turbine you need. It all depends on what you want to power.

Get a handle on what you use and how you use it.

There are questions that need answers even before the wind generator enters the picture. First and foremost: what is your current usage, and what do you use electricity for? If you do not know what your current electrical consumption is, you need to, as this amount is what you are trying to displace. To quote Ian Woofenden at Home Power Magazine, "If you tell us you use a lot of electricity, we'll tell you that you need a really big wind generator." Seems logical, but is rarely thought about.

There are two ways to determine your present electrical usage. You can either add up kilowatt hours (kWh) listed on your past 12 electric bills, or you can call your utility and get your historic electric data for the past year. Either way, you have some frame of reference as to "how many wheels you need on your transport vehicle." For a frame of reference, the average home (whatever that is) in the United States uses nearly 1000 kWh per month, or about 12,000 kWh per year. The average homeowner in the U.S., however, is clueless about energy efficiency or how much money he or she can save by replacing energy-squandering lights and appliances with highly efficient counterparts. Want to save 50% on the cost of your wind system? The average house in the U.S. can easily cut electric usage by 50% by replacing inefficient lighting and appliances, with no change in the "service" delivered by those appliances. For example, the average home has 30 to 60 incandescent lights. Replacing these with comparably 'lumened' compact florescent lights, at an average cost of \$2 apiece, can easily save several hundred dollars on your electric bill per year. Every year. Once you're finished upgrading lights, move on to other large electrical consumers: your refrigerator, freezer, air conditioner, dishwasher, washing machine...the list goes on and on. While many balk at the perceived expense for such retrofits, remember that every dollar invested in efficiency will save three dollars in generating capacity required to meet the "demands" of inefficient appliances. Efficiency is the smartest investment you can make in preparation for a wind system, with a return on investment easily surpassing the best stock market yields.

How much fuel do you have?

Once you have an idea of what you want to power (efficiently of course), the next step is to determine what your wind resource is, not at the ground level where you are but at the top of the tower where your wind turbine will be living and working.

The minimum tower height for any site gets the wind generator rotor at least 30 feet above the surrounding buildings and trees—and not just the height of the trees as they exist today, but the mature tree height over the 20 to 30 year life of the wind system. After you have determined the minimum acceptable tower height for your site, the next step is to assess your wind resource by finding the wind resource map for your state. Wind resource maps are usually available from state energy offices.

You may need to do some extrapolation up or down from the wind map to estimate the wind speed for your proposed tower height. This is a rather technical calculation, and is best done by a trained wind site assessor, but you should be able to get help from the wind turbine manufacturers or a wind installer in your area. If they cannot help, keep looking because without knowing what the wind speed is at your tower height, you are just guessing at how much fuel, your wind resource, you have to work with.

Load + Fuel = ?

Once you've incorporated efficiency into your home, know your monthly or annual electricity usage, and have an idea what the wind resource at the tower height required for your site is, you still have another piece of the puzzle to find, assuming that your home is connected to a utility which provides your electricity. You need to have an understanding of the rate that your utility will credit you for excess electricity that you produce but cannot use when the wind blows hard, and therefore must be "stored" on the utility's grid for retrieval when the wind dies. Often referred to as the "utility buy-back rate," this number will weigh heavily on the size turbine you install. While small-wind owners usually size a wind system to offset all of the energy they buy from their utility on an annual basis, this may not be the case for you, depending on the utility buy-back rate.

If, for example, your utility will credit you at the retail rate for all of the electricity you generate over and above your consumption, you may want to install the largest turbine you can and use the proceeds to help pay for the wind system. If, however, your utility will not pay anything for the excess electricity that goes onto the grid, then you will likely install a much smaller turbine, one that never generates more than you can consume at any give time. If your situation is somewhere in between, say they credit you the retail amount until you reach your average consumption, then pay you wholesale for any excess, your strategy will likely be to install a wind system that will meet, but not exceed, your annual energy needs. No sense in giving away your electricity for a fraction of what you are charged for it, or, worse yet, for free.

Payback – The Wrong Question

When discussing wind turbines, I frequently am asked the question: “So, what’s the payback?” More often than not, the question comes from someone who just drove up in a new 4x4 full-sized, king-cab, long-bed pickup truck that serves as their “commuter” vehicle, getting a dazzling 14 miles to the gallon, maybe. I am always dumbfounded.

“Payback” for renewable energy systems is generally defined as the amount of time it takes for that system to pay for itself in energy savings. The payback period for a wind system can range from several years to several decades, depending on the cost of the system, the cost of the electricity that you are offsetting from your utility, and the average annual wind speed at the hub height of the wind turbine. Since the output of a wind turbine is directly proportional to the cube of the wind speed, small increases in wind speed can result in dramatic increases in potential output. A 10% increase in average annual wind speed, for example, results in a 33% increase in potential output of the turbine. As such, the average wind speed of the site is usually more critical to the payback period of a wind system than is the initial installed cost.

If the only reason to install a small wind system were to make money, then only folks living in windy areas would put them up. However, people install wind systems for other equally valid reasons. I know people who have stated that their system is for their children’s and grandchildren’s futures, or for a cleaner environment. There are people who put their dollars where their values are in terms of not wanting to consume nuclear- or fossil fuel-generated electricity. There are folks who simply want to support the technology because it’s the right thing to do for them. All of these reasons are more “in the community’s interest” than a matter of whether or not the owner will make money on the wind.

Dissecting our purchasing decisions

That said, there is a segment of the population that is interested in renewables, but only if they make sense economically. What baffles me is why so few of our other consumer purchases completely ignore “payback.”

For example, I can go down to the liquor store and peruse several aisles of wines that are available. These range from Mogan David 20-20 Blue (I never knew wine could be bright blue until I conducted this expedition) at \$2.25 a quart to nice vintage table or after-dinner wines at \$40 a bottle and up. Anyone who has graduated from their teenage years to middle age or beyond understands the difference between these two choices—and it’s not about “payback.”

Or, imagine this: it’s your wedding anniversary, and you’ve invited your sweetie out to dinner. Ever conscious of payback, you decide to go to a fast food take-out chain for your romantic meal rather than that new, expensive, candle-lit bistro featuring a well-known chef. What do you think the payback on that date is going to be?

And then there’s the situation that I can never fully understand: investing tens of thousands of dollars in a vehicle. If the primary purpose of a vehicle is transportation, then the payback-conscious individual would consider initial cost, fuel economy, insurance, and resale value. High mileage used cars invariably come out on top of such a comparison. Instead, many people only consider the “prestige-value” of their vehicles. And number of cup holders.

Expanding on this idea, an analysis of the payback of a \$40,000 SUV versus a used vehicle versus public transportation clearly demonstrates that public transportation ‘outperforms’ the SUV by an order of magnitude. One look at the number of people taking public transportation versus single occupancy vehicles on any rush-hour afternoon in any major U.S. city expressway clearly demonstrates that people do not measure payback of their transportation choices the same way they do renewable energy investments.

Yet, we measure renewable energy with a “payback” yardstick which, if it doesn’t pencil out in a “reasonable” amount of time, nixes the purchase. I frequently hear that people expect a two- to three-year payback on renewables if they are going to invest in them. I always reply that they should invest in something that makes more sense for such a quick return, like cocaine, for example.

The only purchases that I can recall that have a “payback” requirement are energy efficiency devices and renewable technologies. And, recently, hybrid vehicles. Judging from that limited number of examples, if one were a conspiracy theorist, one would assume that the fossil fuel and utility industries were behind the payback ruse.

A truly smart buy

What is most interesting is that most of our purchases depreciate in value from the time that they are purchased, while renewable energy systems not only maintain their value, they actually make money for the owner. These savings include not only the cost of the electricity generated, but also the taxes saved on not purchasing that electricity. And, wind generated electricity from a small wind turbine is inflation-resistant since, as electricity rates increase, as they invariably do, the value of the electricity generated increases as well. In that respect,, the case can be made that wind systems actually increase in value with time, something that cannot be claimed for a shiny new car, a boat, or a swimming pool—all comparable in cost to a small wind turbine.

Many people who truly understand the value behind a small-wind purchase simply consider such an investment as prepaying their utility bill for the next 20 to 30 years, less the maintenance and repairs required during that timeframe. Or, many consider the purchase an investment in stable utility rates in an era when carbon taxes, looming on the political horizon, are predicted to seriously impact future utility rates.

Rather than simple payback, the correct question should be, “What is the return on my renewable energy investment?” No one asks what the payback is on a certificate of deposit. If renewable energy is pursued as an investment, it should be evaluated the same way that other investments are. However, this is a much more complicated analysis than it appears, requiring at least a simple spreadsheet that takes into consideration the monetary inflation rate and the escalation rate for energy costs, both of which are, at best, guesses. If you are a business, there are also depreciation and other possible tax advantages that will impact the outcome. Only after all of these “values” are plugged into a spreadsheet can you really evaluate your investment. But unless one is willing to go through with such an exercise, they will never fully understand what the true “payback” is on their renewable energy investment.

Cost-benefit analysis

Years ago I heard someone say that conventional energy economics is a value system masquerading as mathematics. This is especially true for the concept of “payback” as applied to renewable energy. The message was that “payback” of a renewable energy system considers all of the costs associated with that system, its installation, and its maintenance, but does not consider any of the many direct subsidies endowed upon conventional nuclear or fossil-fuel generation, all funded by taxpayers like you and I. Nor does the accounting take into consideration the “socialized costs” of conventional fuels, from toxic emissions, mercury pollution of lakes, and carbon loading to the cost of sending our military around the world to protect our fuel interests, all of which we pay for either directly or indirectly.

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Educate yourself

After all of this, you’re finally ready to go shopping for a wind turbine, right? Well, not quite yet. Your next step involves sizing the wind turbine to meet your now-reduced energy-efficient consumption. You could do this by requesting information for all models of wind turbines available from all manufacturers, but you can save time on this step. Ian Woofenden (of Home Power Magazine) has compiled a review of wind turbines that are available and supported in the U.S., *How to Buy a Wind Energy System*.

The article summarized the design criteria that should be important to any serious wind turbine buyer, as well as monthly energy production data for the range of wind speeds available for most small turbine installations. Keep in mind that the prices quoted in the article are for the wind system only, and do not include the tower, foundation, excavation or crane rental [edit correct?], electrical materials, shipping, and labor costs. You will need to get a complete project quote from your local wind system installer.

While you are researching wind turbines, check out who can install the system for you, and subsequently maintain and repair it over the 20 to 30 year life of the system. Get references and visit with some of the system owners they have installed for. You will need this person for a long time, so make sure that you are compatible.

Almost shopping time

By now you have gathered almost all of the information you need to begin shopping for a wind turbine, including:

- your monthly electric energy consumption
- how much of that electricity can be eliminated with efficiency
- the approximate average annual wind speed at the tower height your site will require
- what your utility will credit you for electricity you store on the grid for later retrieval
- what wind turbines are available that will fit your needs, including your electric usage, budget, and inclination to maintain the system yourself or hire someone to do this.

Remember that what you can reasonably afford goes far beyond the initial cost of the turbine or system installation. Installing a wind turbine means you are essentially prepaying your utility bill for the next 20 to 30 years, provided you purchase a reliable turbine, attend to annual inspections and repairs as needed, and install it on a tower suitably tall enough for your site. And keep in mind that utility rates will invariably increase over that time, making your investment in a wind system that much more valuable.

Do your homework, then invest wisely!

Considerations for Wind Generator Towers

In order to assure good access to their fuel, wind generators are mounted high atop towers. There are two reasons for this. First, ground drag, the friction between moving air masses and the earth, decreases with increasing height above the earth's surface. Second, turbulence caused by obstacles on the earth, trees, and buildings, for example, is reduced with height above those obstacles.

The rule of thumb used in siting a home-sized wind turbine is that the entire wind turbine rotor should be at least 30 feet (10 meters) above anything within 500 feet (150 m) of the tower. Since the rotor sticks down an equal amount that it sticks above the tower height, the length of one blade is added to the tower height to give us the appropriate "hub height" for the wind generator. Let's say that you have done a load analysis on your home, and know the annual average wind speed for your location. Manufacturers' specifications indicate that a wind generator with a 14-foot rotor will supply your electrical needs. You look around your rural property and note that the highest obstacle around is a 45-foot-high silo next to your barn. You are also surrounded by some trees, but at 30 to 40 feet, they are not quite as tall as the silo. What is the minimum height that you can get by with for your tower? Adding the 45-foot height of the silo to the 30-foot minimum rule plus the blade length of 7 feet results in a minimum hub height of 82 feet.

One thing you need to pay attention to is not the current tree height, but the height that the trees will grow to during the life of the wind system, that is, in 20 to 30 years. In my neighborhood, trees grow at a rate of about one foot per year, topping out at about 65 feet. If we take mature trees into consideration in the above example, the numbers are now a 65-foot tree height plus the 30-foot rule plus the blade length of 7 feet for a total hub height of 102 feet. Always remember the second rule of tower sizing: trees grow, but towers don't, regardless of how much it rains. This addresses the problems that turbulence poses for small wind turbines.

Note that the minimum hub height is just that – it's the minimum tower height that you can get by with and still produce electricity without the wind's power either being diminished by ground drag or compromised by turbulence. It is usually cost effective to increase tower height up to a point, depending on the size of the system and the local obstacles.

However, increasing the tower's height above the minimum still results in an increased wind system energy output. The power equation for determining the amount of energy that a wind turbine can generate states that $P = \frac{1}{2} \rho A V^3$, where P is the power available at the turbine rotor, ρ is the density of the air, A is the swept area of the rotor, and V is the wind speed. At a given location, we have no control over air density, so for any given wind generator with a given rotor diameter, the only real variable is V, wind speed. Therefore, we can rewrite the equation to say $P \sim V^3$, or more appropriately $P \sim V^3$.

For those who understand the power equation, this is stunning. While solar photovoltaics dealers cannot make the sun shine brighter at your site, and hydroelectric installers cannot make a river flow faster on your property, a good wind turbine installer can make it windier. And the V^3 portion of the power equation means that there is not a one-to-one relationship between increasing wind speed and increasing electrical generation. Doubling the wind speed does not result in a doubling of potential energy (a 100% increase), but an 800% increase, all because of V^3 . How do you increase wind speed, or V , at your site? Increase the tower height above the 30-foot rule, thereby further minimizing ground drag. Taller towers always result in the wind turbine generating more electricity. As you get away from the surface of the earth, ground drag – or the surface friction between moving air masses we call “the wind” and the surface of the earth – diminishes. As a result, wind speed – or V – goes up. V^3 considerably amplifies that increase. Oftentimes, people rationalize a short tower height based on the cost of the turbine. I have heard it said that a small wind turbine in the size range of 1 kW or so does not justify the expense of a tall tower, which could be four or five times the cost of the turbine. This reasoning completely ignores the physics of fluid dynamics that dictates the tall tower in the first place. A wind turbine close to the tree tops suffers from lack of fuel, the wind, due to ground drag. In addition, the turbulence caused by the surface clutter at the site will cause increased maintenance on the turbine as well as shorten its life. In light of this, shorter towers than the site requires are no bargain because the turbine is not producing much electricity and its life expectancy is decreased.

The minimum acceptable tower height for a given site is always driven by the obstacles at that site. Increasing the tower's height above the minimum is driven by simple economics of incremental tower height at a certain cost versus incremental energy production.

I once told someone who lived in an area with 60-foot trees that the minimum tower he could install was 100 feet tall. He responded that a 30-foot tower should be adequate, because if he was meant to be 100 feet in the air, he would have been given 95-foot legs. If this describes your attitude because you cannot deal with tall towers, then, realistically, wind energy is not for you.

Siting Towers & Heights for Small Wind Turbines

Siting towers and determining tower heights for small wind turbines (up 100 kW in capacity) is quite different than for commercial or utility-scale projects. With a commercial project, the first consideration is access to a utility transmission line, followed by the wind resource, with the final consideration being the potential acceptance of the surrounding neighbors.

Wind farm prospectors look for open land with good elevation relative to the surrounding terrain. A critical criterion is good separation between the potential site of the turbines and nearby obstacles. Wind prospectors like to have at least 2,500 feet between the turbine site and woodlots, farmsteads, and if possible, heavily wooded fencerows. Once they have found some good potential locations, the prospectors will begin contacting landowners about their interest in hosting a turbine or turbines on their land. While prospectors for large-scale installations have specific criteria that they use to determine their ideal location for a wind farm, they have a wide choice of available locations.

This is quite different from the approach for siting small wind turbines. Most people interested in installing a small wind turbine, be they a homeowner, farmer, school district, or small business, has a plot of real estate that he or she owns, which restricts where the wind turbine tower can be sited. Prospective small turbine owners rarely, if ever, look for a patch of ground with a good wind resource to buy for their home, farm, school, or business.

People do not have a propensity to build homes, farms, schools, or businesses on an open, windswept landscape. They seem to prefer locations somewhat sheltered from the weather and

their neighbors. As a result, these sites are cluttered with things like trees, besides the buildings that the people occupy. Woodlots are desirable home sites. Farmers often plant fence rows to act as wind breaks for livestock and to minimize soil erosion. Trees are the first things that come to mind when landscaping school or business sites. Achieving a half mile of separation from buildings, trees, and fencerows is nearly impossible for owners of small turbines.

Since prospective small turbine owners are stuck with the real estate they have, and that real estate is inevitably cluttered, there needs to be other considerations for siting the tower and determining tower height. For a wind farm, prospectors seek horizontal separation from trees and buildings. Since that is not possible for most small turbine sites, vertical separation becomes the critical factor.

There are two things that can diminish the wind resource for a small wind turbine. The first is ground drag. Ground drag is the friction that occurs between the surface of the earth and air masses that flow over it. The more cluttered the landscape (with trees and buildings), the greater the ground drag will be in a given area. Ground drag reduces the wind's speed, reducing its kinetic energy. The reason this is so important is because the output of a wind turbine is proportional to the cube of the wind speed. For example, increasing the wind speed from 10 miles per hour to 12 miles per hour results in a nearly 73% increase in the kinetic energy available in the wind.

The second thing that can reduce the output of a wind turbine is the turbulence caused by the obstacles that clutter the earth. Trees and buildings cause the wind to tumble and swirl rather than flow smoothly. Besides reducing the kinetic energy in the wind by slowing it down, turbulent winds also put undue stress and strain on the wind turbine and tower. Turbulence increases the maintenance on a wind generator, while it effectively reduces its life expectancy. Turbulence is the proverbial double whammy for small wind turbines!

In terms of tower height, the rule of thumb that is used is that the entire rotor of the wind turbine (that is, the three rotating blades) must be at least 30-feet above anything within 500-feet of the tower, or the local treeline, whichever is higher. While not ideal, the 30-foot gives minimum separation between the obstacles on the ground that can create turbulence for the wind generator (trees and buildings) and the wind turbine's collector, the rotor. Taller towers will always result in increased turbine output, since both ground drag and turbulence will be further reduced.

One final note on the 30-foot rule: in most cases, the tower height will be determined by the tree height around the site, or the area tree line. But remember that trees grow over time, while towers do not, no matter how much it rains over the 20- to 30-year life of the wind system. When determining tower height based on the 30-foot rule, you need to know the mature height the trees will reach in 30 years, not how tall they are today. That height becomes the baseline for the 30-foot rule.

In terms of tower location, turbulence can be reduced by siting the tower upwind of as many obstacles as possible, towards the prevailing wind direction. If the prevailing winds come out of the north to northwest in the winter, and south and southwest in the summer, the ideal location for a small turbine tower would be west of the ground clutter.

Types of towers

Towers for small wind turbines (up to 100 kW) come in two basic styles, freestanding and guyed. In most home wind system applications, either will do the job of getting the wind generator away from the earth's surface and ground clutter and up into the turbine's fuel: free flowing, non-turbulent winds. However, there are considerable differences in tower and installation costs between the two, as well as the amount of space the different styles take up.

The wind sees a tower essentially as a lever with which to do some work. The amount of work a lever can do is defined as "force times distance." The "work" the wind is trying to accomplish is to push the tower over and extract the concrete footings from the ground. The "force" exerted by the wind is a function of the wind speed as well as the swept area of the wind turbine's rotor. The "distance" is the height of the tower. As swept area (force) or wind speed (force) increase and tower height (distance) increases, so does the overturning force exerted by the wind on the tower and its concrete footings. As a result, as swept area and tower height increase, the tower and its footings must be built stronger.

Like a stool, the stability of a tower is a function of the spread of the legs. If you bring the stool's legs close together, it becomes less stable. Spread the stool's legs out and it becomes more stable. With freestanding towers, the three (or sometimes four) legs of the tower are analogous to the legs of the stool. With guyed towers, the guy cables serve as the "stool legs."

The amount of concrete in the ground required to keep the tower upright is related to how far the "legs" are spaced (as well as the height of the tower). The closer the legs are together, the more concrete is required to keep the tower from tipping over. Consequently, freestanding towers with legs relative close together are formidable pieces of heavy steel compared to guyed towers. All guyed towers use trigonometry to their favor. The angle the guy cables make between the tower and the ground shifts the loads exerted upon the tower base to some distance away from the tower, just like the leg spread of a stool. In addition, as a lever (distance) gets longer the resultant work the wind can do increases. While a short piece of wood can easily pry a small rock out of the ground, lengthening that piece of wood without increasing its thickness usually only results in breaking the wood, not moving the rock. As the wood lever gets longer, it must also get thicker. Because the legs of a freestanding tower are close together, they require much more steel to keep them from buckling under the loads placed on the tower by the swept area or the rotor and the wind (force) compared to a guyed tower. The result of all of this physics is that guyed towers use relatively little steel in their structures and concrete in their footings. Freestanding towers must incorporate considerable steel and concrete in order to stand the wind's overturning forces. This results in a more expensive tower and installation.

There are two basic styles of freestanding towers, monopoles and freestanding lattice towers. Monopole or tube towers are what people think of first because they are currently used for wind farm turbines. These towers are structural tubes that taper from base to the top. Monopole towers are aesthetically very pleasing. Because there is only one leg on a monopole tower, the tower structure uses the most steel, as well as concrete for its foundation, compared to all other tower options. These are expensive towers and installations, and, as such, are not usually considered for most small wind turbine applications.

An old farm water pumping windmill tower is a good mental image of the most common freestanding lattice towers used for small wind turbines. Freestanding lattice towers are three- or four- legged towers, the legs being made of either angle iron or pipe, with cross and horizontal bracing connecting the legs. The tower legs for a 120-foot tower are only about 12 feet apart, from leg to leg. Using considerable concrete and steel, freestanding lattice towers are on the expensive end, but not nearly as expensive as monopoles. Freestanding towers, whether monopole or with legs, have a small footprint on the property where they're installed, meaning they take up very little ground space. This is their primary attraction to most people.

The second style of tower is the guyed tower. There are two styles of guyed towers: guyed lattice towers and tilt-up towers, and both are quite common for small wind systems, although with very different applications. All guyed towers are held upright with guy cables which stretch from the tower to their anchors in the ground some distance away from the base to the tower.

Guyed lattice towers are the type of tower typically used for tall radio or television broadcasting antennas. Guyed lattice towers for home-sized wind systems are three legged, with the legs being anywhere from 12 to about 18 inches apart. Unlike freestanding towers, the legs of a guyed lattice tower do not taper from base to top. Cross bracing between the legs gives the appearance of a very tall three-sided, three-dimensional ladder. Guyed lattice towers use guy cables strung out in three directions, the minimum required to keep the tower upright. The anchors for a guyed lattice tower are usually spaced about 75% of the height of the tower away from the tower's base. For a 120-foot tower, this means that the guy anchors would be about 90 feet out from the tower base.

Since there are three sets of guy cables stretching out in three directions, considerably more land is required for guyed lattice towers compared to freestanding towers. Because of the geometry of the guy cables spreading out the loads, guyed lattice towers are the lightest in weight and use the least amount of concrete, making them the cheapest tower option for the homeowner.

The second style of guyed tower used with home-sized wind systems is the tilt-up tower. These towers are usually made of pipe or tubing, with four sets of guy cables stretching out in four directions to support the tower. Four sets of guy cables are required to safely raise and lower tilt-up towers. Guy cables can stretch anywhere from 30% to 75% of the tower height to the four guy anchors, depending on the tower manufacturer's design.

Tilt-up towers are a real advantage to turbine owners who don't want to climb to service their wind generators. Unlike freestanding or guyed lattice towers, you are not even able to climb a tilt-up tube or pipe tower. Instead, and the name implies, the entire tower is lowered to the ground for turbine installation or when repairs or maintenance are necessary, then tilted back up to put the wind generator into service. Tilt-up towers require the most land around them for the guy cables, as well as when they are tilted down. Because of the added complexity and hardware required to raise and lower these towers, tilt-up towers are more expensive than guyed lattice towers to purchase and install, but less than freestanding towers.

What's the best tower? That depends on your needs, the space you have available for the tower, and your budget. If you are dead set against climbing, then a tilt-up tower is for you. If you are on a tight budget, a guyed tower is your least expensive option. And if the area you have to squeeze the tower into is limited, a freestanding tower can be tucked away just about anywhere.

One bias I often hear is about aesthetics. Some folks are really attracted to freestanding towers, even though -- because of the large amount of steel they require -- they are highly visible on the landscape. Tall monopole tube towers, arguably the sleekest looking of them all, are out of the reach of most folks because of cost. Guyed towers, on the other hand, quickly disappear on the horizon. If you are shopping for a tower and aesthetics is a concern, your best bet is to visit several different towers and get an idea what they really look like.

Tall Tower Economics

Rules of thumb for tower height

A basic tenant of siting wind turbines, whatever the size, is that wind speed increases with height. Ground drag, or the friction between the earth and the air masses that flow over it, reduces the wind's speed—and therefore the kinetic energy that could have been available to convert to electricity with a wind turbine. As a result, wind turbines are placed on tall towers to get them above the surface of the earth. But how far above do we need to be?

Unlike wind prospectors who go out specifically looking for the ideal piece of property on which to site a wind farm, most of us are stuck with the real estate that we purchased and live on. We are also stuck with the various trees and buildings sitting on our properties as well as those of our neighbors. This ground clutter, as it is known, causes considerable turbulence in the air masses that blow over our property.

Turbulence does many things to a wind turbine. Compounding ground drag, it further reduces the kinetic energy in the wind, resulting in reduced energy production. The gusty winds of turbulence cause the wind turbine to continuously hunt in the wind, resulting in increased wear and tear on the machine. This wear and tear leads to additional maintenance as well as a reduced life for the wind turbine. As a result of both ground drag and turbulence, the standard rule of thumb for siting a wind turbine is to make sure that the entire rotor (that is, the three spinning blades, or the collector, of the wind generator) are at least 30 feet above anything (e.g., houses, barns, trees, whatever) within 500 feet of the tower. However, this is considered only a minimum; going above the 30 feet will always result in increased energy output because ground drag is further diminished with height above ground. Some people may live on a site that is relatively open, with perhaps only a bit of ground clutter, but yet there may be a mature tree line just beyond the 500 foot rule. In this case, the rotor must be 30 feet above the area tree line. Another thing to keep in mind is the age of the trees around your home. They may be only 20 feet tall today, but one thing we know is that trees grow over time. Twenty-five years down the road, those 20 foot trees will likely be 50-60 feet tall. Keep in mind that trees grow, but towers don't, no matter how much it rains in your yard. So, be sure to specify your tower height not on how tall the trees are today, but how tall they will be in the next 25 years.

Folks living in hilly terrain need to pay even closer attention to these guidelines. Rougher terrain results in more disruption of the wind, which can only be minimized with increased tower height. At some point tower height simply gets prohibitive. If this is the case, rethink how successful your wind turbine will be by compromising the tower's height. Just because you want a wind turbine doesn't necessarily make it a good idea in an extremely complicated site where you cannot get above the tree line or ground clutter. People have made good use of reducing the wind's damaging effects for centuries by putting something in its path to disrupt its flow. We use fence rows to reduce soil erosion. County highway crews use snow fence to reduce the amount of snow they have to plow off the roads in the winter time. Some people plant tree lines around their houses to reduce frigid arctic winds robbing their house of heat in the winter. The object is to reduce the kinetic energy in the wind so that it cannot do the work it could do if the wind were not disrupted: soil erosion, blowing and drifting snow, a cold chill blowing through the house. Knowing this, we understand that any obstacle in the wind considerably reduces its impact. The reverse of this can be of use to us when siting towers in very open areas. Typically, the zone of turbulence is twice the height of an object in its path. A 25 foot tall building on an otherwise relatively open piece of property would influence the wind up to 50 feet above the ground.

There may be an obstacle in your yard that you simply cannot reasonable get above, say one prize tree planted generations ago that towers dozens of feet above everything else. What to do? Chop down the tree? Definitely not! Do you need to get the rotor a minimum of 30 feet above this tree, given a shorter tree line ground clutter in the yard?

Not necessarily, but you do need to minimize the impact of the tree on your wind turbine. The best way of doing this is to determine the direction of the prevailing winds in your area. Then site the tower as far upwind of the tree towards the prevailing wind direction. In dealing with hundreds of people and their wind systems over the past two and half decades, the one regret that people repeatedly express is that they wished they had purchased a taller tower when they first installed their system. Learn from their mistakes. Do it right the first time.

All of this can be boiled down to the following rules of thumb for siting small wind turbines:

1. Wind speed increases with height above the ground due to reduced ground drag.
2. Wind farm developers seek horizontal separation from ground clutter. Since we cannot do the, we look for vertical separation to reduce turbulence.
3. The minimum acceptable tower for a given site must be at least 30 feet above anything within 500 feet...
4. Or 30 feet above the areas proximate treeline, which ever is higher.
5. Your "neighbors" (usually the trees in your area) determine your tower height (not what the manufacturer offers or the local dealer sells).
6. Remember that trees grow, but towers do not (no matter how much you water them). Size your tower for 20 to 30 years of tree growth.
7. Rougher terrain will produce gustier winds. This can be mitigated somewhat with a taller tower.
8. Site your tower upwind towards the prevailing wind direction of any major obstacles on your property.

Keep these rules in mind when installing your wind system and you will be rewarded with many years of reliable energy production.

Trials, Tribulations, Myths and Facts

Recently, two Wisconsin utilities, Madison Gas & Electric Co. (MGE) and Wisconsin Public Service Corp. (WPS), applied for zoning permits to install 31 660-kW Vestas turbines in my township and the township next to ours. While utility-scale turbines are considerably larger than home-sized wind systems, the institutional barriers that one may encounter during permitting could very well be the same. Therefore, an examination of the objections raised during the utilities' zoning process should be helpful to anyone dealing with a zoning committee regarding a residential wind generator.

Madison Gas & Electric began their process by holding an open house at a local restaurant/bar. The open house included utility and Vestas representatives who explained the project. During the open house, farmers and landowners interested in "hosting" wind turbines were identified so that the utility could determine whether their property was suitable. After evaluating the sites, MGE signed 30-year contracts with the qualifying landowners. With contracts in hand, MGE applied to the two local township zoning boards for conditional use permits. The local authorities were consulted even though the utilities were authorized by the Public Service Commission of Wisconsin to proceed. (In addition, a new state law prohibits local blockage of the wind project unless it poses a threat to area residents' health or safety.) Both utilities chose to attempt to secure local zoning permits as a show of good faith in dealing with the townships. The first round of meetings in both townships was set up to provide information to residents and the zoning boards. Unlike the festive atmosphere of the open house events, the utilities were faced with

fierce local opposition and a vigilante attitude. A handful of small property owners had riled up many landowners and gathered signatures on petitions opposing the wind projects. (Our area of the world is in flux. Once dotted by small family dairy farms and the occasional rural homestead like my own, the surrounding townships are more frequently populated today by one to two acre suburban-style home sites. Most of the new arrivals, anticipating the day when "obnoxious" manure spreaders are history, would prefer to see the townships subdivided instead of farmed. This sentiment was spurred on by out-of-county realtors who profit more by selling gentrified "farmettes" rather than working farms.)

The range of issues and subsequent objections raised about the 31 turbines were stunning, to say the least. While some of the issues were expected, other seemed to come out of nowhere. The more serious objections brought up included:

- noise from the turbines, based on hearsay, was compared to a train locomotive by someone who had never seen a wind turbine close up;
- land values would plummet because of the wind turbines and towers, comparable to the siting of a trailer park or quarry in the vicinity;
- not only would the 200-foot tall towers be struck by lightning, but they would actually attract lightning, increasing the incidences of strikes in the township;
- the turbines would interfere with TV, radio, and cell phone reception;
- stray voltages would be generated by the turbines or towers;
- blasting the bedrock for the foundations would ruin surrounding wells by dislodging iron and other minerals;
- the utility would have the right to cut down surrounding trees and vegetation on other people's property to reduce turbulence and increase wind flow to the turbines;
- the turbines would attract tourists, which bring with them littering, graffiti, vandalism, and crime;
- tourist traffic would result in children on bikes or farmers on tractors being struck by inattentive drivers gawking at the turbines;
- wildlife would be disrupted and flocks of migrating birds would be killed;
- the utilities could go bankrupt due to deregulation, leaving the abandoned wind turbines to fall into disrepair;
- the ice and snow experienced during Wisconsin winters would damage the turbines, which wouldn't be repaired until warm weather returned;
and
- wind turbines are inefficient, not cost effective, and couldn't be installed without huge government subsidies.

In addition, the local attorney hired by the townships to interpret legal issues for them knew that the utilities were under the pressure of the sun-setting production tax incentives. The attorney was opposed to the project and continuously attempted to delay any decision by the zoning boards in hopes that the utilities would just go away. Needless to say, the utilities patiently responded to all allegations and questions and secured the zoning permits they wanted. Twenty-nine of the 31 requested permits were granted (by three to two votes in one township).

Zoning: 5 Barriers to you Small Wind System

Zoning has turned out to be a major impediment to the installation of small wind systems, one of a handful of serious barriers to small wind consistently identified by installers. This situation has worsened over the past decade as more people with either romantic notions of the country or the not-in-my-backyard crowd move to the countryside. Depending primarily on the community's view of aesthetics, neighbors may support or vehemently oppose a proposed wind system. The permitting of any given project, be it a house addition, garage, storage building, gazebo, or wind turbine, generally includes issues of public health, public safety, and general welfare. This last category, general welfare, is the catch-all that often ends up being the death knell for a residential wind system. People have opposed wind installations for any manner of reasons, many unfounded and outright ridiculous. People have opposed residential wind turbines for reasons that include such things as: -Aesthetics, -Reduced property values, -Insufficient payback or economics of the wind system, and -Harm to wildlife, particularly birds and bats. Most of the objections raised are quite subjective in nature, and as such can not be easily refuted by the applicant, even with an unlimited budget. In the U.S., we pride ourselves in having a judicial system where you are considered innocent until proven guilty. The irony of zoning in the U.S. is that the applicant is nearly always "presumed guilty," and needs to prove that they will not "harm" their neighbors. Right or wrong, the "harm" is often left to the objecting neighbor to define. In such a situation, anyone can object to a proposed wind turbine for virtually any reason, and unless the applicant has the financial wherewithal to disprove the objection with irrefutable evidence, the project does not go forward. This situation has turned out to be a quagmire for many small turbine dealers and installers. Both the applicant and the dealer end up spending considerable time and resources researching and attempting to refute any unfounded accusations made by an opposing neighbor. Often the homeowner or dealer simply gives up in frustration, handing the NIMBY (Not-In-My-Back-Yard) objectors another "success story."

In some cases, wind opponents have seized control of the zoning process and put into place all manner of requirements for a small wind system, based on similar requirements for utility-scale wind farms. An applicant for a residential wind system may need to supply numerous documents that are not ordinarily required of other home improvements of similar costs. I have seen ordinances that have included such requirements for small wind systems as: -a soil survey of the entire area -site soil tests -tower engineering -tower foundation engineering

-structural certification for the tower -bird studies, and bat studies -noise studies -ice "throw" engineering and calculations -blade throw calculations -telecommunication interference testing -an environmental impact study -average wind speed monitoring -power output reporting and economic viability analysis -agricultural impact statement -architectural projections of what the turbine will look like on the property -documentation of nearby sensitive environmental areas -wind access agreements with neighbors -an abandonment plan -determination of the area affected by shadow flicker -stray voltage testing -HAZMAT (hazardous material) reports -well testing -electrical wiring insulation testing -site reclamation plan -bonding It should be fairly obvious that neither a homeowner nor an installer can accommodate such a list. It should also be obvious that a homeowner interested in permitting a house addition, garage, or garden gazebo would never be required to supply such information. The only conclusion that can be drawn is that such requirements were not put in place for any reason other than to dissuade the installation of residential wind systems in the community.

Keeping Zoning Hearings Under Control

Quite often, someone requesting a building permit for a small turbine will need a variance from local zoning ordinances before beginning the project. By all means, secure the required permits before purchasing the equipment. Zoning committees who feel slighted that you took their approval for granted are more likely to take a harder look at your project than if you had come to them first.

While not necessarily what they should be, zoning hearings quite often turn out to be popular referendums on an issue, or even an individual landowner. Alienate your neighbors, and you will inevitably lose every time. Therefore, your primary strategy should be one of public relations. Zoning officials live in your neighborhood and must answer to the local community. Discussions are not limited to your zoning hearing. They will take place in the officials' respective churches, down at the feedmill or hardware store, and in the local tavern or restaurant. You will be talked about. Use this to your advantage. Talk up your project with key neighbors well in advance to applying for the zoning permit. Answer questions in a friendly, non-judgmental manner. Allay fears by distributing appropriate articles on wind turbines or equipment specifications whenever the opportunity arises. Invite potential advocates to appear at the zoning hearing to speak on your behalf.

If possible, get your local newspaper to do a story on your proposed wind turbine. You can actually write and submit your own press release. Include as many facts and benefits as you can, explaining why wind turbines are a good idea. Stay away from any negative aspects of the project. People really do believe what they see in print, so use this to your advantage. When it comes time for your zoning hearing, get as many local supporters for your project to the meeting as possible. Again, zoning hearings are not supposed to be popularity contests, but committee members can certainly count those opposed to a project in an audience versus those in favor.

Many times, meetings will get out of hand due to an especially vocal attendee who has no respect for the rules or process. This problem is exacerbated by the fact that local zoning committee members rarely have training in how to facilitate meetings. Things often go from bad to worse as a shouting match ensues and mob rule takes over. If this happens, calmly suggest that the meeting be continued when an outside neutral facilitator can preside over the hearing. Do this carefully so that you do not make the zoning committee look bad in public. Make it clear, however, that "mob rule" is not in anyone's best interest and is not acceptable. At the zoning hearing, it is imperative that you immediately respond to all wild claims or accusations based on hearsay about wind generators to clear up any misconceptions. Instant rebuttal is critical if you are to keep unfounded fears from becoming perceived truth. You control the flow of information. Don't let things get out of hand. Wild claims and hearsay should be identified as what they are. Make it clear that the burden of proof for the validity of such claims is on the accuser and not on you. One thing you can do is to have individual fact sheets ready to distribute about issues that may be raised. These can include such topics as property values, noise, bird kills, lightning, TV reception, or any other topic of concern that arises during your pre-application PR campaign. Long involved articles will probably not get read. A few paragraphs on a page by an independent authority are sufficient. Also, point out the difference between your authoritative articles and any popular press "Readers' Digest" type of articles brought in by opponents. If an important question comes up that you do not have the answer to or any documentation for, ask that the meeting be continued if it looks like approval hinges on that point.

If need be, get someone to the meeting to support your position. For example, a cell phone technician can attest to the fact that towers do not cause TV or radio interference. Agricultural agents and university extension specialists can also be helpful independent "experts." Address delaying tactics by opponents by suggesting "homework" responsibilities with due dates for yourself or the zoning committee members. This will keep the process moving. In the meantime, you can lobby committee members by discussing any apprehensions they might have about your project. These discussions will also give you an idea of what additional information you may need to provide the zoning committee to help them decide in your favor.

Protecting Your Right

Anyone who has tried to get a building permit to install a residential wind system knows what a hassle this ordeal can be given the wrong chemistry of neighbors with a NIMBY (not-in-my-back-yard) mentality, unsubstantiated rumor about wind energy from anti-wind-farm Web sites, or a jittery zoning committee who has never seen a residential wind system. Fortunately, there is something that you can do.

In Wisconsin, where I live, we have a state statute that limits a zoning authority's ability to put undue requirements and burdens on anyone seeking a building permit for a wind or solar energy system. While many states have solar access laws, my understanding is that Wisconsin, with State Statute 66.0401, is nearly unique in the country in protecting wind systems as well. It was written and adopted into law, in large part, due to grassroots environmental and renewable energy activists participating in the law-making process.

The relevant Wisconsin State Statute is titled "Regulation relating to solar and wind energy systems." Section 1 simply states:

- (1) Authority to restrict systems limited. No county, city, town or village may place any restriction, either directly or in effect, on the installation or use of a solar energy system (as defined in s.13.48(2)(h)1.g.), or a wind energy system (as defined in s.66.0415 (1)(m)), unless the restriction satisfies one of the following conditions:
 - (a) Serves to preserve or protect public health or safety.
 - (b) Does not significantly increase the cost of the system or significantly decrease its efficiency.
 - (c) Allows for an alternative system of comparable cost and efficiency.

The bracketed statutes refer to the legal definitions of these systems. "s.66.0415 (1)(m)" states that "'Wind energy systems' means equipment that converts and then stores or transfers energy from the wind into usable forms of energy." While all of this seems like very simple language, some background information would help.

Zoning ordinances are usually drafted to protect public health, safety, and general welfare. While public health and safety considerations are included in the Wisconsin statute, general welfare was specifically excluded. It should be fairly obvious what a public health or safety issue is, but this may not necessarily be so with general welfare. In practice, "general welfare" can include just about anything imaginable that a neighbor could claim, including that it would decrease property values, impede orderly development of the area, wouldn't fit in the neighborhood based on aesthetics. The neighbor could simply, claim, "I don't want to look at it."

In the U.S., we like to pride ourselves in having a judicial system where you are presumed innocent until proven guilty. Not so with zoning. The interesting thing about zoning in the U.S. is that anyone can stop a building project for virtually any reason if they simply show up to the zoning hearing for that project and complain. The applicant is subsequently saddled with proving that his or her project will not harm the person objecting.

An explanation of the conditions laid out in s.66.0401 will help you understand how this statute works. A restriction may be placed on a wind system if it "serves to protect public health or safety." An example might be standard setbacks from property lines, road right-of-ways, or overhead utility lines, just as most zoning ordinances specify with any other type of building project.

Section (b) states that the restriction cannot “significantly increase the cost of the system, or decrease its efficiency.” An analogy might help explain this condition. Let’s say that a farmer wants to build an 80’ silo, but the neighbors complain that they don’t want to see it from their yards. The solution offered to the farmer might be to construct four 20’ silos instead, which will hold as much as the 80’ silo. However, four 20’ silos will be more expensive to construct than the 80’ silo. Because such a suggestion would increase the system’s cost to the wind applicant, it cannot be considered.

In addition, a wind turbine’s output is directly proportional to the cube of the wind speed. As you move above the earth’s surface, wind speed, and subsequently energy output of the turbine, increases significantly. In many areas, a wind turbine on a 120’ tower will produce twice the energy as two turbines on two 60’ towers. So restricting tower height and requiring multiple turbines is a double whammy for wind: it both increases costs and it significantly decreases efficiency, and therefore would not be allowed under the statute.

The final section stipulates that any restriction must “allow for an alternative system of comparable cost and efficiency.” This does not mean that the option of installing photovoltaic (PV) panels on the applicant’s roof, or simply purchasing electricity from the local utility, is a legitimate suggestion by the zoning authority. The applicant is not requesting a building permit for a PV system, or asking for permission to buy utility-generated electricity. The applicant is seeking to install a wind system, so any alternative system must address a wind system. This section is interpreted as allowing the zoning committee to move the wind turbine from one site on the applicant’s property, say from right next to a neighbor’s house, to another place on the property, farther away from the affected house.

The footnote to 66.0401 states: “This section is a legislative restriction on the ability of municipalities to regulate solar and wind energy systems. The statute is not superceded by...municipal zoning or conditional use powers. A municipality’s consideration of an application for a conditional use permit for a system under this section must be in light of the restrictions placed on local regulation by this section.” This means that the burden of proof that a wind system indeed poses a public health or safety problem is on the municipality, and not on the applicant to disprove. This reverse in responsibility is a significant departure in the way that most zoning permits or other construction projects are dealt with.

Nevada recently passed a law that is very similar to Wisconsin’s in terms of protecting the rights of those who wish to install wind or solar systems. The Nevada Wind Working Group was involved in the drafting and passage of the law.

Similarly, ordinances, statutes, and laws on any manner of environmental energy issues have been championed by state interest groups, and even individuals. Earlier this year, Mike Nelson, a university extension educator in Washington State, saw the fruition of three years of hard work on a renewable-friendly piece of legislation. Mike worked with both houses of the Washington legislature to draft and finally pass the first wind and PV energy “feed-in law” in the U.S. First popularized in Germany, a “feed-in law” essentially pays owners of wind or PV systems a premium for the environmentally benign excess electricity they generate and put onto the utility grid. Mike was even on hand to see the governor sign the bill into law.

The upshot of this is that we all need to take charge of policy issues that we are passionate about or affect us. If you are having problems with the local zoning committee giving you a hard time about permitting your wind system, don’t complain. Do something to change the situation!

Myth & Fact about Birds & Turbines

Electricity generated from renewable energy resources is an environmentally-preferred alternative to conventionally produced electricity from fossil fuel and nuclear power plants. Many people believe that wind turbines should be part of the solution to a healthier environment, not part of the problem.

Over the past fifteen years, a number of reports have appeared in the popular press about wind turbines killing birds. Some writers have gone so far as to dub wind generators "raptor-matics" and "cuisinarts of the sky". Unfortunately, some of these articles have been used as "evidence" to stop the construction of a wind generator in someone's back yard. The reports of dead birds create a dilemma. Do wind generators really kill birds? If so, how serious is the problem? A confused public oftentimes does not know what to believe. Many people participate in the U.S.'s second largest past time, bird watching. Others are truly concerned about the environment and what they perceive as yet another assault on our fragile ecosystem. Unwittingly, they rally behind the few ill-informed obstructionists who have realized that the perception of bird mortality due to wind turbines is a hot button issue, with the power to bring construction to a halt.

Birds live a tenuous existence. There are any number of things that can cause their individual deaths or collective demise. For example, bird collisions with objects in nature are a rather common occurrence, and young birds are quite clumsy when it comes to landing on a perch after flight. As a result, about 30% of total first-year bird deaths are attributed to natural collisions. By far, the largest causes of mortality among birds include loss of habitat due to human infringement, environmental despoliation, and collisions with man-made objects. Since wind turbines fall into the last category, it is worthwhile to examine other human causes of avian deaths and compare these to mortality from wind turbines.

Death by....

Utility transmission and distribution lines, the backbone of our electrical power system, are responsible for 130 to 174 million bird deaths a year in the U.S. Many of the affected birds are those with large wingspans, including raptors and waterfowl. While attempting to land on power lines and poles, birds are sometimes electrocuted when their wings span between two hot wires. Many other birds are killed as their flight paths intersect the power lines strung between poles and towers. One report states that: "for some types of birds, power line collisions appear to be a significant source of mortality."

Collisions with automobiles and trucks result in the deaths of between 60 and 80 million birds annually in the U.S. As more vehicles share the roadway, and our automotive society becomes more pervasive, these numbers will only increase. Our dependence on oil has taken its toll on birds too. Even the relatively high incidence of bird kills at Altamont Pass (about 92 per year) pales in comparison to the number of birds killed from the Exxon Valdez oil spill in Alaska. In fact, according to author Paul Gipe, the Altamont Pass wind farm would have to operate for 500 to 1000 years to "achieve" the same mortality level as the Exxon Valdez event in 1989.

Tall building and residential house windows also claim their share of birds. Some of the five million tall buildings in U.S. cities have been documented as being a chronic mortality problem for migrating birds. There are more than 100 million houses in the U.S. House windows are more of a problem for birds in rural areas than in cities or towns. While there are no required ongoing studies of bird mortality due to buildings or house windows, the best estimates put the toll due collisions with these structures at between 100 million and a staggering 1 billion deaths annually. Lighted communication towers turn out to be one of the more serious problems for birds, especially for migratory species that fly at night. One study began its conclusion with, "It is apparent from the analysis of the data that significant numbers of birds are dying in collisions with communications towers, their guy wires, and related structures." Another report states, "The main

environmental problem we are watching out for with telecommunication towers are the deaths of birds and bats."

This is not news, as bird collisions with lighted television and radio towers have been documented for over 50 years. Some towers are responsible for very high episodic fatalities. One television transmitter tower in Eau Claire, WI, was responsible for the deaths of over 1,000 birds on each of 24 consecutive nights. A "record 30,000 birds were estimated killed on one night" at this same tower. In Kansas, 10,000 birds were killed in one night by a telecommunications tower. Numerous large bird kills, while not as dramatic as the examples cited above, continue to occur across the country at telecommunication tower sites. The number of telecommunication towers in the U.S. currently exceeds 77,000, and this number could easily double by 2010. The rush to construction is being driven mainly by our use of cell phones, and to a lesser extent by the impending switch to digital television and radio. Current mortality estimates due to telecommunication towers are 40 to 50 million birds per year. The proliferation of these towers in the near future will only exacerbate this situation. Agricultural pesticides are "conservatively estimated" to directly kill 67 million birds per year.

These numbers do not account for avian mortality associated with other pesticide applications, such as on golf courses. Nor do they take into consideration secondary losses due to pesticide use as these toxic chemicals travel up the food chain. This includes poisoning due to birds ingesting sprayed insects, the intended target of the pesticides.

Cats, both feral and housecats, also take their toll on birds. A Wisconsin Department of Natural Resources (DNR) report states that, "recent research suggests that rural free ranging domestic cats in Wisconsin may be killing between 8 and 217 million birds each year. The most reasonable estimates indicate that 39 million birds are killed in the state each year."

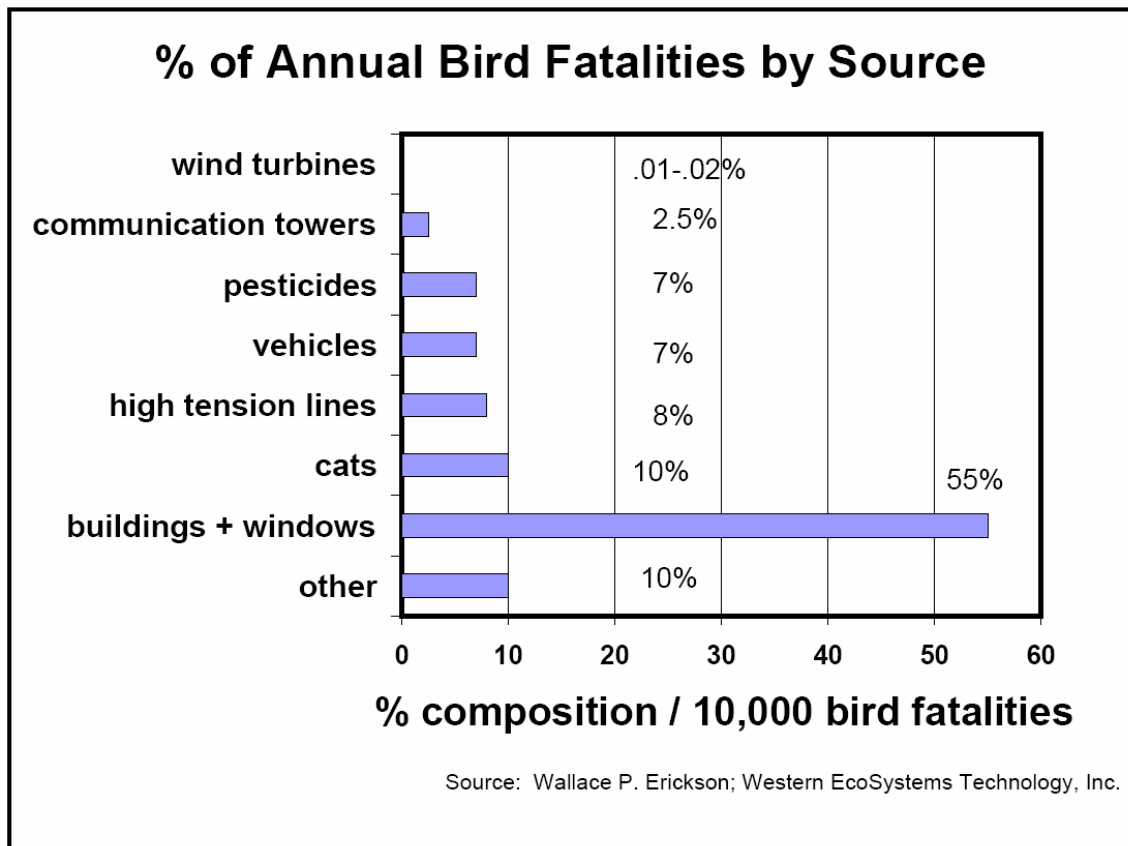
There are other studies on the impacts of jet engines, smoke stacks, bridges, and any number of other human structures and activities that threaten birds on a daily basis. Together, human infrastructure and industrial activities are responsible for one to four million bird deaths per day!

But what about wind turbines?

Commercial wind turbines Since the mid-1980's, a number of research organizations, universities, and consultants have conducted studies on avian mortality due to wind turbines. In the U.S., these studies were prompted because of the relatively high number of raptors that were found dead at the Altamont Pass Wind Farms near San Francisco. After dozens of studies spanning nearly two decades, we now know that the Altamont Pass situation is unusual in the U.S. The high raptor mortality there was the result of a convergence of factors, some of which were due to the bad siting in the local ecosystem while others were due to the wind turbine and tower technology used at the time. In fact, a very different situation exists not far away at the San Geronio Pass Wind Farms near Palm Springs. A 1986 study found that 69 million birds flew through the San Geronio Pass during the Spring and Fall migrations. During both migrating seasons, only 38 dead birds were found during that typical year, representing only 0.00006% of the migrating population.

A report recently prepared for the Bonneville Power Administration in the Northwest U.S. states that "raptor mortality has been absent to very low at all newer generation wind plants studied in the U.S. This and other information regarding wind turbine design and wind plant/wind turbine siting strongly suggests that the level of raptor mortality observed at Altamont Pass is quite unique."

The National Wind Coordinating Committee (NWCC) completed a comparison of wind farm avian mortality with bird mortality caused by other man-made structures in the U.S. The NWCC did not conduct its own study, but analyzed all of the research done to date on various causes of avian mortality, including commercial wind farm turbines. They report that "data collected outside California indicate an average of 1.83 avian fatalities per turbine (for all species combined), and 0.006 raptor fatalities per turbine per year. Based on current projections of 3,500 operational wind turbines in the US by the end of 2001, excluding California, the total annual mortality was estimated at approximately 6,400 bird fatalities per year for all species combined."



The environmental Benefits of Your Wind System

Popular press articles and Web sites about the greenhouse gas emissions of various electrical generating technologies or electrical use by appliances often leave readers confused. Many such pieces are written by authors with either a paid or vested interest in getting a particular view across to the public. Other writers attempt to discredit those whom they see as the opposition—whether they are pro- or anti- on the subject of global climate change. Different sources cite wildly diverse numbers for the amount of carbon dioxide (CO₂) produced by a given coal-fired power plant. Who can you believe?

The first thing to realize is that there are no absolutes in figuring out how much greenhouse gas your household 'generates' while consuming a given quantity of electricity. This is 'fuzzy mathematics' at its worst, as there are so many variables involved. Keep in mind, that the case laid out below is quite conservative in estimating your CO₂ footprint.

Electricity can be produced by your utility from any combination of nuclear, natural gas, petroleum (although infrequently), coal, and refuse derived fuel, plus an array of renewables including wind, solar, hydro, biomass, methane, and geothermal. Since your utility probably uses a continuously varying mix of these fuels, it's easy to see how determining the greenhouse gas effect of your electricity consumption can get quite muddled. Unfortunately, few writers make any such distinction, using instead a 'national average,' whatever that is.

In addition, there are no standard or set measures for gauging the environmental impacts and greenhouse gas emissions and pollutants of extracting and refining the fuels used to generate electricity. But the process can be simplified.

Let's assume that you have installed a wind turbine to generate all of your own electricity. For the purposes of simplicity, let's also assume that your local utility generates its electricity with 100% coal. (Again, though, keep in mind that depending on the utility and the region, utilities generate their power from a variety sources and varying ratios.) If you were to buy power from the utility rather than generate it yourself, how much pollution would you be responsible for?

Average Coal consumption by Electricity Users

Coal has a heat range of 8,100 to 13,000 British thermal units (Btu) per pound, depending on the quality of the coal being burned. If we take the midpoint, or average, of these two numbers, we get 10,550 Btu. It may become apparent now why there is such a wide range of greenhouse gas claims in news magazines about such emissions, depending upon who wrote the article and which extreme of the 'range' they favor.

The conversion process of burning coal to generate electricity is about 33% efficient when using pulverized coal in a new fluidized bed combustion system with emission scrubbers, a process that definitely can be considered cleaner 'brown' electricity relative to other coal systems. This efficiency estimate takes into account transmission and distribution losses, as well as the inefficiencies of the combustion process. So 33% represents the actual amount of a pound of coal that, once delivered to your utility, actually makes it to the electrical outlets in your house in the form of electricity, on average. It does not address the environmental cost of mining, processing, or transporting the coal to the utility.

If we multiply our average 10,550 Btu by 33%, we find that only 3,517 Btu in our pound of coal are actually converted to electricity and delivered to your home. Since there are 3,413 Btu in a kilowatt-hour (kWh) of electricity, it's pretty safe to say that you are responsible for the burning of roughly one pound of coal for every kilowatt-hour of electricity you purchase from your utility, on average.

The average household in the U.S buys, on average, 900 kWh of electricity per month, roughly every 30 days. If we multiply 30 days times 24 hours, we find that there are 720 hours in a month. The average household, therefore, is responsible for consuming 1.25 pounds of coal per hour (900 kWh = 900 pounds divided by 720 hours). (Note: your mileage may vary, as we are assuming an 'average' house here. Check your utility bill for the past 12 months for your actual kilowatt-hour usage.) There are 8,760 hours in a year, so if we multiply 1.25 pounds by 8,760, we find that the 'average' house using 100% coal-generated electricity is responsible for the burning of 10,950 pounds of coal for the electricity they consume per year. That's nearly 5.5 tons!

Greenhouse Gas and other Emissions Due to Burning Coal

Now, what about greenhouse gas emissions? The same problem of 'range' exists, depending on the quality of coal your utility burns to generate electricity. The burning of a pound of coal releases between 1.75 to 2.24 pounds of CO₂, a primary culprit behind global warming. The midpoint for this range is 2.0 pounds and is what most people use to determine CO₂ generation. It is safe to say that you are responsible for producing about two pounds of CO₂ for every kilowatt-hour of electricity you buy from your utility.

Multiplying two pounds of CO₂ by the calculated average (from above) of 10,950 pounds of coal consumed per year reveals that you are responsible for 21,900 pounds, or nearly 11 tons, of CO₂ released into the atmosphere every year that you consume the 'average' amount of coal-generated electricity.

CO₂ isn't the only kind of emission produced by coal plants. Nitrogen oxide (NO_x) and sulfur dioxide (SO₂) are two byproducts of the coal-to-electricity conversion process. NO_x is a key component of smog, while SO₂ combines with atmospheric water vapor to form acid rain. Burning a pound of coal results in the release of about .01 pounds of NO_x and about .0086 pound of SO₂ (again, these are the averages of a range). If we multiply these numbers by the 'average' consumption of 10,950 pounds of coal per year, the average annual release of NO_x is 109.5 pounds and 94 pounds of SO₂.

In addition to greenhouse gases, burning coal to generate electricity has many other negative impacts on our lives as well. For example, in Wisconsin where I live, we have thousands of small-to medium-sized lakes that draw millions of tourists annually. Every single one of these lakes has a mercury advisory posted on them, including our two largest lakes, Lake Superior and Lake Michigan. In fact, nearly half of the mercury in the bodies of Wisconsin residents comes directly from the burning of coal to generate electricity for the state.

The bottom line:

Remember, it takes about 1 pound of coal to generate a kilowatt-hour of electricity. Curious as to what a pound of coal might look like? Make a fist—a pound of good, hard coal is about the size of one and a half of your fists (an average fist). That, by the way, will light a 100-watt incandescent light bulb for a mere 10 hours. That's all. Or a 25-watt equivalent compact florescent light bulb for 40 hours.

Remember, added up, the 'average' house using 100% coal-generated electricity consumes about 5.5 tons of coal per year in the form of electricity. A railroad coal car holds about 60 tons of coal, meaning that the 'average' house consumes one rail car of coal in just under 11 years.

So, if you generate your own electricity rather than purchase it from a utility that generates electricity from 100% coal, what are you doing for the environment? Plenty! If you use the 'average' of 900 kWh per month, you are preventing the release of 21,900 pounds, or nearly 11 tons, of CO₂, 109.5 pounds of NO_x, and 94 pounds of SO₂. On average. Oh, and don't forget mercury.

Code Compliance

There are a variety of different "codes" that come into play when a homeowner applies for a building permit for a residential wind turbine. While some of the codes are universal, others are required only in specific states or even locations. A review of the possible codes that may exist in your area will help you better prepare your building permit application.

1. The Federal Aviation Administration (FAA) becomes a consideration only if a tower is taller than 200 feet or within 3 3/4 miles of a commercial runway. If such is the case, form 7460 must be submitted to the FAA, from which they will make a determination as to whether there will be any restrictions placed on the tower or its location.

2. The National Electric Code (NEC) applies to all wiring and associated hardware that is part of a home wind installation. Some locales require an electrical permit for the installation of a residential wind turbine, while other areas do not. Check with your local zoning officials about their particular requirements. If an electrical permit is required, an electrical inspector will likely visit the installation to inspect and approve of the system before it is allowed to generate. You may need to inform your local zoning authority of the successful inspection. If an electrical permit and inspection are not required, it is still a good idea to make sure that you follow all NEC rules as they apply to your system. The NEC is in place to protect against shocks and fires caused by electricity. If you ever have a problem that involves an insurance claim, and the system was not code compliant when it was installed, it is possible that your insurance company could refuse to honor your claim.

3. Regardless of whether an electrical permit and inspection are required, if you are installing a system that is interconnected with the grid, your local utility may wish to inspect your wind system. It, too, will be looking at whether the system is NEC compliant. Quite often, the utility will require that you submit a one-line diagram of the system designating all electrical components. Such a diagram might also be submitted to the zoning authority to help them understand what you are up to.

4. Also with a utility-intertied wind system, the utility will likely require that you fill out an application for its review, detailing equipment and system specifics. Upon its review and possible inspection, it will sign an interconnection agreement with you before you are allowed to operate the system on its grid. Those four requirements are essentially out of the control of the local zoning authority, as the FAA, NEC, and local utility regulations supercede those of a local zoning authority in granting building permits. However, your local zoning officials may require that they are adhered to as conditions for obtaining a building permit. If the FAA is not an issue regarding proximity to a runway (residential wind turbines never reach 200 feet in height), and no electrical permit and inspection is required, there should be no need for the local zoning authority to require these specifically for a residential wind system. Your wind turbine should be treated just like any other construction application. Local building code compliance rarely covers construction projects like towers. So, there may be some confusion about what needs to be provided to the local zoning authority. However, several documents should be provided to help zoning officials understand your wind turbine project and what it entails.

1. A plot plan of your property indicating the location of any structures on your property, including the proposed location of the tower, should be drawn up and offered to the zoning authority. It is always helpful to include distances of the tower to structures on your property as well as to property lines as well as any roads or overhead utility lines. A simple diagram should be sufficient for the zoning officials to understanding what you are requesting.

2. It is always helpful – even when not required – to submit drawings or blueprints of the tower and the tower footings when requesting a building permit for a wind system. While tower foundations differ considerably from building foundations, a good, detailed blueprint will go a long way toward assuring zoning officials that your project is well thought out.

3. Even though the tower blueprint may not directly state such, you can assure the zoning officials that any commercially available tower conforms to the requirements set down by the Uniform Building Code. Otherwise, it would not be commercially available.

4. In rare cases, I have seen zoning authorities require an engineering analysis of a tower and its foundation. Even rarer, a "wet stamp" is required, meaning a state certified structural engineer has approved the tower and foundation by muddling through all of the engineering calculations for the structure. Such an engineering analysis can easily cost thousands of dollars. This is a ridiculous requirement, since any company selling towers for wind systems will have gone through the engineering just to be in business and to secure liability insurance. My experience with such requirements indicates that the zoning authority is throwing very expensive hurdles in the applicant's way, essentially to make him or her go away. This is inappropriate, to say the least, especially if such requirements are applied selectively and not across the board to all similar construction projects. If such a requirement is placed on your application, I'd suggest that you offer instead to locate the tower a distance away from any property line equal to its height. Sited that way, a failed tower will only affect your property and not your neighbor's.

5. Another rare requirement is that a licensed wind system contractor or installer must install your wind system. No such system of licensing or certifying wind installers is in place anywhere in the U.S. at this time. Unfortunately, no one can meet this requirement.

Wisconsin Law:

66.0401 Regulation relating to solar and wind energy

systems. (1) AUTHORITY TO RESTRICT SYSTEMS LIMITED. No county, city, town, or village may place any restriction, either directly or in effect, on the installation or use of a solar energy system, as defined in s. 13.48 (2) (h) 1. g., or a wind energy system, as defined in s. 66.0403 (1) (m), unless the restriction satisfies one of the following conditions:

- (a) Serves to preserve or protect the public health or safety.
- (b) Does not significantly increase the cost of the system or significantly decrease its efficiency.
- (c) Allows for an alternative system of comparable cost and efficiency.

(2) AUTHORITY TO REQUIRE TRIMMING OF BLOCKING VEGETATION.

A county, city, village, or town may provide by ordinance for the trimming of vegetation that blocks solar energy, as defined in s. 66.0403 (1) (k), from a collector surface, as defined under s. 700.41 (2) (b), or that blocks wind from a wind energy system, as defined in s. 66.0403 (1) (m). The ordinance may include, but is not limited to, a designation of responsibility for the costs of the trimming. The ordinance may not require the trimming of vegetation that was planted by the owner or occupant of the property on which the vegetation is located before the installation of the solar or wind energy system.

History: 1981 c. 354; 1981 c. 391 s. 210; 1993 a. 414; 1999 a. 150 ss. 78, 79, 84; Stats. 1999 s. 66.0401; 2001 a. 30.

This section is a legislative restriction on the ability of municipalities to regulate solar and wind energy systems. The statute is not superceded by s. 66.0403 or municipal zoning or conditional use powers. A municipality's consideration of an application for a conditional use permit for a system under this section must be in light of the restrictions placed on local regulation by this section. State ex rel. Numrich v. City of Mequon Board of Zoning Appeals, 2001 WI App 88, 242 Wis. 2d 677, 626 N.W.2d 366, 00-1643.

66.0403 Solar and wind access permits. (1) DEFINITIONS.

In this section:

- (a) "Agency" means the governing body of a municipality which has provided for granting a permit or the agency which the governing body of a municipality creates or designates under sub. (2).
- (2). "Agency" includes an officer or employee of the municipality.
- (b) "Applicant" means an owner applying for a permit under this section.
- (c) "Application" means an application for a permit under this section.
- (d) "Collector surface" means any part of a solar collector that absorbs solar energy for use in the collector's energy transformation process. "Collector surface" does not include frames, supports and mounting hardware.
- (e) "Collector use period" means 9 a.m. to 3 p.m. standard time daily.
- (f) "Impermissible interference" means the blockage of wind from a wind energy system or solar energy from a collector surface or proposed collector surface for which a permit has been granted under this section during a collector use period if such blockage is by any structure or vegetation on property, an owner of which was notified under sub. (3) (b). "Impermissible interference" does not include:
 - 1. Blockage by a narrow protrusion, including but not limited to a pole or wire, which does not substantially interfere with absorption of solar energy by a solar collector or does not substantially block wind from a wind energy system.

2. Blockage by any structure constructed, under construction or for which a building permit has been applied for before the date the last notice is mailed or delivered under sub. (3) (b).

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