CHAPTER 1

# Introduction to Small-scale Wind Energy

Humans have harvested energy from the wind for centuries. Prior to the advent of steam-powered ships, for example, Phoenicians, Europeans, and others relied on the wind to propel magnificent sailing vessels across a largely uncharted planet. Ships then became an important mode of transport for raw materials and finished products to and from Europe.

Our predecessors also used wind to assist in food production and to manufacture goods. The windmills of Europe, for example, which were in place 800 to 900 years ago, were used to grind grain into flour to feed Europe's masses. The Dutch used wind to pump water from coastal wetlands, so they could be converted to farmland to grow food.

Wind energy has a long history in North America, too, stretching into the late 1800s. During this period, windmills on tens of thousands of farms in the Great Plains of North America pumped water for livestock, gardens, and humans. Without them, many farmers would not have been able to provide sufficient water for their cattle and sheep.

In the 1890s, more than 100 manufacturers were producing water-pumping windmills in the United States, notes small-wind expert Jim Green of the National Renewable Energy Laboratory (NREL). Both wind-electric generators and water-pumping windmills were extremely popular among farmers and ranchers. According to the NREL, over 8 million mechanical windmills (water pumpers) were installed in rural America, beginning in the 1860s (Figure 1.1). Many of these water-pumping windmills have been restored and are

### Windmill vs. Wind Turbine

A windmill is a piece of equipment that drives a mechanical device such as a water pump or a grindstone. A wind turbine drives an electrical generator.

still operating today, providing many more years of reliable service with minimal maintenance.

Although history books make little mention of it, in the 1920s through the early 1950s many Plains farmers also installed small wind turbines to generate electricity. These electricity-generating wind turbines made life on the Great Plains more bearable. Homegrown electricity was used to power lights and a few modern conveniences, among them electric toasters, washing machines, and radios—all ordered from the Sears catalog. The radio was highly coveted as a way of keeping in touch with the world; Sears customers who purchased a radio were given a discount on a wind generator.


**FIGURE 1.1.** Water-pumping windmills like this one, photographed by Dan on a commercial wind farm in southeastern Colorado, were once common through the West and Midwest. The technology is so good that it hasn't changed in 100 years. Credit: Dan Chiras.

Wind energy was not only vital to farmers, it was extremely important to railroads. Windmills were often used to fill water tanks along tracks to supply the steam engines of early locomotives.

Unfortunately, the use of water-pumping windmills and wind-powered electric generators began to decline in the United States in the late 1930s. The demise of these technologies was due in large part to America's ambitious Rural Electrification Program.

This program, which began in 1937, was designed to provide electricity to rural America. As electric service became available, wind-electric generators were mothballed. In fact, local power companies required farmers to dismantle their wind generators as a condition to their provision of service via the ever-growing electrical grid. The electrical grid, typically simply referred to as *the grid*, is the extensive network of electrical transmission lines that crisscross our nation, delivering electricity generated by centralized power plants to cities, towns, and rural customers. Initially, a key advantage of the grid was its ability to provide virtually unlimited amounts of electricity to those who had the wherewithal to pay for it. The grid also made it possible to power large motors, something that wind/battery systems were unable to do.

Although farmers' lives improved as a result of rural electrification, once-profitable manufacturers of wind-electric generators were driven out of business by the early 1950s. In the mid 1970s, however, wind energy made a resurgence as a result of intense interest in energy self-sufficiency in the United States and elsewhere. This new-found interest in self-reliance was stimulated principally by back-to-back oil crises in the 1970s that resulted in skyrocketing oil prices and a period of crippling inflation in the United States. Generous federal incentives for small wind turbines (a 40 percent US federal tax credit), equally charitable incentives from some state governments, and changes in US law that required utilities to buy excess electricity from small renewable energy generators helped spark the comeback. From 1978 to 1985, 4,500 small utility-connected residential wind turbines were installed, according to Mike Bergey, whose company Bergey WindPower manufactures small wind turbines. In addition, approximately 1,000 wind turbines were installed in remote locations not connected to the electrical grid.

In short order, however, wind energy's resurgence died, falling victim to economic forces beyond its control. Energy-efficiency measures in the United States and new, more reliable sources of oil from Great Britain, Russia, and other countries, drove the price of energy downward. These factors, combined with the


**FIGURE 1.2.** Mick Sagrillo, seen here perched on a lattice tower, has been in the small wind industry since 1981. He has served as a mentor and advisor to me on this project, for which I am most grateful. Credit: Dan Chiras.

end of federal and state renewable energy tax incentives and a dramatic shift in the political climate away from renewable energy in the early 1980s, resulted in a precipitous decline in America's concern for energy independence. As a result of these changes, most of the fledgling wind manufacturers went out of business. In fact, six years after the end of the tax credits, virtually all of the 80 or so wind generator companies doing business in the United States disappeared, according to Mick Sagrillo, a small-wind-energy expert who served as a technical advisor for the first edition of this book.

In the 1990s, commercial and residential wind energy made another comeback. This rise in the popularity of wind and other renewable energy resources was spurred by a concern over rising energy prices, declining fossil fuel resources, and growing evidence of global climate change and its many social, economic, and environmental impacts.

Much to the delight of renewable energy advocates, large commercially operated wind farms are popping up on land and in the sea in numerous countries, most notably the United States, Germany, Spain, Denmark, and, more recently, China. Commercial wind farms generate huge amounts of electricity and have significantly changed the way we meet our energy needs. In fact, wind-generated electricity is currently the fastest growing source of energy in the world (Figure 1.3). The United States is a leader in wind energy production. According to the American Wind Energy Association (AWEA), in 2015 there were nearly 1,000 utility-scale wind projects—large wind farms—and over 48,800 large commercial wind turbines installed in 40 US states plus Puerto Rico and Guam. Moreover, there were "more than 500 wind manufacturing facilities spread across 43 states." The United States now generates over 13 percent of its electricity from renewables with over one-third of that electricity coming from large commercial wind farms. Several states lead the way.

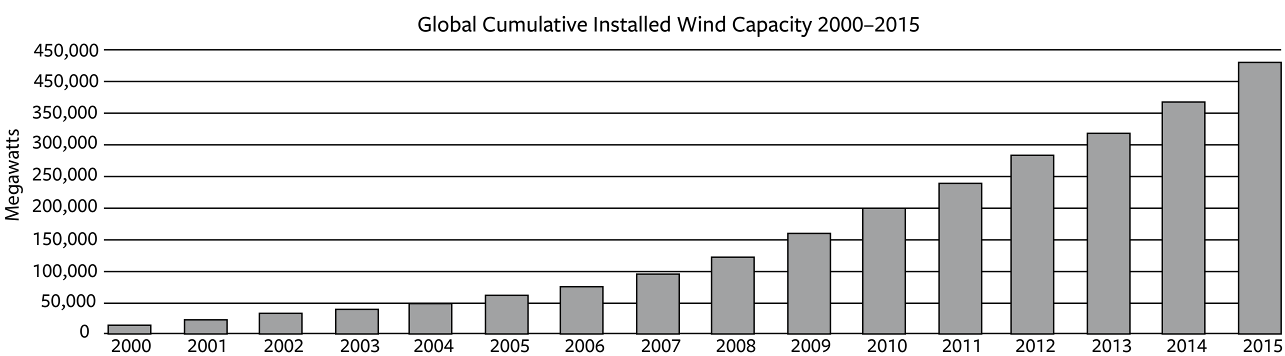


**FIGURE 1.3.** This graph shows the installed global capacity (in megawatts) of commercial wind turbines. Notice the dramatic increase since 2000. Credit: American Wind Energy Association.

## Rated Power and Capacity

Wind turbines are commonly described in terms of rated power, also known as rated output or rated capacity. Rated power is the instantaneous output of the turbine (measured in watts) at a certain (rated) wind speed and at a standard temperature and altitude.

To understand what this means, let's first explore *watts*. Most of us are familiar with the electrical term watts because we've purchased light bulbs and a host of other devices like hair dryers and microwaves that are rated by their wattage.

Watts is a measure of instantaneous power consumption by an electrical device, known as a *load*. The more watts a device consumes, the more energy it consumes, and the more it costs you to operate it.

Watts can also be used to describe the output of electricity-generating devices such as wind turbines, solar modules, and conventional power plants. A wind turbine, for instance, might produce 3,000 watts under moderate winds, but 10,000 watts under winds of 25 miles per hour (about 11 meters per second).

Small wind turbines, the subject of this book, have a rated power of 1,000 to 100,000 watts. Because 1,000 watts is one kilowatt (kW), small wind falls in the range of 1 to 100 kilowatts. Large wind turbines include all of those turbines over 100 kilowatts. Most larger turbines in operation today are 1 megawatt and larger turbines—typically around 1.5 megawatts. A megawatt is a million watts or 1,000 kilowatts. (By the way, a 1.5 megawatt wind turbine can produce enough electricity for 300 to 900 homes, depending on the average wind speed at the site and homeowner energy consumption.)

While rated power has been used to categorize wind turbines for many years, it is one of the least useful and most misleading of all parameters by which one should judge a wind generator's performance. That's because for many years manufacturers rated their turbines at different wind speeds. One manufacturer might rate its wind turbine at 27 miles per hour (12 m/s); another might rate his turbine at 25 miles per hour (11.2 m/s). This made it extremely difficult to compare one turbine to another.

Thanks to the efforts of numerous small wind energy advocates, the industry has recently begun to standardize wind turbine rated output—measuring them all at 11 meters per second (24.6 miles per hour). This makes it much easier to compare one wind turbine to the next.

As you study wind energy and other energy systems, you'll commonly hear experts talk about the "capacity" of a wind turbine. A 20-kW wind turbine, for instance, will produce 20,000 watts, but only at its rated wind speed of 11 m/s. (However, winds at that speed aren't a very common occurrence.) You will also hear talk about things like 300-megawatt wind farms. The capacity of a wind turbine is calculated by multiplying the rated output of each wind turbine by the number of turbines. Two hundred 1.5 megawatt commercial wind turbines would produce a 300-megawatt wind farm. Bear in mind, however, that a wind farm of this size would not produce 300 million watts of electricity at all times. It would only do so when all the wind turbines were operating at their rated wind speed—usually in the mid 20 mile-per-hour range.

That said, capacity is still a handy number to know. For example, many people ask me: "What size wind turbine will I need to power my home?" I tell them that most homes can be powered with wind turbines in the 10 to 20 kW range. That's the approximate turbine size a homeowner needs. Of course, it's more complicated than that, but this gives you a good idea of the range you might require. (More on this topic in Chapter 4.)

Iowa, for instance, in 2015, generated over 30 percent of its electricity from large commercial wind farms. Kansas and South Dakota generated more than 20 percent of their electricity from wind.

Although commercial wind farms are responsible for nearly all of the growth in the wind industry, smaller residential-scale wind turbines have also been popping up in rural parts of America and other countries, supplying electricity to homes, small businesses, farms, ranches, and schools (Figure 1.4). Even a few large businesses have installed small wind turbines (under 100 kilowatts) to power their facilities. Most of the small-scale wind turbines in the United States “feed” the excess electricity they produce back onto the electrical grid. However, most of the small wind turbines produced worldwide are manufactured for off-grid applications. In Canada, for instance, many small wind energy systems power remote off-grid homes in the isolated northern reaches of the country.

**FIGURE 1.4.** Small Wind Turbine on Tower. This ARE442 wind turbine installed at Mick’s house during a workshop is mounted on a guyed lattice tower. Maintenance is performed by climbing the tower. The ARE442 is now manufactured and sold by a company called Xzeres. The turbine is called the Xzeres 442SR. Credit: Dan Chiras.

Ranchers and farmers sometimes use wind turbines to supply power to electric fences, stock watering tanks, and remote lighting—that is, small dedicated loads to which it is not cost effective to run a power line. (A load is any device that consumes electricity.) I’ve seen small wind turbines used to power park facilities in remote locations in Alaska. Many sailboats are equipped with very small wind turbines (under 1,000 watts—typically referred to as *microturbines*) to power lights, fans, and refrigerators (Figure 1.5).

Wind energy is being tapped to power remote villages in less developed countries, where the cost of stringing power lines from centralized power plants is prohibitive. Wind energy has even found a home in remote sites in some developed countries. In France, for instance, the government paid for the installation of wind turbines and solar-electric systems on farms at the base of the Pyrenees—rather than running electric lines to these remote sites. Reportedly, tens of thousands of nomads in Mongolia own tiny wind generators that provide electricity to their yurts to power lights and, get this, small televisions. When a family moves every few weeks in search of new pasture for their livestock, their small, durable wind generators are packed


**FIGURE 1.5.** Wind Turbine on Sailboats. (*a*) Microturbines, such as the one shown here by Marlec, are frequently used on sailboats to charge batteries that supply electricity for loads such as radios, lights, televisions, and refrigerators. (*b*) Microturbines for marine use are designed to withstand the harsh environment. This one is made by Aerogen. Credit: (*a*) Marlec and (*b*) Dan Chiras.

up and transported on the backs of pack animals. For newlyweds in this part of China, a small wind turbine is a highly coveted gift.

Wind clearly has a long history of service to humankind, and it is on the rise. Proponents say it could become a major source of electricity in years to come.

## World Wind Energy Resources

Although wind energy's popularity is at an all-time high and continues to grow yearly, what is its potential? Can wind become a major source of energy in the future?

Wind is a ubiquitous resource. Although not evenly distributed throughout the world, significant resources are found on every continent. Globally, wind resources are phenomenal. Tapping into the world's windiest locations could theoretically provide 13 times more electricity than what is currently produced worldwide, according to the Worldwatch Institute, a Washington, DC-based nonprofit organization that's played a huge role in creating a sustainable future.

In North America, wind is abundant much of the year in the Great Plains and in many northern states. It is also a year-round source of energy along the Pacific and Atlantic Oceans and the shores of the Great Lakes. Tapping into a couple of the windiest locations in the United States—for example, the states of North and South Dakota—could produce enough electricity to supply *all* of the nation's electrical needs. Proponents of wind energy, like the Worldwatch Institute, estimate that wind energy could provide 20 to 30 percent of the electricity consumed in many countries. Others believe that wind could provide an even larger percentage.

Could wind provide 100 percent of the world's electrical energy needs?

Yes, it could, theoretically…*if* we had more efficient ways of storing and then transferring electricity onto an electrical grid.

Will it?

Probably not.

Other sources of renewable and nonrenewable energy will also come into play. As Ian Woofenden, wind energy expert, author, and technical advisor to the first edition of this book points out: "The 'Can wind do it all?' question is a bit of a red herring. Wind is one piece in the puzzle; nothing is the whole answer." In the future, electrical production will no doubt be provided by a number of renewable energy sources. Wind will very likely play a huge role in many parts of the world, but large commercial solar-electric facilities and solar-electric systems on homes and commercial buildings will also produce a significant amount of electricity.

The potential of the Sun, like that of the wind, is nothing short of phenomenal. It's estimated, for instance, that the sunlight striking an area the size of the state of

Connecticut could meet all of the United States' (inefficient and wasteful) electrical demand. Although no one is proposing the construction of such large solar-electric arrays, solar-electric modules on homes, office buildings, schools, and commercial solar-electric facilities in the best locations could provide an enormous amount of electricity, greatly supplementing wind energy production (Figure 1.6).

Geothermal and biomass resources could contribute their share as well. Biomass resources refer to plant matter such as wood chips that can be burned directly to produce heat to generate steam to make electricity. Plant matter such as corn can also be converted into gaseous or liquid fuels that can be burned to create electricity. Animal wastes can also be used to generate methane, the main component of natural gas.

Hydropower will continue to do its part in the future, and lest we forget, conventional fuels such as oil, natural gas, coal (burned as cleanly as possible), and nuclear energy will also be part of the mix for many years to come. I suspect they will gradually transition into being sources of backup power, supplementing renewables.

Renewable energy, including wind, is here to stay and will likely contribute even more energy to power our future. It has to for the simple reason that fossil fuels are limited. Oil could be economically depleted within 30 to 50 years. Production

**FIGURE 1.6.** Solar Array. In a renewable energy economy, large-scale solar-electric installations, like the one at Nellis Air Force Base in Nevada shown here, will supplement electricity produced by other renewable resources, including wind, hydropower, and biomass, as well as conventional fuel sources. Credit: David Amster.

rates worldwide are on the decline now. Natural gas production could also peak in the not-too-distant future. The Sun, however, which powers solar energy systems and creates winds that can be tapped by wind turbines, is going to be around for at least another five billion years.

## The Pros and Cons of Wind Energy

Wind is a seemingly ideal fuel source that could ease many of the world's most pressing problems. Like all energy sources, wind power has its advantages and disadvantages. Let's look at its downsides first.

### *Disadvantages of Wind Energy*

As you read the downsides of wind energy, you'll discover that many of them pertain to large commercial wind projects. These concerns, in turn, often trickle down unfairly to small wind—the kind of system you are no doubt contemplating. You'll also see that, while there are legitimate problems with wind energy, many are only *perceived* problems—"problems" that result from misconceptions, ignorance, and, frequently, outright deception on the part of opponents. I'll be sure to point these out as we proceed.

#### Variability and Reliability of the Wind

Perhaps the most significant "problem" with small- and large-scale wind energy is that the wind does not blow 100 percent of the time in most locations. Like solar energy, wind is a variable resource. A wind turbine may operate for four days in a row, then sit idle for the next two days. In most locations, winds are typically strongest in the fall, winter, and early spring, but die down during the summer months.

Wind even varies during the course of a day. Winds may blow in the morning, then die down for a few hours, only to pick up later in the afternoon and blow throughout the night.

Even though wind is a variable resource, it is not unreliable. Just like solar energy, you can count on a certain amount of wind each year. With smart planning and careful design, you can design a wind system to meet some or all of your electrical needs.

Wind is also predictable. With advanced weather forecasting, it's easy to know when it will be windy and when it won't. This allows utilities to integrate wind into their existing system.

Moreover, on a commercial level, wind turbines are most often installed in the windiest locations—places where the winds blow 65 to 85 percent of the time—for

example, along coastlines or in the Plains states in the United States. Residential wind turbines provide the most reliable and economical power when installed in similar locations. Keep that in mind when considering this renewable energy option.

Wind's variable nature can be managed to the benefit of off-grid system owners with the installation of batteries to store surplus electricity. The stored electricity can power a home or office when the winds fail to blow—or when demand exceeds the output of the turbine.

Surplus wind-generated electricity produced by grid-tied systems can also be "stored" on the electrical grid. That is, when a wind-electric system is producing more power than a home or business is using, the excess can be backfed onto the grid. When a wind turbine is not producing at all or is producing less than is required, electricity is drawn from the grid.

On a commercial level, wind energy surpluses generated in one region of a country can be used to offset shortages in another. For example, in Colorado, wind farms in the northern part of the state may be active while wind farms in the southern part of the state are not. Electricity from the former as well as wind farms in neighboring Wyoming could ensure a steady supply of renewable energy to residents. Wind can be integrated into an electric grid supplied by large-scale solar facilities, too. These concepts are illustrated in Figure 1.7.

Wind's variable nature can also be offset by coupling small wind systems with other renewable energy sources, for example, solar-electric systems or micro hydro systems. These are referred to as *hybrid systems*. Solar-electric systems or photovoltaic (PV) systems generate electricity when sunlight strikes solar cells in solar modules. Micro hydro systems tap the energy of flowing water in nearby streams or rivers. They convert this energy into electricity. Hybrid systems can be designed to provide a reliable year-round supply of electricity. As you shall see in Chapter 3, residential wind-generated electricity can also be supplemented by small gas or diesel generators.

As a power source, wind energy is less predictable than solar energy on a day-to-day basis, but it is also typically available for more hours in a given day.

Mike Bergey,
Bergey WindPower

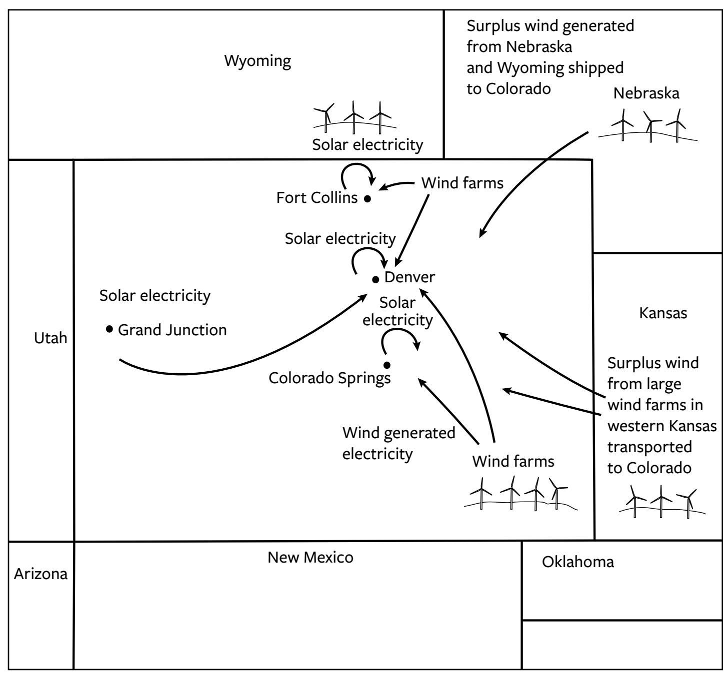


**FIGURE 1.7.** Electricity produced by wind farms and small- and large-scale solar operations can be shipped from areas of surplus to areas in need of energy via the electrical grid, helping create a reliable source of energy throughout a country. Credit: Forrest Chiras.

The topic of wind's presumed unreliability is even raised when comparing different renewable energy systems—for example, when wind is compared to solar electricity. Some individuals mistakenly view solar electricity as a more reliable resource than wind. However, the wind is much more predictable than you'd think. To understand what I mean by this, let's look at *capacity factor*, a measurement used to compare different electrical generating technologies.

Capacity factor is the ratio of the output of a power plant over some period to what its output would have been had it operated at its rated power for the same period. For example, let's suppose you live in an area with an average of five peak hours of sunlight for PV production per day (for example, Kansas City). In this location, the capacity factor for PV would be 5 hours per day divided by 24 hours per day, or about 21 percent.

**FIGURE 1.8.** Ian Woodfenden and His ARE110 (no longer manufactured). Perched on top of this 168-foot tower is wind energy expert, author, and workshop teacher Ian Woofenden, who served as a primary technical advisor on the first edition this book. This extremely tall tower raises the turbine well above the trees that carpet the island where Ian lives, allowing access to the wind and permitting excellent performance. Credit: Shawn Schreiner.

In the lower 48 states, the capacity factor for most PV systems ranges from 8 to 25 percent. According to wind expert Mick Sagrillo, the capacity factor for small wind systems ranges from 10 to 28 percent. So, PV and wind systems are fairly similar.

The capacity factor for wind is higher because wind turbines can work day or night. They can operate on sunny or cloudy days—so long as the wind is blowing. What is more, because wind and sunlight are often available at different times, the two technologies complement each other extremely well. Hybrid systems increase the electrical energy produced at a site and ensure steadier supply of electricity.

### Site Specific

Yet another criticism of wind—often lodged by solar proponents—is that wind energy is more site specific—or restricted—than solar energy.

To understand what this means, let me point out that there are good (sunny) solar areas and good (windy) wind areas. In a good solar region, most people with a good southern exposure can access the same amount of sun. In a windy area, however, hills and valleys or stands of trees can dramatically reduce the amount of wind that blows across a piece of property. Therefore, even if you live in an area with sufficient winds, you may be unable to tap into the wind's generous supply of energy because of topography or vegetation like tall stands of trees. That's what critics mean when they say that wind energy is more site specific.

That said, I'd be remiss if I did not point out that solar resources also vary. If you live in a sunny region but your home is located in a forest, you'll receive less solar energy than a nearby neighbor whose home is in an open field. Note, though, that homeowners can access the wind at less-than-optimum sites by installing turbines on tall towers. Ian Woofenden, for example, installed a turbine at his home which is nestled in a densely forested island in the Pacific Northwest. He made it work by installing the turbine on a 168-foot tower—well above the tops of the trees. Tall towers help us overcome topographical and other barriers. They can also be used to augment or "magnify" the wind. That is, an individual can harvest more wind energy by increasing tower height. As Mick Sagrillo points out in his wind energy workshops, you can't make a location sunnier, but by increasing tower height you can move a turbine into smoother, higher velocity winds to boost its output.

### Bird and Bat Mortality

Another perceived problem that frequently arises in debates over wind energy—particularly large wind energy—is bird and bat mortality. This issue has been blown way out of proportion. Although a bird may occasionally perish in the spinning blades of a residential wind turbine, this is an extremely rare occurrence. Renewable energy expert Ian Woofenden is aware of only one instance of a bird kill, when a hawk flew into a small wind turbine. "Because of their relatively smaller blades and short tower heights, home-sized wind turbines are considered too small and too dispersed to present a threat to birds," notes Mick Sagrillo in his article, "Wind Turbines and Birds" published by Focus on Energy, Wisconsin's energy efficiency and renewable energy program.

The only documented bird mortality of any significance occurs at large commercial-scale wind turbines—but even then, the number of deaths is extremely small. In my view, the argument that wind energy development should be halted because of bird kills is ill-informed; in fact, it is often a ploy used by individuals and organizations that oppose wind energy development. In editorials and public hearings, opponents often use inflammatory language to make their case, calling wind turbines "bird blenders" or "eagle killers." Outlandish numbers of deaths are often attributed to them.

If citizens and governments were serious about bird kills, we'd ban the truly lethal forces discussed in the accompanying textbox: domestic cats, utility transmission towers, cars, pesticides, and windows (Figure 1.9). We'd even prohibit farming, which destroys bird habitat and poisons birds with pesticides.

**FIGURE 1.9.** Cats are the leading cause of bird deaths. Our kitty is perched on top of a bluebird nest box at my home in Evergreen, Colorado. Credit: Linda Stuart.

## Bird Kills from Commercial Wind Farms: Fact or Fiction?

While commercial wind turbines do kill a small number of birds, scientific studies show that the problem has been grossly exaggerated. These studies indicate that bird kills from large commercial wind turbines pale in comparison to deaths from several common sources, among them domestic cats, electric transmission lines, windows, pesticides, motor vehicles, and communication towers (Table 1.1). Worldwide, hundreds of millions of birds—perhaps even billions—are killed each year by these sources. Commercial wind turbines, on the other hand, kill a miniscule number of the birds. So why has wind gotten such a bad reputation?

Wind turbines got a bad rap from one of America's oldest and largest wind farms: the Altamont Pass Wind Farm in California. Located just east of San Francisco, Altamont Pass was once home to a mind-boggling 5,000 wind turbines. It is also the habitat of numerous raptors. Soon after the wind turbines were erected, the birds began to perch on the wind towers in search of prey (ground squirrels and other rodents) that live year-round in the grasses at the base of the towers. Some died as they flew into the blades of the turbines toward prey on the ground.

A two-year study of bird kill in the region revealed only 182 dead birds in that time. While any raptor death is of concern to those of us who cherish wildlife, the death rates at Altamont from wind turbines, while significant locally, are insignificant compared to deaths from other factors.

Cats are probably the most lethal force that birds encounter. According to one study, a feral cat kills as many birds in one week as a large commercial wind turbine does in one to two years. Declawing a cat doesn't seem to help much. According to one researcher, the majority of cats (83 percent) kill birds; even declawed and well-fed cats prey on wild birds. Neutering or spaying a cat does not seem to cut down on hunting, either. With more than 64 million cats in America alone, what's the total loss?

No one knows for sure, but if the situation in Wisconsin is indicative of the national toll, America's bird population is being decimated by our furry feline companions. In Wisconsin alone, researchers estimate that cats kill approximately 39 million birds per year. Nationwide, the number is estimated to be around 270 million, and is very likely much higher. "Even if wind were used to generate 100 percent of US electricity needs, at the current rate of bird kills, wind would account for only one of every 250 human-related bird deaths," which includes kills from our furry friends, the cat, according to the AWEA.

Another 130 to 174 million birds die each year as a result of collisions with or electrocution by electrical transmission lines that crisscross the nation. Many

**Table 1.1. Estimated Annual Bird Death in the United States by Source**

| Activity/Source of Bird Mortality | Estimated Annual Mortality |
|---|---|
| Killed by cats | 270 million or more |
| Collisions with and electrocution by electrical transmission wires | 130–170 million |
| Collisions with windows | 100–900 million |
| Poisoning by pesticides | 67 million |
| Collisions with motor vehicles | 60 million |
| Collisions with communications towers | 40–50 million |

victims are raptors, waterfowl, and other large birds, electrocuted when their wings bridge two live wires.

Another 100 million to 900 million birds perish after flying into windows, mostly in rural areas, according to another report.

Pesticides kill an estimated 67 million birds each year. And, according to the American Wind Energy Association's report "Facts about Wind Energy and Birds," scientists estimate that about 60 million birds die each year in the United States after being struck by motorized vehicles.

Yet another 40 to 50 million birds perish after flying into communications towers and the guy wires that support them. Studies of one television transmitter tower in Eau Claire, Wisconsin, showed that it killed over 1,000 birds a night on 24 consecutive nights. This same tower killed a record 30,000 birds one evening! A similar tower in Kansas killed 10,000 birds in a single evening.

Another 1.25 million die as a result of collision with tall structures such as buildings, smokestacks, and towers.

Clearly, even the Altamont Pass Wind Farm is benign compared to this host of other factors. Altamont is also an isolated case. No other wind farm in the United States experiences mortality rates remotely close to Altamont Pass. Why?

Aware of the problem, contemporary wind site developers conduct bird studies of potential sites and have been selecting sites for new wind farms that are out of migratory pathways. Improvements in the design of commercial wind turbines have also helped to minimize bird kills at commercial wind farms. Over the years, wind turbines have gotten taller, blades have gotten longer, and the speed at which the blades rotate has declined substantially. These large, slower-moving blades are more easily avoided by birds, especially raptors. Many of the wind turbines at Altamont Pass have been replaced with these more-raptor friendly models. Ever-larger commercial wind turbines currently under development could reduce the risk even more. Modern wind turbines are also mounted on large tubular towers that, unlike earlier lattice towers, provide no space for predatory birds to perch and watch for prey.

As shown by the graph on the following page, large commercial wind turbines are only a minor source of bird mortality.

"Double the number of turbines," Sagrillo notes, "and we're up to 0.02 to 0.04 percent. Increase the number by 1,000 percent and we're up to 0.1 percent! How many birds does habitat destruction such as mountain top removal to mine for coal kill—forever?!?"

A fact that's rarely discussed is that producing electricity from wind turbines rather than from conventional sources—which create many environmental problems, including air and water pollution, mercury emissions, habitat destruction, and climate change—can actually *benefit* birds and bats—all while protecting a host of other species, ourselves included.

To learn more about efforts to further reduce bird deaths, check out "Facts about Wind Energy and Birds" at the American Wind Energy Association's website, awea.org. Mick has written several articles on the topic, which you can find at renewwisconsin.org. On the lower left, click on "Small Wind Toolboxes." If you want more recent findings, check out the online publication "Wind Turbine Interactions with Birds, Bats, and their Habitats," published in the spring of 2010 by nationalwind.org.

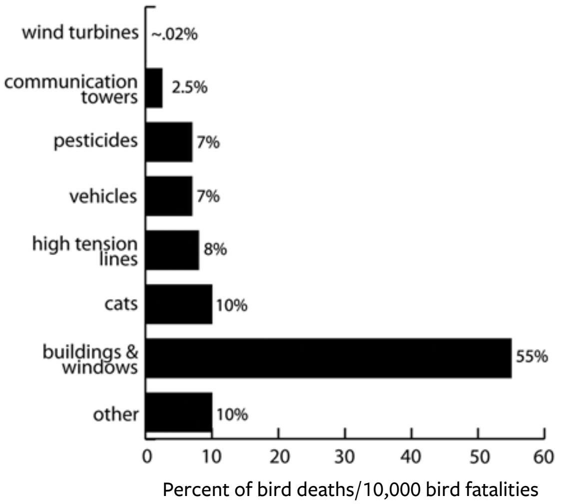


**FIGURE 1.10.** This graph shows the relative number of bird death from various sources. Note that wind turbines are responsible for only a tiny portion of total annual bird deaths. Credit: Wallace P. Erickson; Western EcoSystems Technology, Inc.

Studies also show that while bats are killed by large commercial wind turbines in certain locations, such occurrences are rare. Most deaths occur during the late summer and early fall, when many species of bats begin their annual migration. Researchers believe that bat deaths occur at this time because the bats may switch off their echolocation to conserve energy while migrating.

According to researchers, large wind turbines in certain locations kill, on average, 2.45 to 3.21 bats per year.

While bat deaths, like bird deaths, are regrettable, there's no indication that bat populations in the vicinity of large or small wind turbines are in any way threatened by them. Other factors play a much larger role in bat mortality, including pesticides, habitat destruction, lighthouses, communication towers, power lines, fences, and human disturbance during hibernation. For more on this topic, check out the accompanying textbox.

## Aesthetics

Another downside of wind turbines is that some people don't like the look of them. They believe that wind turbines detract from natural beauty. Although some individuals object to the sight of a residential wind turbine or a commercial wind farm, others find them to be things of great beauty. Ironically, those who find wind turbines to be unsightly often ignore the great many forms of visual blight that litter our landscape, among them cell phone towers, water towers, electric transmission lines, radio towers, and billboards. To be fair, there are differences between a wind tower and these common sources of visual pollution. For one, a turbine's spinning blades call attention to themselves. Another is that they are *new*; we've grown so used to the ubiquitous electric lines and radio towers that many of us fail to see them anymore. Yet another difference is that these structures we choose to ignore are often ones that were erected without public consent. That is, they were exempt from public hearings. People had no choice in their placement and have eventually grown used to them.

Given the opportunity to oppose a structure in their view shed—for example, at a public hearing required for permission to install a residential wind system—many neighbors are quite willing to speak up in opposition. As Mick Sagrillo points out in an article on aesthetics in AWEA's *Windletter*, "anyone who has tried to deal with aesthetics in a public hearing knows only too well why art has never been created by committee."

While the battle continues over commercial wind development and individual battles arise as homeowners or business owners attempt to install small-scale wind to meet their needs, it may be comforting to those who support wind to learn that when windmills were first introduced into Holland, they were looked upon by some with distaste. Another case in point: a large commercial-sized wind turbine built at the Portsmouth Abbey School in Rhode Island drew criticism at first, but is now widely loved by most residents of the community. In Chapter 10, I'll discuss ways individuals can help prevent and overcome opposition from neighbors.

### Proximity

Critics raise concerns when it comes to the placement of wind turbines near their properties. Most of the issues related to proximity have been raised by individuals and groups that oppose large commercial wind farms. They cite aesthetics, noise, interference with satellite TV transmissions, potential health issues, and a potential decline in property values.

That said, residential systems can also cause a stir among neighbors. They raise similar issues as well as others, including safety.

#### An Opposing View

"I think that the goal should be to site wind turbines near homes without fear," Ian argues. "It's better to build relationships with your neighbors, and get them excited about renewable energy. Then the question will be 'Will I be able to see the blades spin?' not 'Must I look at it?' When dealing with neighbors, remember that many of them share your excitement for renewable energy. Many people would love to reduce their electric bill or achieve greater energy independence, or just enjoy the coolness factor that owning a wind turbine brings, but not all can. "Your neighbors can be cool by association," Ian notes, "if you do the PR in advance."

To avoid problems, we recommend installing turbines, whenever possible, in locations out of sight and hearing of sensitive neighbors. Safety issues like tower collapse are extremely rare and are always the result of bad design or improper installation; should the worst happen though, homeowner's insurance should cover damage to individuals and property. Nonetheless, it is best to place a wind turbine and tower away from your neighbors' property lines to overcome potential objections. In the next few pages, I'll discuss these and other related issues.

> Remember that sound is very subjective—what to some might be irritating is the pleasant sound of renewable energy at work to others.
>
> Ian Woofenden

*Unwanted Sound*

Opponents of wind energy and apprehensive neighbors sometimes voice concerns about unwanted sound, aka noise, from residential wind turbines. Small wind turbines do produce sound, and, as wind speed increases, sound output increases.

Sound is produced primarily by the spinning blades and alternators. The faster a turbine spins, the more sound it produces. Over the years, I've found that sound levels vary considerably from one wind turbine to the next. My Skystream 3.7 produces a considerable amount of sound. The 5-kW Endurance wind turbine I installed at a business in Winfield, Missouri, is as quiet as a kitten.

As I point out in Chapter 5, high-rpm wind turbines tend to be louder than low-rpm units. Individuals can reduce unwanted sound by selecting quieter, low-rpm wind turbines. If you are concerned about sound, make this a high priority as you shop for a turbine—and let your neighbors know this is an issue to which you are sensitive.

Wind turbines also come with governing mechanisms, systems that slow down the turbines, even turn them off, when winds get too strong to protect them from damage. Different governing systems result in different sound levels. (I'll discuss this topic in Chapter 5.) When researching your options, I recommend that you listen to the turbines you're considering buying in a variety of wind conditions, including those that require governing. (That's a lot easier said than done, I know.)

Besides buying a quieter wind turbine to reduce sound, it's also important to mount your turbine on a tall tower. Suitable tower heights, which I'll discuss later, are usually at least 80 to 120 feet. (To give you a visual: A 12-story apartment complex would be about 120 feet tall. An 80-foot-tall apartment building would be about 8 stories.) A residential wind turbine mounted high on a tower catches the smoother and stronger—and hence most productive—winds. This strategy also helps reduce sound levels on the ground. Part of the reason for this is that sound dissipates quickly over distance. (For mathematically inclined readers, sound decreases by the square of distance.)

Residential (and commercial) wind turbines are also much quieter than many people suspect because the sounds they make are partially drowned out by ambient sounds on windy days. Rustling leaves and wind blowing around one's ears often drown out some of the sound produced by a residential wind turbine. Experience has shown me that we get used to the sound of wind turbines, too. I wasn't at all pleased when I first installed my Skystream wind turbine in 2010. I could hear it at most locations on my 60-acre property. Now, I barely notice it, and when I do, it brings a smile to my face because I know it's producing electricity from the strong winds that blow through.

Sound is measured in two ways—by loudness and by frequency. Loudness is measured in decibels (dB). Frequency is the pitch. A low note sounded on a guitar has a low frequency or pitch. A high note has a high frequency. Let's consider loudness first.

We live in a noisy world. In fact, the average background noise in a house is about 50 dB. Nearby trees on a breezy day measure about 55 to 60 dB. According to Sagrillo, "Most of today's residential wind turbines perform very near ambient levels over most of their effective operating range."

However, even though the intensity of a sound produced by a wind generator may be the same as ambient sound, the frequency often differs. As a result, wind turbine sounds may be distinguishable from ambient noises, even though they are not louder. The blades of my Skystream, for instance, produce a high-pitched sound when the winds blow at high velocity. It's quite noticeable.

"Today's home-sized wind turbines typically operate from just below to just above ambient environmental sound levels at their loudest when governing," Sagrillo notes. "This means that while the sound of a wind turbine can be picked out of surrounding noise if a conscious effort is made to hear it, home-sized wind turbines are by no means the noisy contraptions that some people make them out to be."

For more on sound, you may want to read Mick's column, "Residential Wind Turbines and Noise" in the April 2004 issue of AWEA's *Windletter*. I'll also spend more time on this topic in Chapter 5, and in Chapter 10 I'll discuss strategies for addressing sound issues at zoning hearings.

### *Ice Throw*

Like trees and powerlines, wind turbines can ice up during ice storms. Some worry that ice buildup will result in "ice throw"—hunks of ice being hurled off the blades. This, they worry, may pose a danger to people and structures on the ground.

While ice builds up on blades in ice storms, it is typically deposited on turbines and towers in very thin sheets. When the blades are warmed by sunlight, however, the ice tends to break up into small pieces, not huge and potentially dangerous chunks. Moreover, when it melts, it falls down, around the base of the tower. It's not flung into neighbors' yards.

Also bear in mind that ice buildup on the blades of a wind turbine dramatically reduces the speed at which a turbine can spin.[1] Ice accumulation on a wind turbine blade is a little like trying to drive a car with four flat tires; there is a lot of resistance to movement. Because the turbine is slowed down so much, ice is not thrown great distances; it tends to fall around the base of the tower—just as it does from trees and power lines.

Any prudent person would be advised to stay away from the tower base when ice is shed from the blades, just as they would from ice falling from trees or power lines. Ice-laden trees are also considerably more dangerous, as ice-coated branches can and often do break and fall to the ground, damaging power lines and cars or houses. Entire trees can topple as a result of ice buildup.

On the rare occasion that ice builds up on a wind turbine, experienced wind turbine operators shut down their turbines until the Sun or warmer temperatures melt the ice; no electricity is generated when ice induces such low rpms anyway. By the way, we've experienced numerous ice storms over the past six years and never once had to worry about ice dropping from or being flung by our wind turbine.

### *Interference with Telecommunications*

Some opponents of wind energy also raise the issue of interference with telecommunications signals.

While there are a few reports of large-scale wind turbines causing interference with television reception, these problems arose because the turbines were installed directly in the line of sight between the TV transmitter and a residential antenna. The spinning blades chopped up the signal, causing flickering on televisions. Interference represented isolated cases and was easily corrected by installing larger antennas or signal boosters.

With small wind turbines, interference is extremely unlikely. Turbines for homes and small businesses have small blades that do not interfere with such signals. The blades of modern wind turbines are also made out of materials that are unlikely to cause problems. Unlike the metal blades of years past, which can reflect TV signals, the fiberglass and plastic blades in use today are "transparent" to telecommunications signals.

As a case in point, we should note that small wind turbines are often installed to power remote telecommunications sites. A US-based small-wind turbine manufacturer, Abundant Renewable Energy (now operating as Xzeres Wind Power), mounted their internet receiver/transmitter on their wind turbine tower. Telecommunication equipment wouldn't be installed in such locations if there were problems with interference.

### *Strobing and Photosensitive Epilepsy*

Yet another issue that may be raised from time to time by concerned neighbors or opponents of wind energy is the possibility that shadow flicker from wind turbines will stimulate epileptic seizures in individuals who suffer from photosensitive epilepsy. This is an extremely rare type of epilepsy in which seizures are triggered by flickering or flashing light.

This concern, most often raised by opponents of large commercial wind turbines, but occasionally raised at zoning hearings for small wind turbines, is not just overblown, it's not even true. According to researchers, there's never been a case of epileptic seizure triggered by a wind turbine in human history.

While blades of small turbines may form small and rather vague shadows, it is difficult to see the shadow of individual blades due to the speed with which the blades spin. As Jim Green notes, "The rotors of residential-scale wind turbines, 10 kilowatts and smaller, essentially become transparent at typical operating speeds because the blades spin faster than the eye can detect."

The true test of this issue's seriousness may come from installers and dealers. Mike Bergey of Bergey WindPower, for example, has never received a complaint about shadow flicker from customers or neighbors, and he's been in the business for nearly 39 years, as of 2016.

### *Property Values*

Opponents of wind farms often raise the specter of declining property values, despite the lack of any evidence to support their assertions. Nonetheless, concerns over property values often arise in zoning hearings over small wind turbines. As Sagrillo puts it, the rationale is that the neighborhood "view shed" will be compromised as a result of the installation of a home-sized wind turbine. Neighbors worry that they will not be able to sell their property for its true value.

While wind turbines on tall towers are visible, lots of other tall structures like silos, barns, high-power transmission lines, water towers, and cell phone towers are present in the same rural environments where residential and small business wind systems are typically installed. Small wind systems are often much less visible than these structures. Moreover, I've never heard of an instance in which a residential wind turbine adversely affected the value of a neighbor's property. For the system owner, a wind turbine could increase property values, in part as a result of reduced utility bills. I find my wind turbine perched on top of the hill to be a thing of beauty. You can easily see it from a mile away—and it looks terrific! In fact, I often use it to help people locate my educational center. "Turn left onto Pin Oak Road. We're a mile up on your left. You'll see a wind turbine on a tower on top of the hill. That's our place," is what I tell students and delivery truck drivers.

### *The Advantages of Wind Energy*

Although residential wind turbines and their energy source, the wind, have their downsides, many features make them well worth considering. To begin with, wind energy is an abundant and renewable resource. We won't run out of wind for the foreseeable future—which stands in stark contrast to the future of coal, natural gas, oil, uranium.

Wind energy—both large and small—can also play a meaningful role in offsetting declining US natural gas supplies. In the United States, 33 percent of all electricity is currently generated by natural gas, according to the U.S. Department of Energy. As supplies continue to decline, wind could help ease the crunch, supplying a growing percentage of our nation's electrical demand long into the future.

**FIGURE 1.11.** Dan and His All-Electric Nissan Leaf. This is a perfect commuter car. Depending on the model, it travels 84 to 104 miles on a single charge. If you are replacing a car that gets 30 miles per gallon, and you pay 10 cents per kilowatt-hour for electricity from a utility, it would cost you about 68 cents to travel 30 miles on electricity. The same trip in a gas-powered vehicle would cost $2.00 (if gas prices were $2.00 per gallon). With higher gas prices, the savings accrued when driving an electric car become even more attractive. Credit: Linda Stuart.

Wind could even replace nuclear power plants the world over. Nuclear power plants generate about 20 percent of the United States' electricity, and substantially higher percentages in countries such as France. Although wind energy does have its impacts, it is a relatively benign technology compared to fossil fuel and nuclear power plants. Because of this, it could help all countries create a cleaner and safer energy future at a fraction of the cost and impact of conventional electrical energy production.

While many proponents of wind and solar energy claim that these technologies will help us reduce our dependence on oil, few realize that in the United States only a tiny fraction (about two percent) of our electricity comes from burning fuels derived from oil. That said, if wind and solar-generated electricity were used to power electric vehicles, slowly but surely replacing gasoline-powered vehicles, these renewable energy sources could help us reduce our dependence on oil. I drive a Nissan Leaf powered entirely by solar and wind energy. In the first six months, it reduced our consumption of gasoline by 90 gallons—and our other car is a Toyota Prius that routinely gets 50 miles per gallon or more.

Another huge benefit is that when wind is used to power electric and plug-in hybrid vehicles, it helps them clean up the air and reduces the buildup of the greenhouse gas carbon dioxide, which is largely responsible for global warming and climate disruption.

Another benefit of wind energy is that, unlike oil, coal, and nuclear energy, the wind is not owned by major energy companies. The cost of wind is not subject to price increases. Price hikes caused by rising fuel costs are not probable in a wind-powered future. However, this is not to say that wind energy is immune to the rising price of fossil fuels. While the fuel itself (the wind) will not increase in price, the price of wind generators is likely to increase as traditional fuel prices rise. That's because it takes energy to extract and process minerals to make the steel, copper, and rare earth magnets needed to manufacture wind turbines and towers. It also takes energy to make turbines and towers and ship and install them.

An increasing reliance on wind energy—and electric cars—could also ease political tensions worldwide. If we free ourselves from Middle Eastern oil, we won't need costly military operations aimed, in part, at stabilizing a region where the largest oil reserves reside. We'll likely never fight a war over wind energy resources. Not a drop of human blood need be shed to ensure a steady supply of wind energy to the fuel the economy.

Yet another advantage of wind-generated electricity is that it uses existing infrastructure, the electrical grid, and existing technologies like computers, microwaves, and so on. A transition to wind energy could occur fairly seamlessly.

Individuals can also meet all or part of their energy needs in rural areas with good wind resources at rates that are competitive with conventional electricity. In remote locations, wind or wind and solar-electric hybrid systems may be cheaper than conventional power delivered through newly installed and costly electric lines from the utility grid.

Finally, lest we forget, wind is a clean resource. Wind energy will help homeowners and businesses do their part in solving costly environmental issues such as acid rain and global climate change. As Mick points out in his workshops, the average home in the United States consumes 900 kilowatt-hours of electricity per

> Envision a future in which distributed (small) wind power is *embraced* in the local landscape because it *expresses community support* for clean air, reduced carbon emissions, and strong local economies through use of a sustainable, indigenous energy source.
>
> Jim Green, National Renewable Energy Laboratory

month. Replacing the electricity generated by a coal-fired power plant with wind-generated electricity will reduce a family's consumption of coal by approximately 5.5 tons per year. This, in turn, will reduce the emission of carbon dioxide by about 11 tons per year. It will also reduce mercury emissions. You couldn't ask for more reasons to justify a switch to wind energy.

Wind energy also provides some substantial economic benefits. Wind energy development creates jobs—more jobs per kilowatt-hour generated than any other type of power plant. At the start of 2016, American wind power supported a record 88,000 jobs—an increase of 20 percent in a year—according to AWEA's *U.S. Wind Industry Annual Market Report* for the year ending in 2015. "Strong job growth, the report notes, "coincided with wind ranking number one as America's leading source of new generating capacity last year, outpacing solar and natural gas."

Wind energy development also concentrates economic benefits locally and within states. "Wind power benefits more American families than ever before," notes Tom Kiernan, CEO of AWEA. "We're helping young people in rural America find a job close to home. Others are getting a fresh chance to rebuild their careers by landing a job in the booming clean energy sector. With long-term, stable policy in place, and a broader range of customers now buying low-cost wind-generated electricity, our workforce can grow to 380,000 well-paying jobs by 2030."

And wind power does not require extensive use of water, an increasing problem for coal, nuclear, and gas-fired power plants, particularly in the western United States and other drought-stricken areas.

### The Purpose of This Book

This book's principal focus is on small wind-electric systems. As noted earlier, the rated output of small wind turbines ranges from 1 kilowatt to 100 kilowatts. Most of the turbines I'll be discussing fall in a narrow range from 1 kilowatt to 20 kilowatts. The blades of small turbines (1 to 100 kilowatts) run from 4 feet to 32 feet in length. Small-scale wind systems serve a variety of purposes. The smaller units within this category are sufficient to power cabins and cottages. Larger turbines power homes, small businesses, schools, farms, ranches, manufacturing plants, and public facilities.

This book is written for individuals who want to learn about small-scale wind systems. It is also written for those who aren't particularly well versed in electricity and electronics. You won't need a degree in electrical engineering, renewable energy, or physics to make sense of the material covered in this book.

The overarching goal in writing this book was to create a user-friendly book that teaches readers the basics of wind energy and wind energy systems. This book is *not* an installation manual. It will not turn you into a wind energy installer or equip you to install a wind turbine and tower on your own. It will, however, help you determine if wind energy is right for you. When you finish reading and studying the material in this book, you'll know an amazing amount about wind and wind energy systems. You will have the knowledge required to assess your electrical consumption as well as the wind resource at your site, and to determine if wind will meet your needs.

When you are done with this book, you should have a good working knowledge of the key components of wind energy systems, especially wind turbines, towers, batteries, and inverters. In keeping with my long-standing goal of creating knowledgeable buyers, this book will help you know what to look for when shopping for a wind energy system. You'll also know how wind turbines are installed and have an understanding of their maintenance requirements.

If you choose to hire a professional wind energy expert to install a system—a route I highly recommend—you'll be thankful you've read and studied the material in this book. The more you know, the more input you will have into your system design, components, siting, and installation—and the more likely that you'll be happy with your purchase.

In keeping with another long-standing goal of mine, this book should also help readers develop realistic expectations. I believe that those interested in installing renewable energy systems need to proceed with their eyes wide open. Knowing the shortcomings of wind energy—or any renewable energy technology, for that matter—helps avoid mistakes and prevent disappointment fueled by unrealistic expectations.

Over the years, I've found that there's a lot of ignorance about wind and its potential, and this leads to very unreal expectations. Many people I've talked to think they can simply install a wind turbine on a short tower on their property and live happily ever after, merrily consuming electricity as if there were no tomorrow. Truth is, you will need very likely need a fairly large wind turbine mounted on a tall tower and a very good (translated: windy) site to make such a dream come true. In addition, wind energy systems require annual inspection and maintenance—climbing or lowering a tower to access the wind turbine to check for loose fasteners and blade damage and, much less commonly, to make an occasional part replacement. If you are not up for it or don't want to pay someone to climb or lower your tower once or twice a year to check things out, you may want to invest in a solar-electric system instead.

## Organization of This Book

Now that you know a little bit about the history of wind energy, the pros and cons of this clean, renewable energy source, and the purpose of this book, let's start our exploration. I'll begin in the next chapter by studying wind, the driving force in a wind energy system. You will learn how winds are generated and explore the factors that influence wind flows in your area.

In Chapter 2, I will also explore the factors that affect energy production by a residential wind turbine. That is, you will learn the simple, undeniable mathematics of wind energy. The math isn't difficult, and this discussion will demonstrate how the proper design and placement of a wind turbine can result in dramatic increases in electrical output. When you finish, you will understand why it is important to mount a wind turbine as high as you can and out of the way of obstructions that reduce wind speed and create turbulence when the winds blow. This advice could make the difference between a successful wind venture and a costly failure.

In Chapter 3, I'll explore wind energy systems. You'll learn the three types of residential wind energy systems: (1) off-grid, (2) batteryless grid-tie, and (3) grid-connected with battery backup. You'll also learn about the basic components of each one. We'll also look at hybrid systems.

Chapter 4 explores the feasibility of tapping into wind at your site. I'll teach you how to assess your electrical energy needs and how to determine if your site has enough wind to meet them. You'll learn why cost-effective energy-efficiency measures that reduce your electrical demands will save you heaps of money when buying a wind energy system. You'll also learn ways to evaluate the economics of a wind system.

Chapter 5 introduces you to wind turbines. You'll learn about the different types of wind turbines and how they work. I'll also give you shopping tips—what to look for when buying a wind turbine. I'll even spend a little time looking at ways to build your own wind generator and introduce you to wind turbines designed to pump water.

Chapter 6 describes the three basic tower options. You will learn how towers and guy wires (used to support certain types of towers) are anchored to the ground. I'll underscore the importance of mounting a wind turbine high above the ground—out of turbulent ground-level air and dead air zones and into the much smoother and more powerful winds that blow higher up. I'll also look briefly at how towers are installed.

Chapter 7 addresses another key component of wind energy systems, the inverter. You will learn how inverters work, what functions they perform, and what to look for when shopping for one.

In Chapter 8, I'll tackle storage batteries, one of the key components of off-grid wind systems. You will learn whether you will need a battery bank and, if so, what kind of batteries you should install. You will learn about battery care and maintenance and ways to make your life with batteries much easier. You'll benefit from my many years of experience with battery systems as I point out common mistakes and ways to avoid them. You will also learn about battery safety and how to size a battery bank for a wind energy system.

In Chapter 9, I'll give a brief overview of wind energy system maintenance. Because each wind turbine and tower is different, I won't go into specifics. I will, however, stress the importance of regular inspection and maintenance and describe some of the things you'll have to do to keep your wind energy system performing optimally.

With this information in mind, in Chapter 10 I'll explore a range of issues such as homeowner's insurance, financing renewable energy systems, obtaining building permits and electrical permits, and zoning issues.

Finally, this books ends with a fairly comprehensive Resource Guide. It contains a list of books, articles, videos, associations, organizations, workshops, and websites on residential wind energy.

What do you say—shall we get started?