COLORADO

Wind Energy Installation Guide

for Agriculture and Rural Applications

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Cover photo: 10 kW Bergey Excel-S Wind Turbine mounted on a Rohn 120 ft. Self-supporting Lattice (SSL) tower at Poss Farms, Hugo, Colorado. Back page photo: windmill near Flagler, Colorado. Photos by Phil Brink.

Introduction

We hear a lot these days about America's need to shift from using fossil fuels to cleaner, renewable sources of energy. In many areas of rural Colorado, one energy source that is both abundant and cost-effective to utilize is wind energy.
Using wind power to generate electricity can lower your electricity bills, reduce your reliance on fossil-fuels, and help the environment. But how do you know if wind power is right for your farm, rural home or business?

In this guide, we'll look at how to evaluate and install a wind energy system, beginning with how to determine if wind power is right for your operation, tips on selecting the right wind turbine, and guidance on installing and commissioning the system.

First let's go over the basics of how wind energy works, and why average wind speed is so important in determining whether wind energy will be is a cost-effective investment.

Wind is simply a moving air mass. The amount of energy contained in wind is determined by its density and speed. Wind density declines with increasing altitude and increasing temperature. So, cool air is denser than warm air. Also, the higher the altitude, the lower the air density. For example, the air at Fort Collins, Colorado, is about 14% less dense than air at Sea Level.

The most important aspect of wind power is **wind speed**. This is because the energy available in wind is proportional to its speed, taken to the third power, or "cubed." The wind turbine power output chart (right) shows how energy "cubing" affects the actual energy output of a wind turbine.

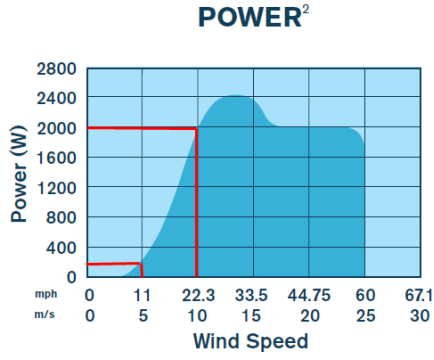


Chart source: Southwest Windpower Skystream 3.7 (2.4 kW) Power Curve

The wind turbine will produce about 200 watts of energy when the wind is blowing 11 mph. But when the wind speed increases to 22 mph, the same turbine will make about 2,000 watts of electricity. By doubling the wind speed, the turbine produces 10 times more energy. This is the effect of the energy

"cubing" of wind speed, and it is why wind speed is so important in evaluating whether a site is appropriate for a wind energy system.

Now that we've covered the basics of wind energy, let's discuss how to determine if wind energy is a feasible, cost-effective investment for you. Phase One includes 11 steps that are involved in making an economic feasibility determination.

Phase One: Steps to Determine the Economic Feasibility of Wind Energy

1. Identify your site's average wind speed
2. Determine how much electricity you use annually
3. Estimate the output of different turbines to determine the best fit for your situation.
4. Estimate the Installed Cost of Wind Systems
5. Determine Turbine Payback Times
6. Select the Right Wind Turbine
7. Identify Government Approvals Needed
8. Select the Right Tower
9. Determine whether your project will be eligible for government Tax Credits and Grants, and add up the value of incentives to see how much they will lower your system's installed cost.
10. Calculate Revised Payback Time

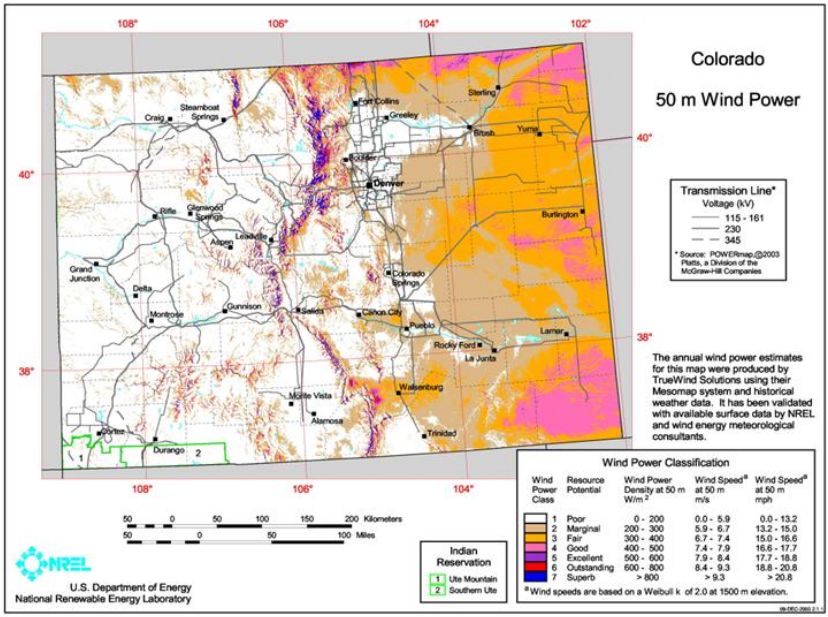
Step 1: Identify your site's average wind speed

The first step is to identify your site's average wind speed. The National Renewable Energy Laboratory in Golden has developed a "50 Meter Wind Power" map (shown on the following page) for Colorado that estimates average wind speeds throughout the state. The map can be viewed at www.windpoweringamerica.gov, along with other information about wind resource development in Colorado, including *Small Wind Electric Systems: A Colorado Consumer's Guide*, which is a useful companion document to the guide you are reading.

The different colors on the map represent different average wind speeds, or Wind Classes, as shown in the table at the lower right of the map. For example, the area around Yuma in Northeastern Colorado

has a Class 3 wind resource, which means the average wind speed range is 15.0 to 16.6 mph.

Figure 1. Colorado 50 Meter Wind Power Map



The ranges shown on the map are based on wind speeds at 50 meters above the ground, which is about 163 feet. Since most farm and residential wind turbines are mounted on towers that are not this tall, use the lower end of the range to represent the average wind speed at your site.

In most cases, sites with a Class 3 wind speed and higher can utilize wind power cost-effectively. And, in some cases, sites with only a Class 2 wind resource can work if electricity usage is high and utility-provided electricity is expensive.

Wind speed data is also collected at most airports and may be useful in estimating your site's average wind speed, if the airport is located nearby. And some private companies also provide wind speed data for a fee.

Step 2: Determine you annual electricity usage

The next step is to figure out how much electricity you use in a year. Your monthly utility bill indicates the number of kilowatt-hours used during the month and the associated cost. Simply add up the kilowatt hours used over the last 12 months to get your annual usage. Your utility company also maintains these records if you do not have them.

Table 1. Electricity usage and cost determination

Example Electric Utility Company	Average monthly bill	Average kilowatt-hours (kWh) used per month	Approximate kWh used ANNUALLY
Meter: House, farm shop, outbuildings	$ 183	1,667	**20,000**

Step 3: Identify the right wind turbine

Step 3 involves identifying the turbine size that is right for your operation. Most wind turbine manufacturers publish energy output charts on their websites that allow you to estimate how much electricity their turbine will produce based on your site's average wind speed. And some manufacturers have "estimator" applications that allow you to simply enter your location, and the software does the rest.

Figure 2. Estimated Annual Energy Output

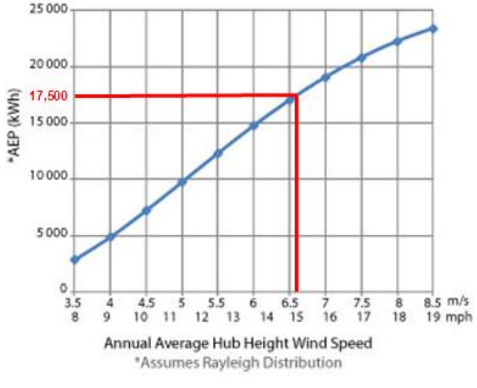


Chart source: Endurance S-343 (5 kW) Electricity Output Chart

The most cost-effective turbine is usually the one that produces about the same amount of electricity as you use annually. This way, all of the electricity that the wind turbine generates offsets actual usage, so all of the electricity produced by the turbine is valued at the same retail rate that you pay your local electric utility.

A farm that uses

about 20,000 kilowatt-hours (KwH) of electricity per year and has an average wind speed of 15 mph would find the 5 kilowatt wind turbine (represented in the Figure 2 chart) to be a good fit, since the turbine will produce about 17,500 kWh of electricity per year, or about 88% of the farm's annual electricity usage.

In contrast, a turbine that produces more electricity than a facility uses is less cost-effective because the excess electricity is sold back to the power company at a rate that is usually much lower than the retail rate.

Step 4: Estimate the installed cost of the wind system

Once you identified the approximate turbine size that is right for your application, the next step - Step 4 - is to estimate the installed cost of the wind turbines within the size class you have identified. This will be a ballpark figure that you will use as a screening tool to zero in on the best-fit turbine for your operation.

Figure 3. Cost Estimate Example

Item	Description	Estimated Price
Wind Turbine	Bergey Excel-S, 10 kW Wind Turbine ((Color: WHITE); Blade Color (WHITE) with PowerSync II Power Processor - 240 VAC, 60 Hz Single Phase	**$ 29,500**
Tower: 120 Ft. SSL	Rohn Industries 120' (37m) Self-Supporting Lattice Tower with Safety Climb	**$ 19,500**
Tower Assembly	Assemble Tower (SSL), including tightening bolts after tower & turbine are erected	**$ 1,000**
Tower Wiring kit	Tower Wiring Kit includes a fused disconnect switch, lightning surge arrestor, armored tower cable and connectors.	**$ 1,350**
Totalizing meter	Cumulative Energy (kWh) Meter with Base, 240 AC only, for use with 10 kW Excel-S	**$ 250**
Remote monitoring system	Remote, wireless turbine output and inverter health monitoring system (includes hardware and software) not including wiring cost).	**$ 500**
Shipping Costs:	Wind Turbine & Tower Wiring Kit, SSL Tower Kit & Hardware	**$ 2,600**
Tower Foundation	Reinforced Concrete Foundation Installed; including Soil sampling and testing, Engineering, Forming, Pouring and Finishing)	**$ 20,000**
Fees and Permits	Public Utility grid-interconnection fee, building permit, county permit, electrical permit and inspection fee	**$ 300**
Electrical	Trenching, wire runs, backfill, Wiring system into inverter and utility grid, test system	**$ 3,000**
Crane Service	Raise tower	**$ 1,000**
	TOTAL	**$ 79,000**

The installed cost of a wind system will include a soils investigation, foundation design and installation, the turbine, tower, and inverter, crane service, trenching and electrical wiring, and interconnection and permit fees.

Many turbine manufacturers and dealers recommend specific towers for their turbines, and can give you a good estimate of the final installed cost of a system. And, most will provide an estimated turbine payback time.

If the only information available is the retail price of the turbine and tower, take the total of these two numbers and multiply it by 1.5 to estimate an approximate final installed cost.

Step 5: Estimate turbine payback time

Using manufacturer or installer prices for turbines and towers, estimate for each wind system the time it will take to pay off the investment without any subsidies or tax credits. Simple payback time can be estimated by using the formula: Installed cost of the turbine ÷ (Annual turbine output in kWh × average cost you're paying for electricity).

For example, if a wind energy system will cost $76,000 installed and its estimated annual electricity output is 20,000 kilowatt hours, and the retail rate currently paid for electricity is $0.13 per kWh, the payback time equals $76,000 ÷ (20,000 kWh X $0.13 per kWh) = 29 year payback before any tax credits or grants are factored in.

In general, the higher the cost of electricity being purchased from the utility, the faster a wind turbine will pay for itself, since the turbine will be offsetting power you would otherwise have to buy from the utility.

Loan interest, maintenance, and inflation also influence a turbine's payback time. Most wind turbine manufacturers offer estimator applications on their websites that estimate how much time it will take for their turbine to pay for itself at your location. Or you can contact the company directly and ask them for an estimate. Be ready to provide them with your location, average annual electricity usage and cost, and the tower height in which you are interested.

Step 6. Select the right wind turbine

Now that you have estimated and compared the payback times of different wind systems, you can now identify which wind turbine is right for your operation. Usually, the best wind energy system is the one that pays for itself in the shortest period of time. However, the expected reliability of the system is also an important factor to consider.

Remember, for a wind turbine to be cost-effective, it must keep producing electricity year-round, in all kinds of weather and temperature extremes, with minimal maintenance or downtime. So be sure the turbine and tower manufacturer you choose has an established track record with a large number of units already in service, and a strong warranty.

Step 7. Identify government approvals needed

Once you have decided on the turbine that best fits your facility, you'll need to find out if the wind system will require any government approvals. This may include reviewing HOA by-laws, city and county ordinances, and state and federal permit requirements for wind energy systems.

Begin with a review of local zoning ordinances related to tower height limits and acreage requirements, as this may affect your turbine and tower purchase options. If the site is near an airport, check with the FAA regarding any restrictions. Towers less than 200 feet tall usually do not require lights; however, the FAA may require lighted markers if it considers the tower a particular hazard due to its location.

Step 8. Select the right tower

The appropriate tower height for a typical site is influenced by the size of the turbine, cost of the tower, surrounding landscape features and zoning restrictions.

The four main types of towers are: monopole, self-supporting lattice (SSL), tilt-up, and guyed-lattice. Costs vary with the height and type of tower. Monopole towers are typically most expensive, and guyed-lattice are usually the least expensive. Most turbine manufacturers recommend specific towers that meet their requirements.

10 kW turbine on guyed lattice tower

Since wind speed increases with increasing height above ground, tower height should be maximized. One study found that guyed-lattice towers become more cost efficient with increasing height, whereas monopole towers did not. In addition to budget considerations, the type of tower you select must be suitable for the site. Guyed-towers may not be appropriate on small acreages because of how far the guy wires extend out from the tower. Lattice-type towers may not be suitable for sites with public access, due to potential liability issues. And tilt-down towers are generally not needed unless they will be mounted in extremely high-wind areas.

Step 9. Determine the value of tax credits and grants

Identify all tax credits and grants available for small wind power, and determine your eligibility and the potential value of each type of incentive. Check the Database of State Incentives for Renewables and Efficiency at **www.dsireusa.org**. This website provides a comprehensive list of available incentives for small wind projects.

At a minimum, most projects will be eligible for a 30 percent federal renewable energy tax credit, which is administered by the U.S. Dept. of Treasury, Section 1603. Go to the U.S. Department of Treasury website at **www.treasury.gov** for terms and conditions, and an application.

Step 10. Calculate the revised payback time

Subtract the dollar value of each subsidy and tax credit from your total estimated installed turbine cost (Wind System Installed Cost - eligible tax credits and subsidies) to estimate the final installed cost, and then re-calculate the payback time. In some cases, the combination of rebates, cost-share funding and tax credits can reduce the installed cost, and corresponding payback time, by 50 percent or more

Step 11. Make your purchase decision

If the final estimated cost of the system and payback time frame is acceptable, proceed with the project. If financing will not be used, remember that you will have to carry the entire project cost until any subsidies are received and/or tax credits are realized.

Phase Two: Pre-Installation Preparation

Careful pre-installation preparation is essential to ensuring the actual installation goes smoothly. Once the right turbine and tower combination have been identified, and the estimated cost of the

system is known along with the payback timeframe, it is time to perform the pre-installation groundwork.

1. Perform an energy audit

The first step in the pre-installation process is to have an energy audit performed. The most cost-effective way to reduce electric and gas bills is often by replacing older, inefficient equipment with newer energy saving devices. An energy audit will identify inefficiencies and describe which upgrades will be most cost-effective. Having an Energy Audit is a good idea, and it is required to be eligible for Colorado's renewable energy rebate. The Governor's Energy Office maintains a list of certified energy auditors. Utilities, such as Excel Energy, provide rebates to help offset the cost of an energy audit. The USDA Rural Development Program also offers grants to rural residents to help cover energy audit costs.

2. Tower siting & interconnection meeting

The next step is to plan the location and layout of your wind energy system. First, decide where the tower will stand. At this stage, you may need the input of the local electric cooperative representative and the turbine installer.

When siting the tower, remember the " 30 & 300 ft." guideline: The turbine should be at least 30 vertical feet above the tallest object within 300 feet of the tower.

When your wind energy system is complete, it will be feeding power through your utility meter. So, the tower should be positioned close to the meter. Long distances (more than 600 feet) between the tower and meter will result in a significant drop in voltage and increased wire, pipe and trenching expense. If your system will have an externally-mounted inverter, decide its location ahead of time. Typically, the inverter will be installed near the tower or in a nearby structure. Be sure to review and follow the inverter manufacturer's specifications regarding the size and type of structure in which the inverter must be housed.

3. Soil sampling, testing and foundation design

Once you've decided where the tower will stand, you'll need to test the soil that will be supporting the tower and foundation. This will involve soil boring or digging to collect soil samples for testing. The test results can then be used to design the tower foundation. At the case study site, soil testing revealed that the native soils had a low load bearing capacity. Using the soil test results, a professional engineer can design an appropriate foundation for the local soil type.

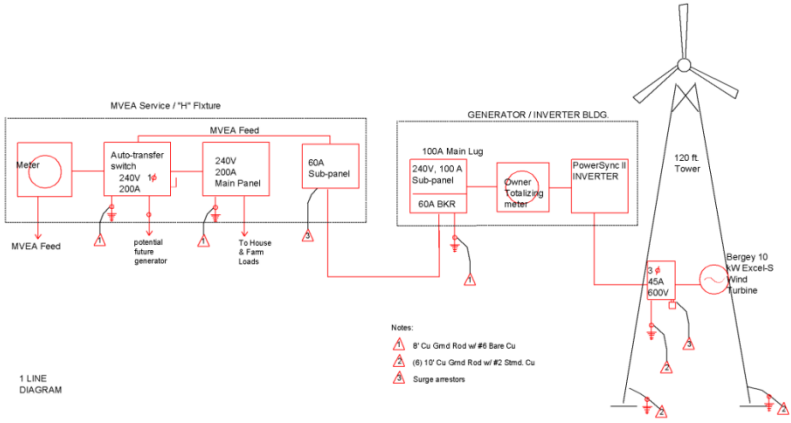
Before doing any soil boring or excavation, be sure to have all buried utilities in the area located by calling **811** – the Utility Notification Center of Colorado. Remember – think safety first!

Soil excavation for tower foundation design.

4. Prepare a One-line electrical diagram

Your electric service provider will require something called a 1-line diagram. A 1-line electrical diagram displays all of the electrical components of the planned wind system from the tower to the point of grid interconnection. The wind turbine installer or your electrician can prepare the 1-line diagram.

Figure 4. 1-Line Diagram



5. Submit the interconnection application

If the system will be tied into the utility's electrical grid, submit a completed interconnection agreement application to the utility company. This will include a site map showing the planned turbine location, distances and the type of turbine that will be installed, as well as the one-line electrical diagram, inverter UL listing, and payment for the application fee.

As part of connecting into its power grid, your electric utility may ask you to sign a renewable energy credit (REC) agreement. RECs are credits for electricity produced from a renewable source – such as

wind power. Renewable energy credits have value and they are typically sold in blocks of 1,000 kilowatt-hours. Non-profit organizations and private companies broker RECs for customer-generators.

The U.S. Department of Energy maintains a list of REC brokers at http://apps3.eere.energy.gov/greenpower

Some utilities will trade all future RECs that your system will produce for the cost of a new meter (one that spins forward and backward). And some utilities require customer-generators to sign over all of their RECs to the utility as the price for connecting to their grid. The value of RECs is modest at the present time. A typical wind turbine used for residential or farm use will produce $20 to $150 worth of RECs per year.

6. Obtain contractor bids

With the tower foundation design in hand, solicit contractor bids for all applicable services needed, including foundation excavation, concrete work (if applicable), crane service (if applicable), and electrical work (if a turbine installer is not being used). Reinforced concrete foundations are used for most wind turbine towers.

The top of the concrete pad (where the tower is mounted) is typically no more than six inches above the finished site grade. The bulk of the tower foundation is below grade, and may be several feet deep depending on design. In non-sandy soils, the excavation walls and bottom may provide the "forms" for the sides and bottom of slab-type concrete foundations. This eliminates the need for portable forms and reduces cost. It is imperative that the excavator understand that the sides of the excavation must be straight and the bottom flat and well compacted. This may require adding water to the bottom of the excavation to achieve proper compaction.

7. Select contractors

Select contractors and obtain from each a certificate of liability insurance. Note: insurance liability certificates should be requested before work begins from all contractors that will be working at the site (excavator, concrete contractor, turbine installer, crane company, trencher, etc.) This is also a good time to contact your own insurance agent and initiate the paperwork to have the wind system added to your home or farm insurance policy.

8. Identify the tools and equipment needed

If you will be assembling the tower yourself, identify the types of equipment (boom lift, etc.) that will be required to maneuver the tower sections during ground-assembly.

The turbine and tower manufacturer's installation manuals should indicate the tools and equipment required for the job. Locate the tools that will be needed and ensure they will be available. If a wind turbine installer / dealer is being used, they will supply their own equipment.

PHASE THREE: Installation & Commissioning

Once you've selected your wind turbine and tower and completed all of the pre-installation work, it is time to install your wind energy system.

1. Install foundation for tower

The foundation design provides the specifications for the size and shape of excavation and type of concrete and steel reinforcement that will be needed.

Be certain that tower anchor bolts are properly oriented and at the correct height before and during concrete pouring. All concrete specification should be provided to the concrete supplier well in advance of mixing and delivery. Follow the design specifications regarding concrete finishing and curing. If USDA cost share will be used, ensure all USDA concrete requirements are also followed.

2. Receive turbine, tower and components

Large equipment, such as a boom-lift, forklift or loader will likely be needed to unload the tower kit and turbine. Check with the manufacturers beforehand and ensure you are properly prepared to safely unload and move the wind system components when they

arrive. The turbine, inverter and related equipment should be kept in an enclosed and secure structure until installation. Tower sections may be kept outside.

3. Assemble the tower

Tower sections are typically assembled on the ground and may require a boom lift or similar equipment to maneuver the sections, depending on the size of the tower. Monopole and self-supporting lattice towers will require a crane to install. Guyed-lattice towers may be raised with a gin pole or with a crane.

4. Mount turbine on tower

The turbine and blades should be mounted on the tower shortly before you are ready to raise the tower. Follow the blade fastening and turbine mounting instructions in the guidance manual. Be sure all necessary tools are available as special tools may be required. Care must be taken to protect the blades during the process of fastening to the turbine and raising the tower. Secure the wiring assembly to the tower before raising the tower.

5. Raise the tower

Raise and secure the tower to the anchoring system. Follow the installation instructions indicated in the tower manual. If a crane will be used, make sure the crane operator knows in advance the height of the tower and combined weight of the tower & turbine, and provide them with any manufacturer recommendations relating to raising the tower. Once secured to the base, the tower must be leveled. For self-supporting lattice towers, like the one shown here, all bolts must be tightened to manufacturer's torque specifications after the tower has been erected

and secured to the foundation.

6. Trenching

Trench in the wires between the tower and utility meter. The inverter may be located near the tower or meter, depending on site characteristics. Wires should be run through approved pipe conduit rather than direct-bury.

Trenching can also be done ahead of time; right after the foundation is poured. In fact, getting the lines installed early will help you have the system up and running sooner.

7. Wire the system

The 1-line diagram developed in the pre-installation phase will illustrate how the system should be wired. Structures may need to be built before wiring can proceed, such as an enclosure to house the inverter and "H" type structures for sub-panels.

In this case, the owner built a metal shed at the base of the tower to house the inverter and a separate back-up generator. Remember: a licensed Master Electrician must oversee and approve all electrical work.

8. Electrical inspection

Before the system can be connected into utility grid at the meter, a county or state electrical inspector must review and approve the project Arrange to have the electrical inspection coincide with wiring completion.

9. Commission the system!

The utility company can connect your wind system to the grid as soon as the electrical inspector approves the system. The utility may install a new meter - one that spins forward and backward. Congratulations, those spinning blades on your new wind turbine mean your investment is now starting to pay you back!

10. Complete the paperwork

With all project-related costs accounted for, complete the application processes for the federal tax credit and any cost-share funds and rebate.

Congratulations! The project is now complete! The installed cost of the system shown here –located near Hugo, Colorado - was about $80,000. This wind system produces about 19,000 kilowatt-hours per year.

11. Maintain the system

Maintenance instructions for the turbine and tower will be provided in the respective owner's manuals. Like everything, proper maintenance is key to getting the most of your investment.

To obtain an electronic copy of this booklet and a companion video, visit www.deltawindenergy.com, or the "grants" section of the Market Division of the Colorado Department of Agriculture website at www.colorado.gov/ag.

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