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ABSTRACT

The booklet, intended for students and other visitors to the Lathrop E. Smith Environmental Education Center (Rockville, Maryland), explains how windmills work and their economic and environmental advantages. The history of windmills in Europe and Asia is briefly described, as well as the history of windmills and wind generators (for electricity) in America. The windmills at the Smith Center (an American multi-bladed wind pumper, an 1800-watt wind generator, and a 200-watt wind generator) are explained and illustrated. Factors affecting windmill performance, such as wind speed, tower height, and tower location, are covered. Economic and environmental advantages of wind power are detailed. Additional sources of information are listed: six books, two periodicals, two agencies, and four films. A 13-item glossary is provided. (MH)

## FOREWORD

Recent fuel shortages have made most everyone aware of America's prodigious use of energy, most of which comes from finite fossil fuels. Fortunately there are other sources of energy which are not only inexhaustible, but non-polluting as well. The sun has been shining for millions of years and delivering abundant free energy to the earth without benefit of power lines or underground cables. The primary reason for constructing the solar school house at the Lathrop E. Smith Environmental Education Center was to demonstrate for large numbers of students how solar energy can be used to heat a building.

The sun also makes the wind blow, and, as Buckminster Fuller has observed, "Wind-power is by far the most efficient way to recapture solar power." To demonstrate this and help students understand how the wind can be used to generate electricity, I have supported the installation of two windmills at the Smith Center. This booklet explains how these windmills work as well as their economic and environmental advantages.

Today's students are living in a world where problems of air pollution and resource depletion are becoming increasingly critical. As educators we have a responsiblity to see that they have some knowledge and understanding of alternative forms of energy. This booklet and the windmills and solar building at the Smith Center can provide us with significant help in meeting that responsiblity.

**Harry Pitt**
**Deputy Superintendent of Schools**



Booklet By
David Harrison

September, 1981

"There's something in the wind."

*William Shakespeare,*
*THE COMEDY OF ERRORS,*
*ACT III, SCENE 2*

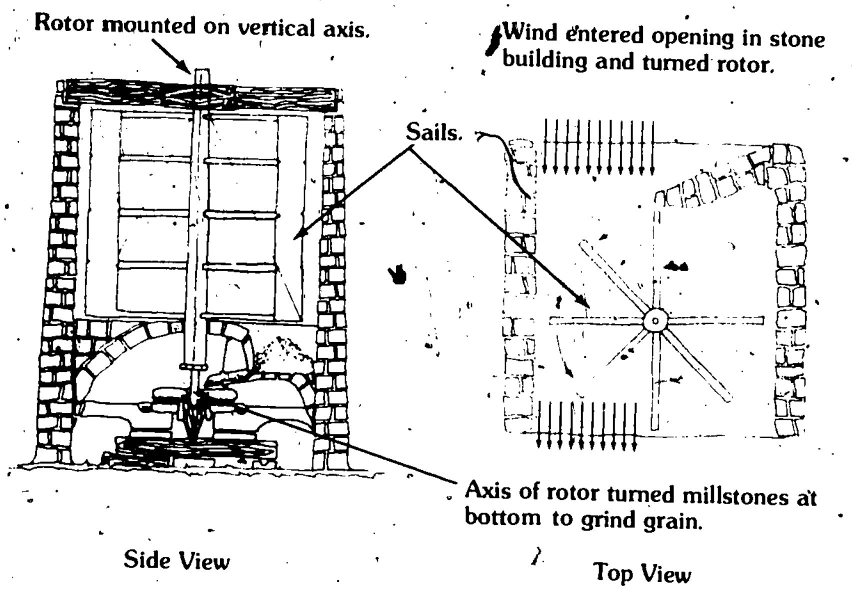
# wind energy guide

## Background

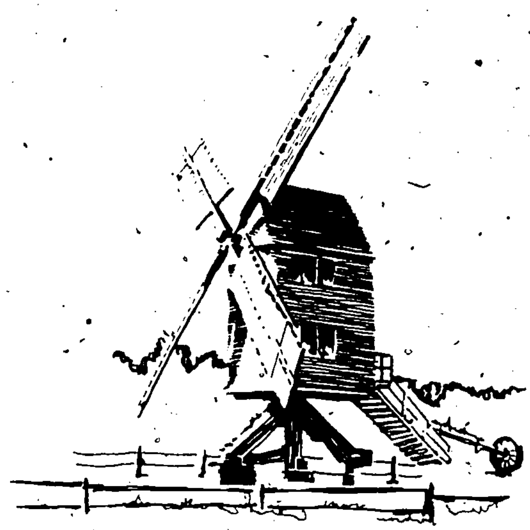
Wind is a form of energy given to us by the sun. Behind it is the simple principal that warm air rises and cool air falls. All the sun's rays that make up a bright summer's day do not reach the earth. Clouds, mountains, and hills block sunlight at scattered parts of the earth. Also, because of the tilt of the earth, less solar energy is received by polar regions than by the regions closer to the equator. As air rises from the more heated places, heavier, cooler air from less heated areas moves horizontally across the earth to take its place. We feel this air movement as wind. This alternate emptying and filling of air spaces goes on ceaselessly throughout the world; sort of breathing on a planetary scale!

Since early history, the wind has been harnessed to power windmills. In the tenth century, Persians were using windmills to grind grain. Later followers of Ghenghis Khan brought the idea of windmills to the East when they returned home to China. Many of the oriental windmills were used to pump water to irrigate crops. By the end of the twelfth century, they were found throughout northern Europe. The picturesque Dutch windmills, which are so familiar, were the means by which sea water was pumped from low lands, turning them into rich farmlands. By the end of the thirteenth century, Italy was using windmills, but Don Quixote didn't tilt at one until the sixteenth century. Windmills weren't introduced into Spain until the previous century.

Soon after English settlement in America, windmills were common throughout the 13 colonies, especially along the coast. They were used for a variety of purposes: milling flour, sawing lumber, and grinding axes. They, along with water mills, were the only source of power outside of human and animal muscle. A splendid reproduction of a colonial American windmill can be seen today in Williamsburg, Virginia.



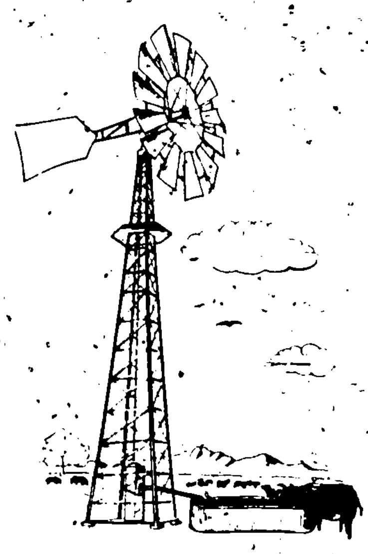

Diagrams showing how a windmill of ancient Persia worked. The rotor of this windmill was mounted on a vertical axis.



The reconstructed Robertson windmill at Colonial Williamsburg, Virginia.

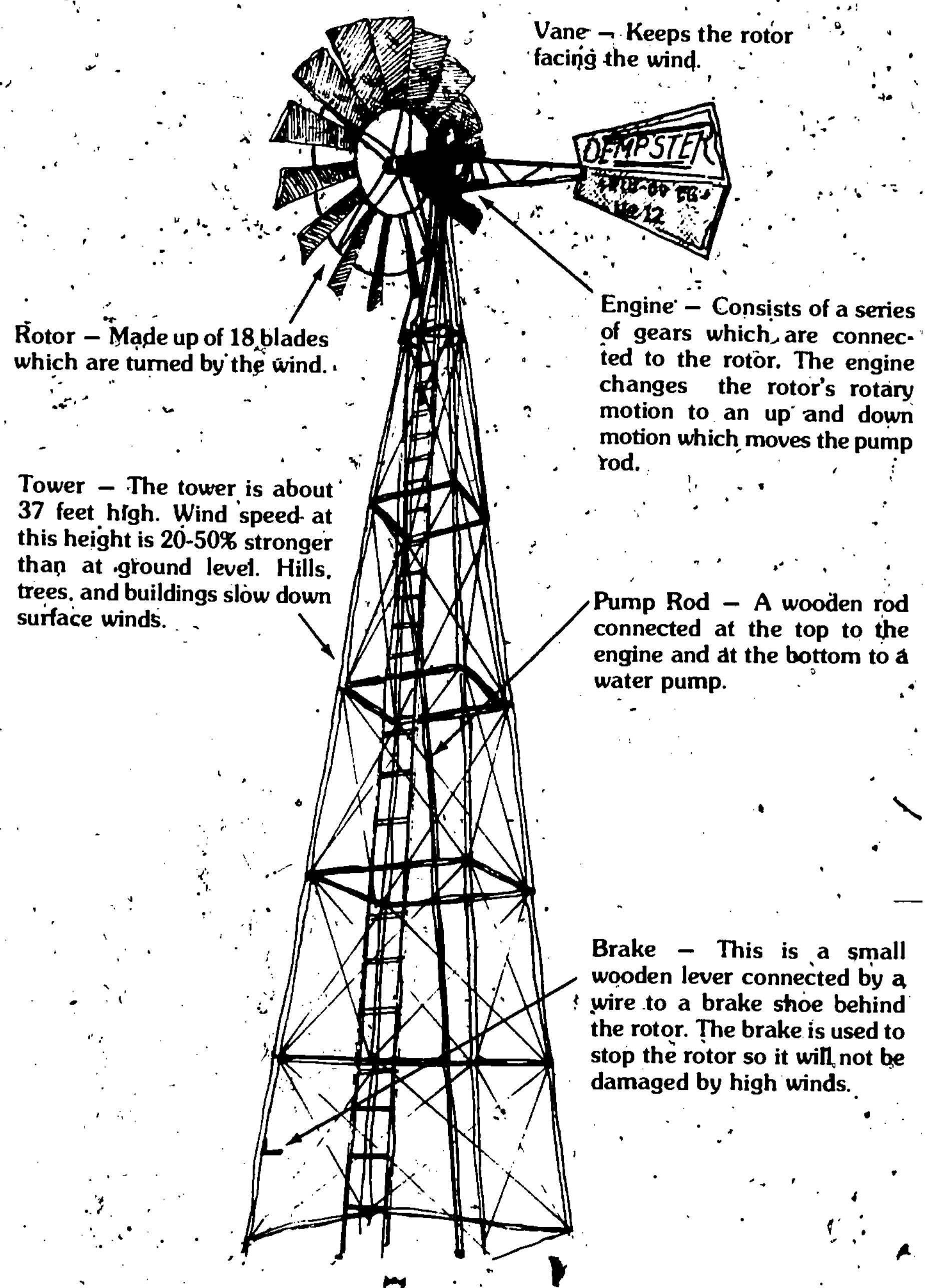
## The American Multi-bladed wind pumper.

This windmill, better termed wind pump, is a type that was commonly used to pump water. It was previously located on a farm near Laytonsville and was donated by the owner to the Smith Center in 1977. It was cleaned, painted, and spruced up by students in Montgomery County. The pumper was manufactured by the Aeromotor Company of Chicago in about 1925. Its rotor is made up of 18 blades and has a diameter of eight feet. When used as a water pumper, the motion of the rotor moved a rod up and down. The rod, in turn, operated a pump at the tower bottom. In its heyday, it cranked out about 1/10 horsepower in a 15 mph wind and was capable of pumping 23 gallons of water a minute to a height of 25 feet. Water was pumped into tanks for use by cattle or to irrigate crops. In some places, the wind pump provided the only source of water for small towns. A family could even have the, then, luxury of running water in the house by pumping water into a tank about 20 feet off the ground and by connecting water pipes from the tank to the house.



**A wind pump used to supply drinking water for cattle.**

The water pumping windmill was invented by an American, Daniel Halladay, in 1854. For almost half a century these windmills were a familiar sight in rural America, particularly on the western prairie. Between 1880 and 1930, more than six and one half million windmills were built in the United States. Though far fewer in number now, many can still be seem on farms and ranches providing water for livestock. They are still being manufactured, and interestingly enough, their sales are increasing.


Vane — Keeps the rotor facing the wind.
DEMPSTER
Rotor — Made up of 18 blades which are turned by the wind.
Engine — Consists of a series of gears which are connected to the rotor. The engine changes the rotor's rotary motion to an up and down motion which moves the pump rod.
Tower — The tower is about 37 feet high. Wind speed at this height is 20-50% stronger than at ground level. Hills, trees, and buildings slow down surface winds.
Pump Rod — A wooden rod connected at the top to the engine and at the bottom to a water pump.
Brake — This is a small wooden lever connected by a wire to a brake shoe behind the rotor. The brake is used to stop the rotor so it will not be damaged by high winds.

# THE EARLY YEARS OF AMERICAN WIND GENERATORS

The idea of using windmills to generate electricity is not new. Beginning in the 1920's, thousands of farmers in the Midwest and Great Plains had wind-powered generators. They were huge, bulky machines weighing about 500 pounds and were mounted atop high towers. These generators were connected to storage batteries and provided between 1000 and 3000 watts of power, which was enough for all the lights and utilities of an average size house of the day. Despite their bulk and cumbersome batteries, they were cherished by the farmer's wife and family because they brought them the luxury of electricity for the first time. The beginning of the end came with the Rural Electrification Administration (R.E.A.) in the 1940's. This was a federal program, which brought electric lines and cheap power (about one cent per kilowatt) to rural America. Farmers, unable to resist such cheap electricity, forgot about their backyard generators. By the early 1950's, the last few wind generators were abandoned. On rare occasions, one can still be spotted from a remote, dusty, back road, its blade stilled and weathered, and its engine and tower rusting away. Now, the rapidly rising costs of electricity (the cheap rate promised by REA of one cent per kilowatt has increased to over seven cents per kilowatt) has renewed interest in wind generators.

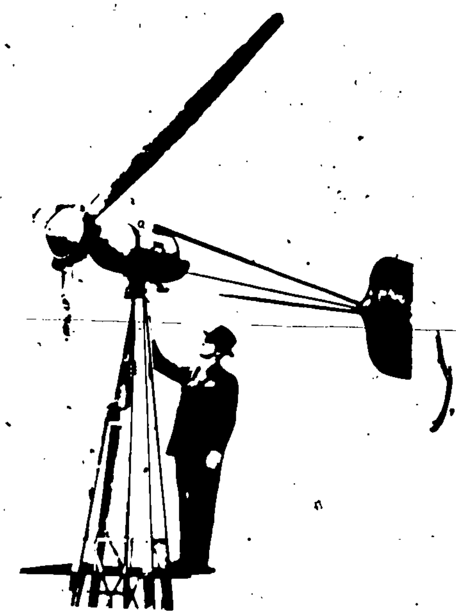


Photo Courtesy of Jacobs Wind Electric Company.

The Jacobs wind generator, the forerunner of modern wind machines, provided electricity for thousands of American farms and ranches beginning in the 1930's. Even now, the Jacobs is admired for its classic design and performance. Here the inventor, Marcellus Jacobs, poses atop a 1940's wind generator.

# 1800 WATT WIND GENERATOR

The 1800 watt wind generator at the Smith Center is the modern, more efficient version of the machines which lighted farmers' houses in the 1930's. It serves as a supplemental electric power source for the buildings at the Smith Center. It changes whatever energy is available on a windy day into useable electricity and sends this current into the building's wiring system. As more power is made by the wind generator, accordingly less is needed from the electric utility company. On days when there is no wind, all electricity comes from the utility company.

## How the Generator Works

The wind generator is mounted on a 50 foot tower because wind speed increases dramatically with height. As the rotor, consisting of three blades, is moved by the wind, it turns the axle on which it is mounted. The axle powers an electric generator located in the bullet-shaped housing behind the rotor. The spinning motion within the generator makes electric power which is carried by wire down the tower and into the Smith Center.

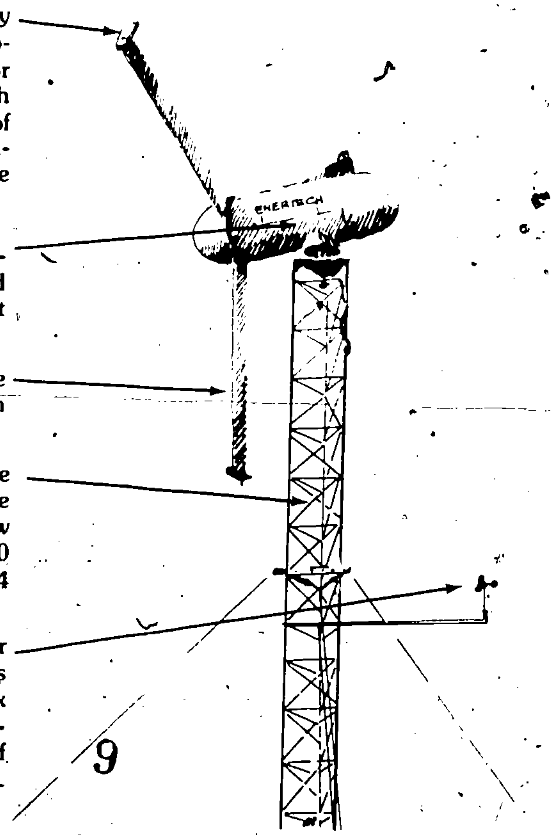
**Tip Brakes — These are emergency back-up brakes. Should the automatic brake behind the generator fail to work in dangerously high winds, the metal strips at the end of each blade swing out from centrifugal force, slowing the rotor to a safe speed.**

**Generator — The generator is located in the compartment behind the rotor. In a wind of 24 m.p.h. it produces 1800 watts.**

**Rotor — The rotor consists of three wooden blades and is 13 feet in diameter.**

**Tower — The 50 foot height of the tower places the generator above trees and other objects which slow the wind. When the wind is 10 m.p.h. at ground level, it is about 14 m.p.h. at the tower's top.**

**Anemometer — The anemometer measures wind speed and sends electric signals to the control box inside. The signals turn the generator on in winds of 10 m.p.h., and off when windspeed drops below 8 m.p.h.**



## Rotor

The rotor is 13 feet in diameter. Its blades are made from the wood of the Sitka spruce, the same wood used in the old wind generators of the 1920's and 30's. Sitka spruce is light and strong, and takes paint well. It is also straight-grained, which means that it can be shaped easily and resists warping and cracking.

## Generator

The generator is an inductive-type generator motor. An iron core within the generator is connected to the axle of the rotor. The core spins as the wind turns the rotor. Spinning around the core is a magnetic field, which is created by the revolving core. The interaction of the core with the moving magnetic field in which it is encased indirectly produces (induces) a current to flow in an electrical coil, which surrounds both the core and its magnetic field. This current is carried away by wires as usuable electricity.

An important concept in understanding the behavior of the wind generator is synchronous speed. Synchronous speed is reached when the iron core of the generator is turning at the same rate as the magnetic field surrounding it. This affects performance of the wind generator in the following ways:

1. At synchronous speed — This is produced by a wind speed of about eight mph. Again, rotor speed is equal to the speed of the revolving magnetic field within the generator. At synchronous speed, the machine is neither a generator (producing electricity) or a motor (using electricity).

2. Above synchronous speed — The wind generator is designed to produce electricity only when the revolving magnetic field is turning faster than the rotor. Above synchronous speed (eight mph), the turning of the rotor begins forcing this field to revolve at a faster rate than the rotor, itself, is moving, thus making the machine an electric generator.

As wind speed increases, the rotor speed remains about constant. At first this seems hard to understand. The reason for it is that, with increased wind speed, greater and greater magnetic forces are created, which act to slow down the rotor. As changes in the magnetic field occur to break the rotor's speed, that much more electric current is induced in the surrounding coil. So the extra force of the winds, which one would predict would move the rotor faster, is consumed in the work needed to make more electricity.

3. Below synchronous speed — Below eight mph, the electrical field is revolving slower than the rotor. No electricity is being produced. Not only that, but because the generator is wired to utility power, it becomes a motor below synchronous speed and would use electric power if the blades of the rotor were allowed to turn.

## CONTROL FEATURES

### Anemometer

The anemometer, with the cup-shaped hands, is mounted just below the top of the tower. Its rotation measures wind speed and sends electric signals to a printed circuit in the control box, which averages wind speed, and turns the generator on or off.

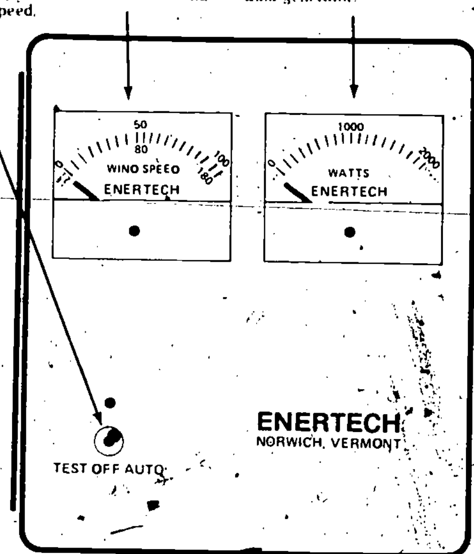
### Control Box

On the left side of the control box is a wind speed indicator, which shows wind speed as measured by the anemometer on the tower. In winds of less than eight mph, the generator acts like a motor and draws utility electricity to rotate its blades. When winds exceed eight mph, the machine acts as a generator and produces electricity. Therefore, an automatic switch in the control box stops or brakes the rotor at speeds of eight mph or less and starts it again in winds of ten mph or more. Ten mph is the start-up speed to prevent the generator from going on and off too frequently when winds are hovering around eight mph. The averaging circuit in the control box also prevents frequent on and off switching by preventing the generator from starting up until an average wind speed of 10 mph is reached for about 20 seconds. On the right side of the control box is an output meter which shows the amount of electricity being generated in watts. It is this meter which graphically shows the economic advantage of the wind generator. As the needle moves further to the right, less and less watts are needed from the utility company!

Wind speed meter. Receives signals from anemometer near top of tower to indicate wind speed.

Watt meter. Shows the amount of electricity produced by the wind generator.

Three way switch.
AUTO – Normal operating position. Generator automatically turns on in wind speed of 10 m.p.h. and turns off automatically when winds are 8 m.p.h. or less.
OFF – Position used when high speed winds or ice storm might damage blades and generator.
TEST – Position used for troubleshooting or testing. In TEST position the generator becomes a motor and turns the blades using utility power when wind is less than 10 m.p.h.



## Automatic-Off Test Switch

This switch is located on the control box. Its three positions control the wind generator in the following ways:

**Automatic** — This is the normal operating mode of the wind generator. With the switch in this position, the generator will:

1. Turn on automatically with winds averaging ten mph
2. Shut down when winds drop to eight mph or when they exceed 40 mph.
3. Generate usuable electricity when running as indicated on the output meter.

**Test** — This position is used for testing and trouble shooting. The machine will run at any speed on **Test** below 40 mph, but below eight mph, it will turn into a motor and draw utility power to turn the rotor. This is the only position where the blades will turn without wind.

In **Test** position, the reading on the watt meter shows how much utility power is being used to turn the rotor.

**Off** — Moving the switch to **Off** disconnects utility power to the generator. Whenever outside power is cut off, a hydraulic brake stops the rotor. **Off** position is recommended during prolonged, extreme winds, such as hurricanes, or during ice storms.

## Brakes

Excessive rotor speed caused by high winds can seriously damage the blades and generator, so some form of braking device is very important. The main brake is located behind the generator. It's electrically controlled and automatically stops the rotor in winds above 40 mph. It also stops the rotor in winds below eight mph to prevent the machine from drawing power. Should the utility power fail, such as during a severe storm, the sudden loss of current triggers the brake automatically, causing the rotor to stop. When power is restored, the brake is released. The tip brakes located at the end of each blade provide a back-up braking system. Should the main brake fail, a rotor speed of 100 rpm above normal causes centrifugal force to pull the tip brakes out. This causes drag on the blades that slows and eventually stops them.

## Vanes

Most older windmills such as the Smith Center's multi-bladed pumper were upwind machines, i.e., the blades were upwind from the tower. In such machines, wind strikes the rotor from the front and a large vane behind the blades keeps them facing the wind. The 1800-watt wind generator, on the other hand, is a downwind machine, because the rotor is downwind from the tower. When the wind blows, the rotor always moves into a position so the wind strikes the blades from behind. The rotor, then, is the machine's windvane!

# FACTORS AFFECTING WINDMILL PERFORMANCE

## Wind Speed

The amount of power produced by a wind generator is equal to the cube of the wind's speed. This means that when speed doubles (say from eight mph to 16 mph), eight times as much power is produced $\left(\frac{16 \times 16 \times 16}{8 \times 8 \times 8} = \frac{4096}{512} = 8\right)$!

As can be seen on the chart below, even a small increase from eight mph to ten mph nearly doubles the electrical output. Average winds of at least eight mph are required for the 1800 watt wind generator to produce appreciable amounts of power. In winds of 14-20 mph, there is substantial power output.

| Average windspeed in miles per hour: | 8 | 10 | 12 | 14 |
|---|---|---|---|---|
| Estimated monthly output: | 120 kwh | 240 kwh | 370 kwh | 500 kwh |

One of the obstacles facing the wind energy movement is that there are few sites where detailed wind data is available. The Smith Center is fortunate to have a state air monitoring station about 200 feet from the wind generator, which has measured and recorded wind speed during 1980-81. According to this data, the average wind speed at the top of the 50 foot tower was between eight-ten miles per hour during the school year (September to June ). The chart above indicates that such winds would produce between 120 to 240 KWH, enough power to light one or two rooms at the Smith Center.

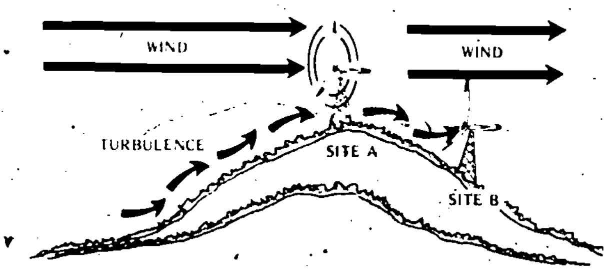
## Tower Height

The tower of the 1800 watt generator is 50 feet high. Towers should be at least 40 feet high, and preferably 60-100 feet in height. There are two reasons for this. First, the amount of wind energy rises dramatically with height because surface features such as trees and buildings catch and slow the wind. Friction with the ground slows wind even as it blows over flat, treeless surfaces. Secondly, a tall tower places the wind plant above any constructed or natural objects. Such objects not only create turbulence but wind shadow, a place where the wind has been blocked by obstacles. To illustrate the advantage of a high tower, in a wind of ten mph at ground level, the Smith Center generator will produce 125 watts. But, with the same wind, it generates 500 watts at 40 feet and 700 watts at a height of 100 feet. A general rule of thumb is to use a tower 30 feet higher than any obstacles within a radius of 100 yards.

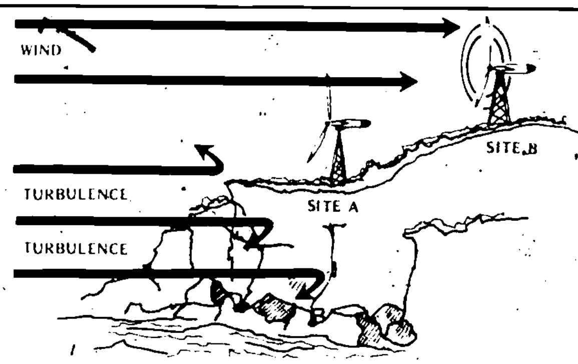
## Tower Location

Obstructions of various types, such as mountains, cliffs, and trees, all can block a generator from the best available winds. These obstacles cause turbulence, which is air movement with up or down currents. Because their rotors are designed to be turned by horizontal air movement, wind generators produce no power in turbulence. The three diagrams illustrate ways to catch good winds and avoid turbulence.

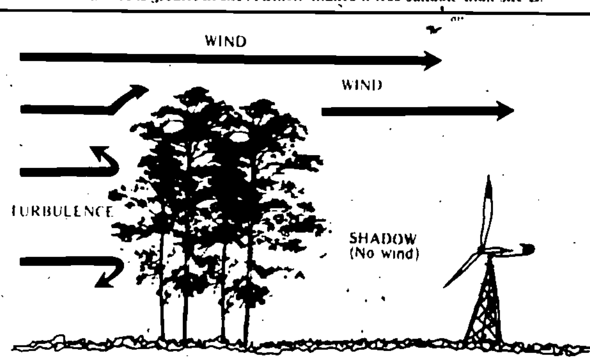
**Windmill should be located so as to avoid turbulence and wind shadow.**




Turbulence at site B makes it less suitable than site A.



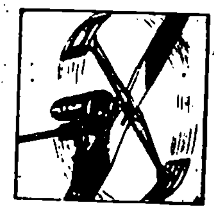

Turbulence is greater at site A which makes it less suitable than site B.



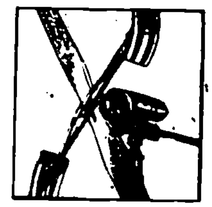

The trees at this site make a wind shadow which makes the site unsuitable.

## 200 WATT WIND GENERATOR

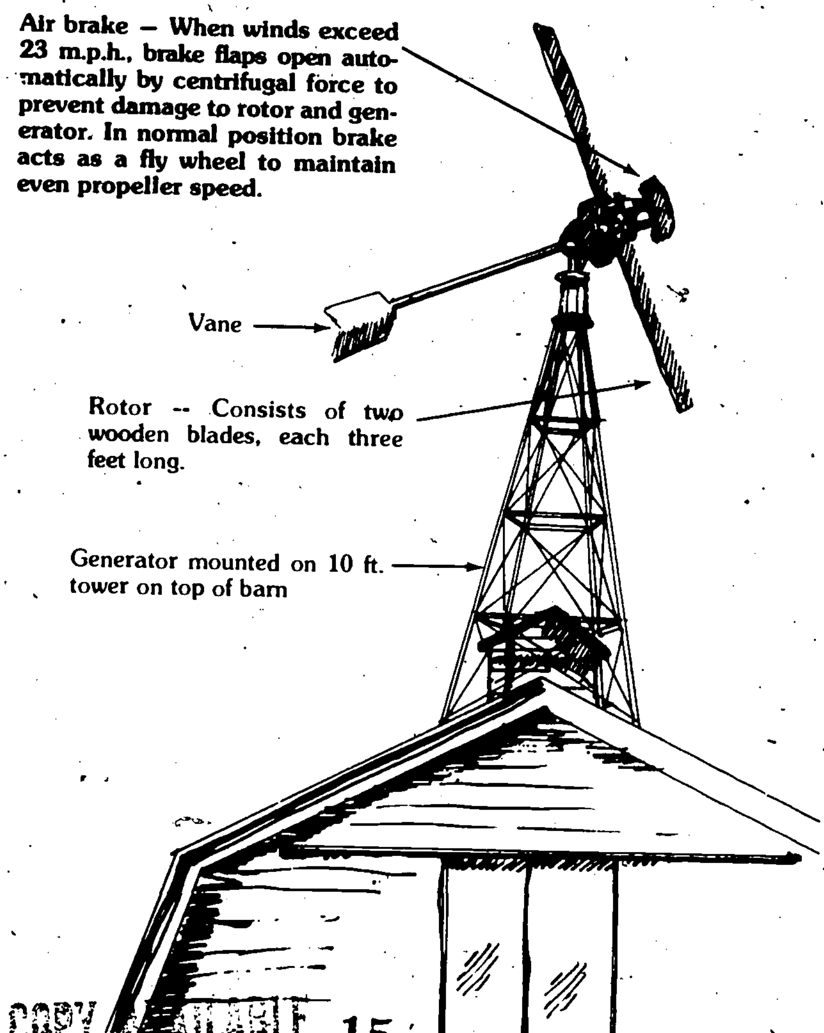
This generator is mounted on a ten foot tower on top of the barn. It is connected to a series of batteries which provide elecricity for interior and exterior lights on the barn.



normal



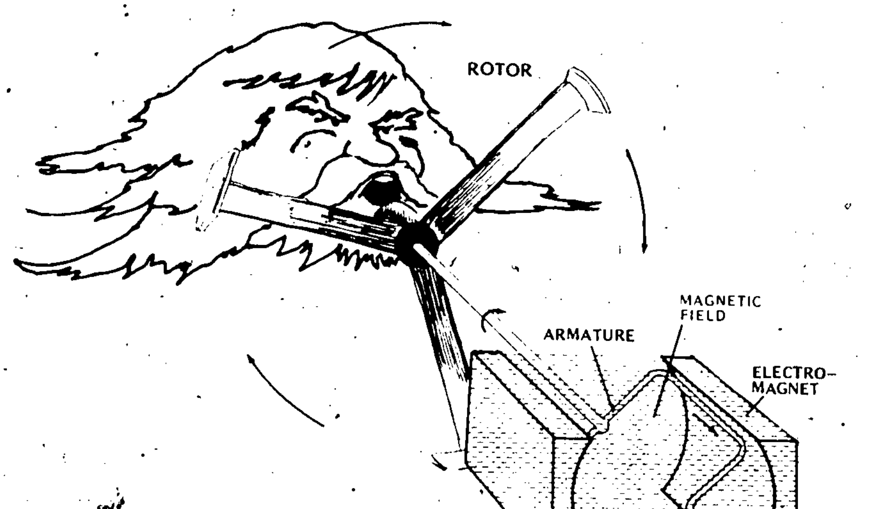
braking

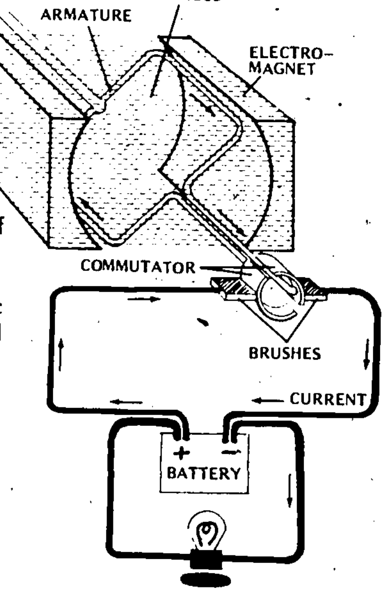


## How the Generator Works

Unlike the 1800 watt generator which produces alternating current (A.C.), the 200 watt wind generator provides direct current (D.C.), which is the same type produced by storage batteries.

In general, whenever a magnet is passed in and out of a wire coil current is caused to flow in the wire. This wind generator is designed around this principle. The blades making up the rotor are connected to a core, called an armature, in the center of the generator. As the rotor turns in the wind, it rotates wire loops of the armature as seen in the illustration. As the wire loops pass through the magnetic field, electricity is generated in the loop. The current is carried away to charge a series of batteries. Energy from the batteries is then available to power the barn lights when needed.




**1) The wind turns the rotor which causes loops of wire (armature) within the generator to rotate.**

**2) As the armature passes through the magnetic field between the magnets, a current is caused to flow in the armature.**

**3) The two wires from the armature are connected to a split ring (commutator) which is made to spin by the rotating armature.**

**4) As the commutator spins, carbon contacts (brushes) touch the spinning commutator and carry electricity to storage batteries which provide power to the light bulb.**

### Batteries

There are four 12 volt batteries which are charged by the generator. They are similar to automobile batteries in the amount of power they supply. Unlike car batteries, they can be charged and recharged many hundreds of times and still perform well. By connecting the generator to batteries, a constant source of power is available, regardless of changing winds. Electrical energy that is produced during good winds (10-20 mph) can be stored and used later when there would be only a light breeze or no wind at all. The generator starts to charge batteries in a seven mph wind and reaches its maximum charge of 400 watts in a wind velocity of 23 mph. It provides about 20 kilowatt hours of electricity per month with winds averaging ten mph. This is sufficient power to light two 40 watt bulbs in the barn every night for eight hours.

### Vane and Rotor

The rotor has two wooden blades and is six feet in diameter. It is upwind from the tower, which means that wind strikes the blades from the front. Mounted on a rod behind the generator is a small vane, which keeps the rotor facing the wind.

## ECONOMIC ADVANTAGES

### Kilowatt Hours

The cost of electric power is based on how many kilowatt hours (KWH) of power are used each month. Kilowatt hours are found by multiplying the watts which an appliance uses by the number of hours it is running and dividing that number by 1000. For example, if you use a 100 watt lamp for ten hours, you will add one kilowatt hour to your electric bill.

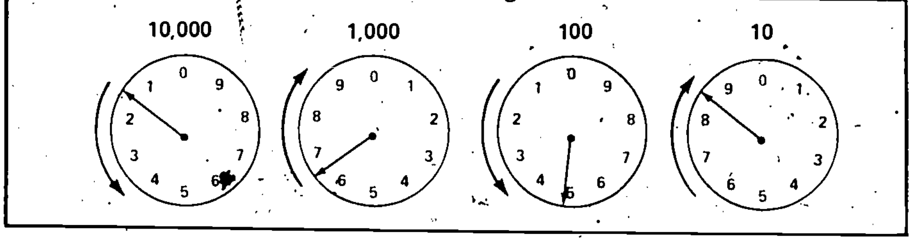
$$\frac{\textbf{100 watts x 10 hours}}{\textbf{1000}} = \textbf{1 KWH}$$

## ELECTRIC METER

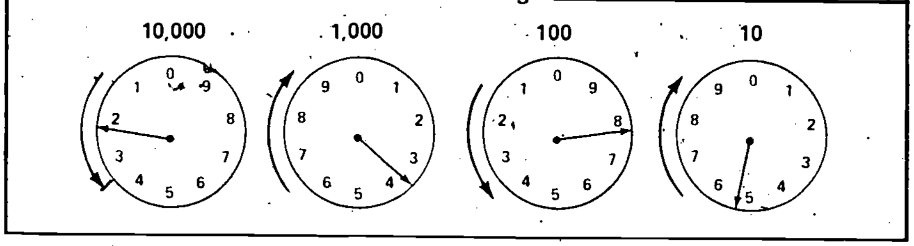
Mounted on the wall of the Retriever Room next to the control box is an electric meter. It's just like the ones mounted on the sides of homes, with one important difference. House meters provide the information necessary to figure an electric bill by showing how much power has been used over a period of time.

This meter indicates the amount of power the wind generator has produced, or how much electricity does not have to be paid for. Electrical energy consumption is measured in kilowatt-hours. The diagram below shows a typical home kilowatt-hour meter at two different times. The first reading is on the top. A second reading a month later is on the bottom. The steps below show how the meter is read.

**First reading.**



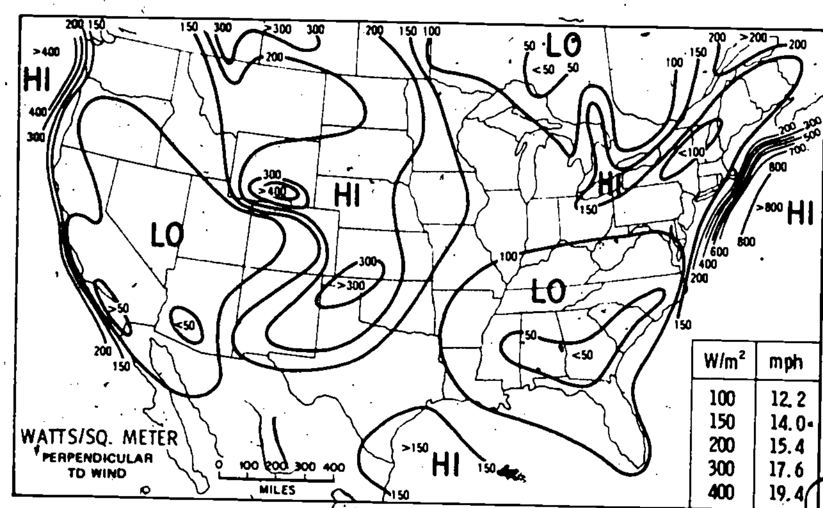

**Second reading.**




1. Read the meter shown at the top. Start with the small dial on the left (10,000 kwh) and read left to right. Always record the number that the hand has just gone by, going from lowest to highest. For example, on the 10,000 kwh dial, the hand has just gone by 1; so you should write down 1 as the first number. Next you should read the 1,000 kwh dial, with 6 being the number the hand has just gone by. For the next two dials, the numbers would be 4 for the 100 kwh dial and 8 for the 10 kwh dial. The completed reading should be read as 1,648 kilowatt-hours.
2. Now read the meter shown at the bottom using the same procedure. Your answer should be 2,375 kilowatt-hours.
3. To find the amount of energy used between the times the observations were made, you subtract the first reading from the second. For example: 2,375 kwh − 1,648 kwh = 727 kilowatt-hours.
4. To find your electric bill, multiply 727 by the rate (assume \$.07 per kwh): 727 x \$.07 = \$50.89.

Because of its smaller output, the wind generator kilowatt-hour meter readings after a month's time would look more like this:

1. Second reading = 0874
2. First reading = <u>0521</u>
3. KWH saved = 353
4. 353 x \$.04 (school rate) = \$14.12




Map courtesy of Sandia Laboratories.

This map shows the amount of wind power in watts which is produced by placing a square meter ($m^2$) of sail perpendicular to the wind. The map is very general and is based on prevailing wind patterns. Local winds, caused by lakes, mountains, and other natural features, can cause large variations in the figures shown on the map.

The Smith Center is close to the $100/m^2$ line. Assuming wind machines are about 25% efficient, the 1800 watt wind generator (which has a rotor of 14 $m^2$) would contribute the following percentages of electic power to a family that uses 600 kilowatt hours per month:

| | |
|---|---|
| **Montgomery County, Maryland** | **20-30%** |
| **Atlanta, Georgia** | **15-25%** |
| **Cheyenne, Wyoming** | **150-200%** |
| **Cape Cod, Mass.** | **75-100%** |

## Savings for a House

A typical house with four family members uses about 700 KWH per month, assuming the house has no air conditioning, but an electric stove, clothes dryer, refrigerator, automatic washer, exhaust fan, color television, and other small appliances. The present retail rate of electricity in Maryland is about seven cents per KWH. This makes the family's monthly bill $49.00. If the family had an electricity generating windmill in the backyard and lived in an area with an average ten mph wind, the wind would pay for 25 pecent of their bill and save them $12.25 monthly!

## ENVIRONMENTAL ADVANTAGES

The wind is a renewable, alternative energy source, which can lessen our need for conventional fuels. Energy made from oil, coal, and atomic power have side effects, which can harm people and the environment. Coal blackens the lungs of miners, pollutes the air, and causes acid rain. Oil spills destroy sea life and degrade beaches. Even so, oil and coal are gifts from nature and represent millions of years of condensed solar energy. Many question whether it is morally right to squander these resources, leaving future generations with none.

Atomic energy also has disadvantages because of the danger of radiation from nuclear accidents. In addition the tons of nuclear waste piling up yearly at atomic plants will be radioactive for tens of thousands of years, and storing it on earth is a continuing concern.

Wind energy will last as long as the sun is in the sky. It does no harm to air, water, or life. Perhaps most importantly, wind energy fosters a kind of ethic, which makes one less tolerant of waste. Many of our so-called convenience appliances are very wasteful of energy. A 12 cu. foot frostless refrigerator for example, uses 70 percent more power than one that is not frostless. A window air conditioner, cooling one room, requires about five times as much electricity as an attic exhaust fan which will cool the entire house. With a wind generator in the back yard producing a steady, but only modest, amount of power, one would quickly discard needless appliances to conserve energy, which not only would be economical but would promote an environmentally sensitive life style.

# ADDITIONAL INFORMATION

## Books

1. ***Electric Power from the Wind.*** Henry Clews, Enertech, 1974. P.O. Box 420, Norwich, Vermont 05055.
2. ***Energy Primer.*** Portola Institute, 1974. Menlo Park, California.
3. ***Handbook of Homemade Power.*** Mother Earth News, Bantam Books, 1974. New York, N.Y.
4. ***Wind Catchers.*** Volta Torrey, Stephen Greene Press, 1976. Brattleboro, Vermont.
5. ***Wind Machines, Second Edition.*** Frank R. Eldrige, Van Nostrand Reinhold Co., 1980. New York, N.Y.
6. ***Windmills and Watermills.*** John Reynolds, Praeger Publishers, 1970. New York, N.Y.

## Periodicals

1. ***Alternate Sources of Energy.*** Route 2, Box 90A, Milaca, Minnesota 56353. (Quarterly).
2. ***The Mother Earth News.*** P.O. Box 70, Hendersonville, North Carolina 29739. (Bi-monthly).
3. ***Government & Other Resources***

   National Climatic Center, N.O.A.A.
   Environmental Data and Information Service, Federal Building, Asheville, North Carolina 28801.

   The American Wind Energy Assn., 1621 Conn. Ave., N.W., Washington, D.C. 20009.

## Films (available from MCPS Film Library)

1. **8017 WIND POWER,** Electric Power Research Institute, 1981.
2. **8018 SUN POWER,** Electric Power Research Institute, 1981.
3. **8019 HARNESS THE WIND,** Bullfrog Films, 1979.
4. **8020 SOLAR PROMISE.**

## Glossary

**Anemometer** — A device which, as it is turned by the wind, measures wind speed.

**Average Wind** — A location's average wind speed as measured over a long period of time.

**Downwind** — A characteristic of a windmill where the rotor (blades) are downwind from the tower. In such machines, the wind strikes the rotor from behind.

**Energy Winds** — Winds with speeds of 10-25 miles per hour. They blow, on the average, two out of seven days, but provide most of a wind generator's power.

**Kilowatt Hour (KWH)** — The unit by which the cost of electric power is measured.

$$\frac{\text{Watts of Appliance x Hours Used}}{1000} = \text{Kilowatt Hours}$$

**Local Winds** — Winds which are the result of local features such as seashores, lakes, mountain tops, etc.

**Prevalent Winds** — Winds which are continental in scope and which predominate each month. They consist of 5-15 m.p.h. winds, and they blow about five out of seven days.

**Rotor** — The blades of a windmill.

**Turbulence** — Irregular air movement characterized by up and down wind currents.

**Upwind** — A characteristic of windmills where the rotor (blades) is upwind from the tower. In such machines the wind strikes the rotor from the front.

**Vane** — The tail behind some windmills which keeps the rotor facing the wind.

**Wind** — Horizontal movement of air across the earth's surface.

**Wind Shadow** — A windless condition produced when tall objects, such as trees and buildings, block the wind's movement.

**WIND ENERGY PROGRAM**

| | | |
|---|---|---|
| Lathrop E. Smith Environmental Education Center | | 5110 Meadowside Lane<br>Rockville, Maryland 20855 |
| Owner of Wind Machines: | | Montgomery County Public Schools<br>850 Hungerford Drive<br>Rockville, Maryland 20850 |
| 1800 Watt Wind Generator: | Manufacturer | Enertech Corporation<br>P.O. Box 420<br>Norwich, Vermont 05055 |
| | Output | 1800 watts in winds of 24 m.p.h. |
| | Tower | steel, 50 feet in height |
| | Rotor | three wooden blades, 13 feet in diameter |
| 200 Watt Generator: | Manufacturer | Dyna Technology, Inc.<br>P.O. Box 3263<br>Sioux City, Iowa 51102 |
| | Output | 200 watts in winds of 23 m.p.h. |
| | Tower | steel, 10 feet in height |
| | Rotor | two wood blades, 6 feet in diameter |
| Wind Pumper: | Manufacturer | Aeromotor Company (1925)<br>Chicago, Illinois |
| | Output | 1/5 h.p. in 15 m.p.h. wind |
| | Tower | steel, 37 feet in height |
| | Rotor | 18 steel blades |
| Distributor for Wind Generators: | | The Energy Store<br>9130 Red Branch Road<br>Columbia, Maryland 21045 |
| Supervisor, Outdoor Ed. Programs: | | Joe Howard<br>Lathrop E. Smith Environmental Education Center |
| Consultants: | Staff | Division of Extractive Industries<br>National Museum of American History<br>Smithsonian Institute<br>Washington, D.C. 20560 |

OUTDOOR EDUCATION PROGRAM

Montgomery County Public Schools