America takes stock of a vast energy resource

Utility Wind Interest Group

Average Annual Wind Power of the United States

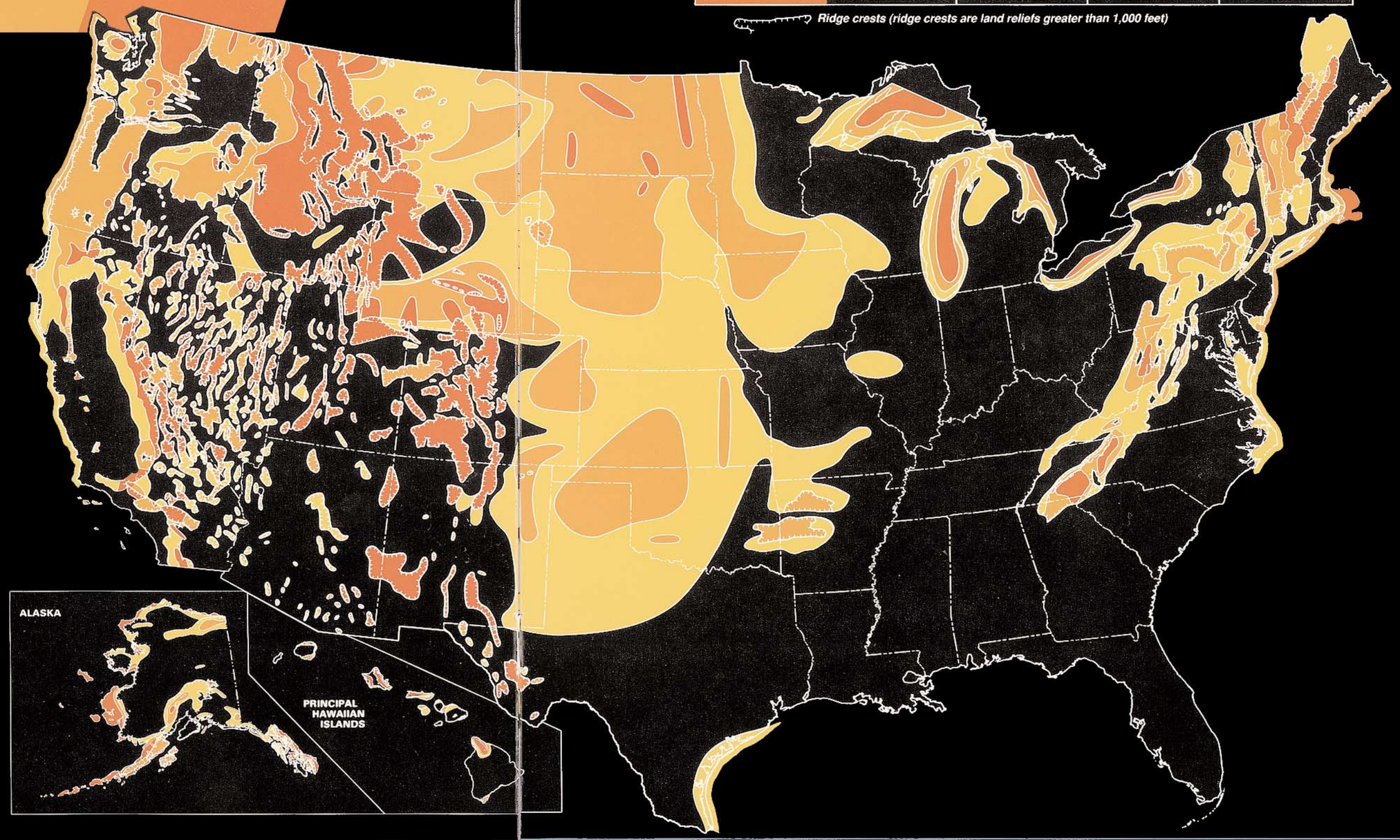
Moderate wind energy resource

Good wind energy resource

Excellent wind energy resource

Wind Power Class	Wind Energy Resource Potential	Wind Power Density at 30 m [W/m^2]	Wind Speed at 10 m [mph]	Wind Speed at 30 m [mph]
3	Moderate	240–320	11.5–12.5	13.4–14.6
4	Good	320–400	12.5–13.4	14.6–15.7
5-7	Excellent	400+	13.4+	15.7+

Ridge crests (ridge crests are land reliefs greater than 1,000 feet)



Wind Power Classes

The energy contained in wind is expressed in terms of wind power classes, ranging from class 1 (the least energy) to class 7 (the greatest). Wind power classes are based on the average "wind power density," expressed in watts per square meter (W/m^2), which incorporates in a single number the combined effects of the time variation of wind speed and the dependence of wind power on both air density and the cube of the wind speed. Each wind class is based on a range of average wind speeds at specified heights above the ground. In the same wind power class, the energy contained in the winds at 30 meters (m) above the ground is 60% greater than the power density at 10 m (assuming the site-average wind speed increases with height according to the "1/7 power law" that is typical of large areas on the Great Plains). At U.S. weather stations, most wind data are taken about 10 m above the ground.

Local Terrain Affects the Wind

The adjacent map represents the average annual wind power density for well-exposed locations free of obstructions to the wind. These areas include plains, tablelands, hilltops, ridgelines in mountainous terrain, and large clearings in forested areas. Local terrain features that do not show up on the scale of this map greatly affect the amount of energy in the winds at any specific location. High wind areas may occur within regions shown here as generally having lower winds.

WIND POWER

A Vast Energy Resource

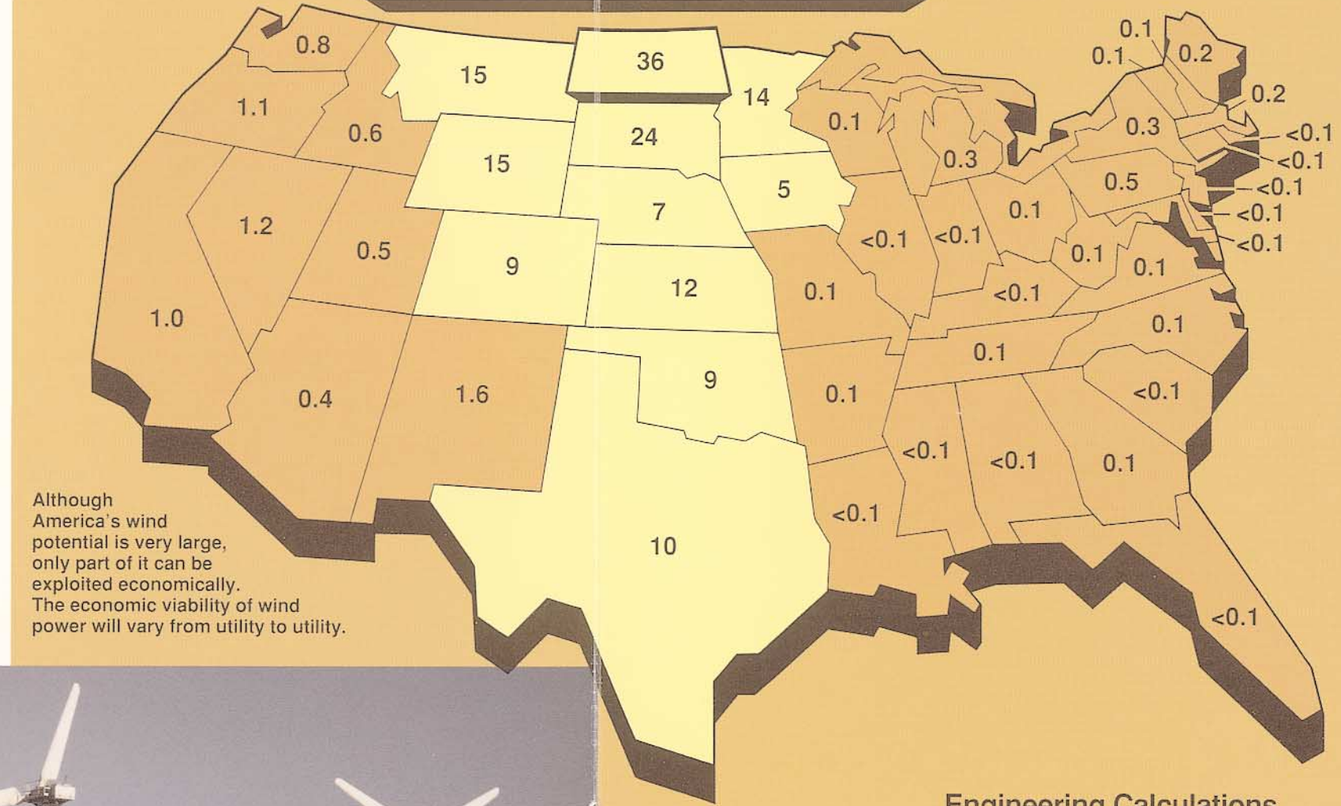
With today's wind turbine technology, wind power could supply 20% of this country's electricity, according to a recent study by Pacific Northwest Laboratory (PNL). Today's technology exploits high-wind locations—those in wind power class 5 or greater—with average annual wind speeds of approximately 16 mph and higher at a height of 30 m. To provide 20% of America's electricity, 560,000 million kilowatt-hours (kWh) per year, 0.6% of the land of the lower 48 states would have to be developed with wind power plants. This area, about 18,000 square miles, is about the size of four counties in Montana. Furthermore, less than 5% of this land would be occupied by wind turbines, electrical equipment, and access roads. Most existing land use, such as farming and ranching, would remain as it is now.

The PNL study found that almost every region of the country has some areas of good wind energy resources. In fact, the Northeast, Northwest, Southwest, and Atlantic Coastal regions all contain significant wind energy resources. And some states, such as those that lie on the Great Plains from Texas to North Dakota, have a huge electricity-generating potential from the wind. The wind potential from each of these states far exceeds its current electricity consumption.

Wind Resource of Each State

as a Percentage of 1990 Electrical Consumption of the Lower 48 States

This map shows the contribution that wind energy could make to the electrical needs of the entire nation. For example, North Dakota alone has enough energy from good wind areas, those of wind power class 4 and higher, to supply 36% of the 1990 electricity consumption of the lower 48 states.



Although America's wind potential is very large, only part of it can be exploited economically. The economic viability of wind power will vary from utility to utility.

Energy in winds of wind power class 4 and higher have the potential to supply more than one and a half times the current electricity consumption of the United States, according to another study by PNL. Technology under development today will be capable of producing electricity economically from good wind sites (wind power class 4) in many regions of the country by the year 2000. In this study, 6% of the contiguous U.S. land area is considered to be available for wind power plant development.

Land Not Considered for Wind Development

The following land areas, totaling 35% of the windy land area in the United States, are excluded from consideration for development of wind power plants in the projections of this study:

- 100% Environmentally restricted
- 100% Wetlands
- 100% Urban
- 50% Forest
- 30% Agriculture
- 10% Range

Engineering Calculations

In addition, the following assumptions were made in estimating the potential electricity production from the wind:

- Class 4 and higher winds exploited (at least 320 W/m^2)
- 30-m hub height
- Turbine spacing 10D x 5D (D = rotor diameter)
- 25% wind-to-electricity conversion efficiency
- 25% additional losses (array effects, transmission losses, etc.)

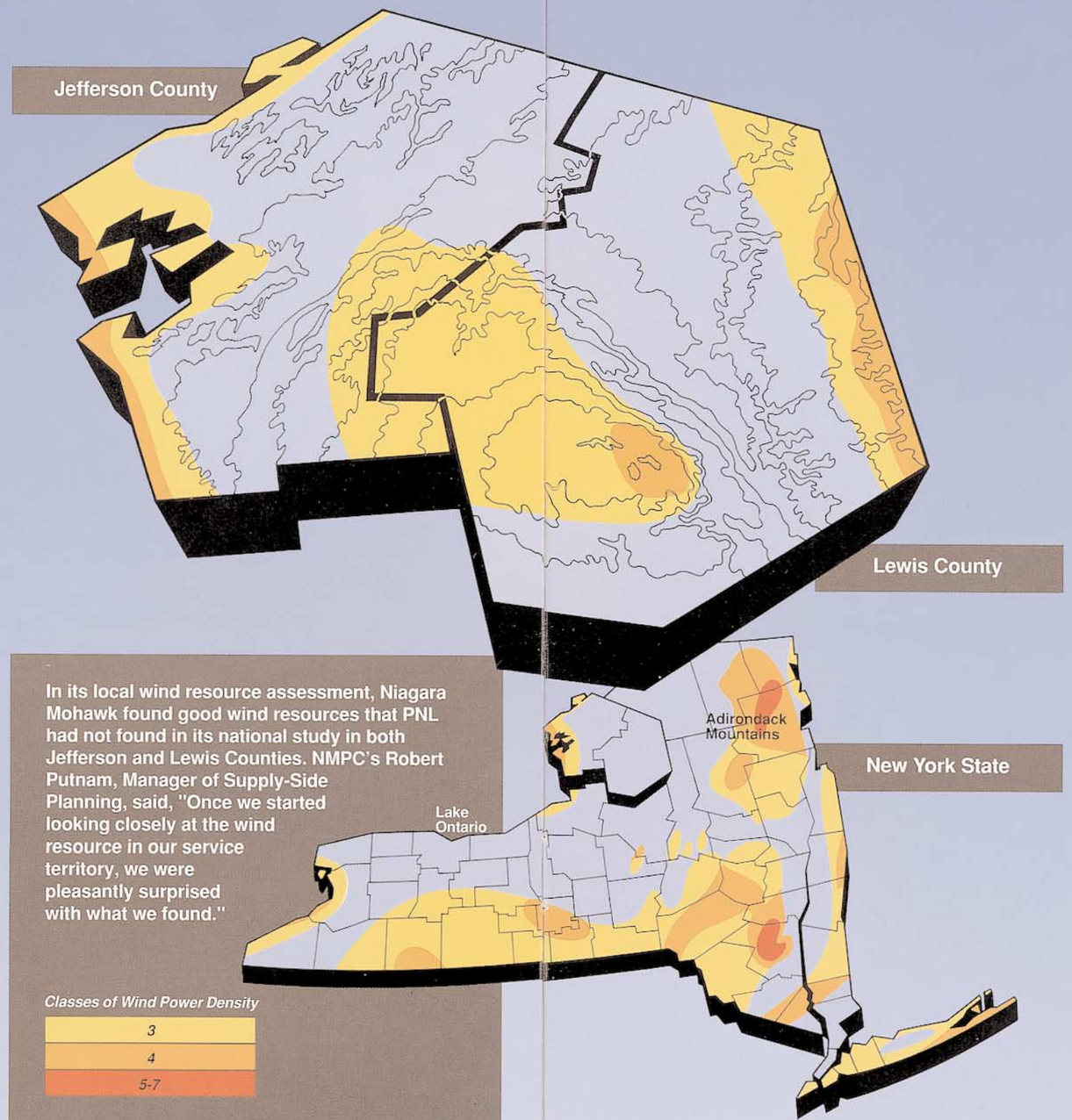
Resource Assessment Is the Essential First Step

The large size and site-specific nature of the wind energy resource point to the need for well-planned assessments. Local terrain has a strong effect on the amount of energy in the wind at a given location, and a thorough study of the wind at a particular site is advisable before any wind turbine installations begin.

A site-specific wind resource assessment study provides other important information in addition to average annual wind speeds. For example, a utility would be interested in the correspondence of the wind at a particular location with the utility's seasonal and daily peak-load profiles. Problems such as potentially damaging turbulence and high winds must be identified before a particular wind turbine design is selected for a particular location. In addition, utilities can use information that is available locally, such as county zoning restrictions and the presence of transmission lines, to determine the value of the local wind resource.

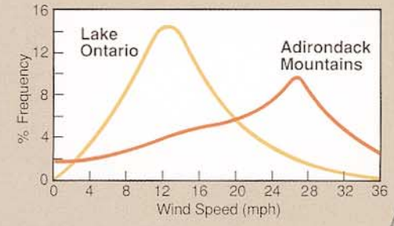
States can help utilities assess wind energy. Experience has shown that attractive sites are found that do not show up on the larger scale national maps. New York, for example, has found areas of high average wind speeds on ridges in the Adirondack Mountains and near the shores of Lake Ontario. Niagara Mohawk Power Corporation (NMPC) of Syracuse, New York, used this information to carry out its own resource assessment near the shores of Lake Ontario. In addition to helping utilities identify high-wind areas, states can identify other areas that will be excluded from wind development. Much of Long Island, for example, has high average winds, but it is unlikely that Long Island will be developed to accommodate wind power plants because of existing land use.

Utilities can determine the wind resource inside their territory with little financial risk. They can identify large areas of good potential with a small number of anemometers (to measure wind speeds). They can also take advantage of national studies, such as those from PNL, and state studies, where available, by placing their anemometers in regions already identified as promising.



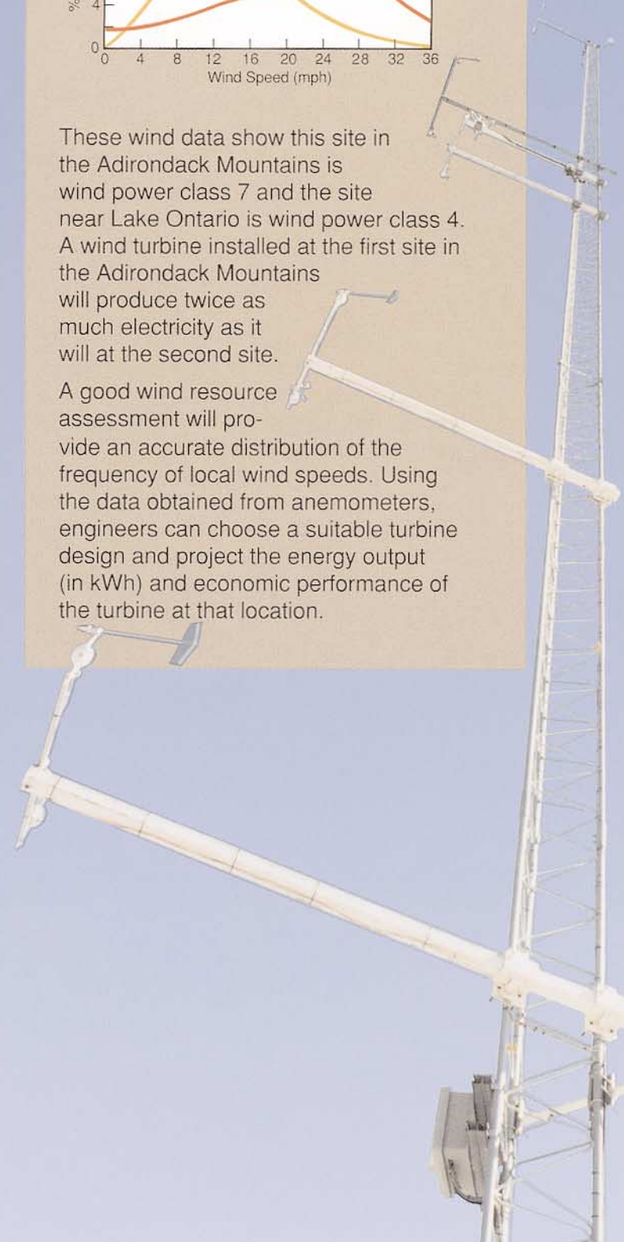
In its local wind resource assessment, Niagara Mohawk found good wind resources that PNL had not found in its national study in both Jefferson and Lewis Counties. NMPC's Robert Putnam, Manager of Supply-Side Planning, said, "Once we started looking closely at the wind resource in our service territory, we were pleasantly surprised with what we found."

Wind-Speed Distributions for Two Geographic Settings in New York

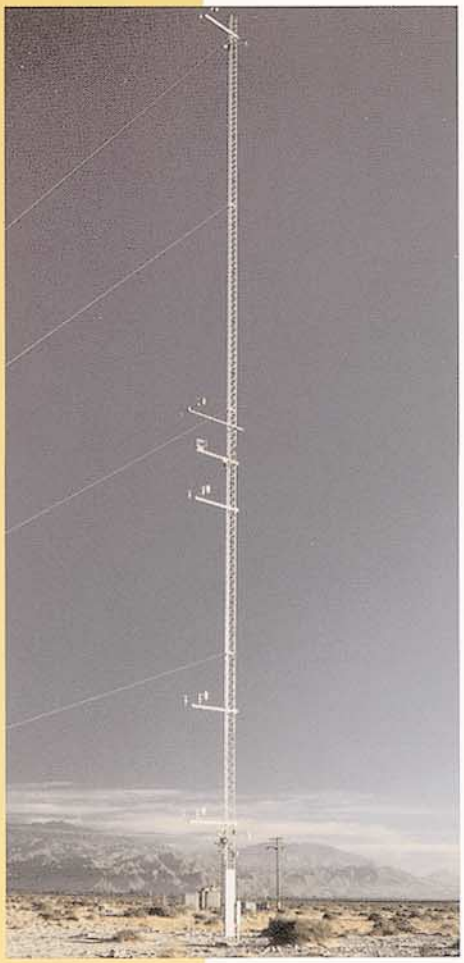


These wind data show this site in the Adirondack Mountains is wind power class 7 and the site near Lake Ontario is wind power class 4. A wind turbine installed at the first site in the Adirondack Mountains will produce twice as much electricity as it will at the second site.

A good wind resource assessment will provide an accurate distribution of the frequency of local wind speeds. Using the data obtained from anemometers, engineers can choose a suitable turbine design and project the energy output (in kWh) and economic performance of the turbine at that location.



Utilities Can Carry Out a Wind Resource Assessment with Little Financial Risk



During the past decade, our understanding of the basic phenomena governing wind turbine behavior has greatly increased. Small, first-generation machines are now making way for new designs with increased annual energy output, improved availability, and lower installed cost. Industrial firms, with the Electric Power Research Institute (EPRI) and the U.S. Department of Energy (DOE), have active programs under way to further improve the outlook for this promising renewable energy technology.

The Utility Wind Interest Group, in cooperation with EPRI and DOE, supports the appropriate integration of wind technology for utility applications. Active members include

- Bonneville Power Administration
- Green Mountain Power Corp.
- Hawaiian Electric Industries Inc.
- New England Power Service Co.
- Niagara Mohawk Power Corp.
- Northern States Power Co.
- Pacific Gas and Electric Co.
- Pasadena Water and Power Department
- Southwestern Public Service Co.
- Western Area Power Administration

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Map credits: U.S. Wind Resource Maps: Pacific Northwest Laboratory (PNL), **An Assessment of the Available Windy Land Area and Wind Energy Potential in the United States;** *New York maps and wind-speed distribution data: AWS Scientific, Inc.*