



Wind Energy Resources

The United States could meet 70 percent to 40 percent of its electricity demand with wind power.

Development of wind energy depends upon a clear understanding of wind resource. Site location, turbine performance and physical effects of turbulence and energy extraction represent a few of the issues that must be addressed by any community, state or region interested in developing wind energy.

Possessing one of the largest wind energy resources in the world, the United States has the potential to supply anywhere from 10 percent to 40 percent of U.S. electricity demand with wind power. These figures take into account restrictions on land use, limits on the efficiency of energy extraction, cost, siting issues and other factors.

Wind potential is characterized by seven wind classes, each representing a range of wind power densities or wind speeds at a specified height above the ground. For the most part, areas suitable for large wind turbines are ranked as class 5 and above. Classes 3 and 4 may be developed in the near future as wind turbine technology becomes more efficient at lower wind speeds. Class 1 and 2 areas may be suitable for smaller wind turbines in remote communities that receive great value from energy produced.

Wind energy resources vary across the United States. Class 4 and higher areas usually are found near the coasts, along ridges of mountain ranges and in a wide belt that stretches across the Great Plains. Class 1 and 2 winds dominate southeastern regions. Wind classification is, however, only one component of wind energy potential. Many windy sites are unsuitable for development because of rocky terrain, inaccessibility, environmental protection or population density.

The strongest winds usually are found in well-exposed areas such as hilltops and ridges.

Characteristics of wind

Wind is caused by uneven heating of the earth's surface by the sun. When the heat is transferred to the air, differences in air temperature, density and pressure create wind. Temperature differences between the tropics and the poles also drive global trade winds that keep extreme temperatures in check in these areas. On a smaller scale, wind is created because of temperature differences between land and sea and

mountains and valleys. The earth's rotation, local topographical features and the roughness of the terrain also cause air movement.

Wind energy can be converted to electricity by using wind turbines. The amount of electricity created depends on the amount of energy contained in wind that passes through a turbine in a unit of time. This energy flow is referred to as wind power density. Wind power density depends on wind speed and air density (air density is dependent on air temperature, barometric pressure and altitude).

Wind speed, wind shear and turbine costs help to determine a site's wind energy potential.

To predict wind turbine performance, one must know the average wind speed at a particular location and how wind speed varies at different heights and during different lengths of time. Variations during a short time period (seconds to minutes) have little significance for wind resource evaluation unless the wind is extremely turbulent or frequently changes direction. Information about variations over hours to days is essential because wind speeds typically persist for several days, reflecting weather conditions, and often exhibit daily patterns. Monthly, seasonal and annual variations also have significant effects on a wind power plant's performance. A few years of measurement data is necessary to accurately capture a site's wind energy potential.

Wind shear describes the increase in wind speed related to an increase in height. Geographic features -- mountains, plains, coastlines -- exhibit different wind shear characteristics. Wind shear determines the proper height to place the turbine hub to receive the maximum wind speed over time. Turbine costs also influence size determinations. Current technology indicates the optimum tower height for large wind machines is approximately 40 to 50 meters.

Developing a wind resource assessment program

Conducting a survey of available wind resources is a first step for many states and utilities interested in developing wind energy. The National Renewable Energy Laboratory's (NREL) *Wind Energy Resource Atlas of the United States* is a useful resource for initial examination of estimated wind energy resources and information about climate, topography and measurement. NREL also provides technical support and some funding for resource assessment programs.

Resource assessment programs generally begin with a survey of the entire focus region's potential. This step may involve a review of available wind resource maps, information about meteorological characteristics and wind speeds, and development of siting criteria. Geographic information systems (GIS), a computer mapping and analysis system, have proven to be a useful tool to screen potential sites.

Micro-siting results are used to most effectively position wind turbines.

Once a list of potential sites is developed, site visits often are conducted to look for physical evidence of strong winds, to discover potential siting constraints, to meet with property owners and to select a position for a wind monitoring station. After these visits, budget considerations determine the number of sites that are chosen for wind speed monitoring projects that last two or three years. Monitoring a single site for two years costs approximately \$25,000 to \$40,000; monitoring multiple sites decreases this cost to between \$19,000 and \$30,000 per site. The final stage, called micro-siting, is usually undertaken by wind project developers. Surveys and extra monitoring are conducted at the most promising sites to quantify small-scale variances in the wind resource in the area. The results of micro-siting are used to position the wind turbines to maximize their wind energy production and minimize costs.

Reliable, accurate measurement of a wind resource is crucial to successful development of wind energy. State policymakers are finding that wind resource assessment programs are popular and important investments in a natural resource that may offer many benefits to their states.

This brief was summarized by Jeff Dale, National Conference of State Legislatures, from a *Wind Energy Series Report* by Michael Brower, Brower & Company.

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