Wind Energy: An Emerging Energy Resource

By Ann Fritz

Introduction

North Dakota has one of the greatest wind energy resources of the nation, so says a recent report commissioned by the Office of Intergovernmental Assistance and prepared by the PanAero Corporation. Anyone trying to fly a kite or launch a model rocket in North Dakota knows that we get some pretty strong winds in our state. According to U.S. Department of Energy studies, North Dakota has enough good wind energy areas that wind power generated in North Dakota alone could supply 36% of the 1990 electricity consumption in the lower 48 states.

In the not-so-recent past, wind energy may have been thought of as prohibitively expensive, or something that occurs only in California. Wind power is being used all over the country: Wisconsin, Minnesota, Iowa, New Mexico, Texas, and Wyoming all have wind-powered turbines, or are building wind turbines, as part of their local power utilities' energy generating mix. The idea of harnessing the wind is becoming commonplace as electric customers across the nation demonstrate their willingness to try alternative energy sources, and open their pocketbooks to pay slightly more per kilowatt hour for renewable energy sources than for conventional energy sources.

The Windmills of history

The word "windmill" brings to mind images of the Dutch countryside where windmills are surrounded by fields of tulips. Although the technology was perfected in Denmark, windmills were not invented there. A report in World Watch magazine states that windmills were first used in Persia, about 1,000 years ago. The practice of using a windmill to grind grain spread to China, throughout the Mediterranean and to northern Europe. The Danes perfected the windmill, and have led the world in perfecting wind power technology.

In North Dakota, windmills were commonly used to convert wind energy to mechanical energy to pump water. Lambert Vogel, in his book, *The North Dakota Wind Energy Handbook*, states that the first successful design of a water-pumping windmill was back in 1854 by Daniel Halliday. Halliday created a hinged rotor constructed of wooden slats fastened to a steel ring by hinges. As the rotational velocity of the slats increased, flyweights pushed the slats parallel to the wind, creating what looks like a bottomless basket. Vogel states that Halliday's hinged rotor had a relatively large number of moving joints and pivots that tended to be maintenance problems.

Halliday's invention was improved upon, and numerous patents and inventions were created to make the water-pumping windmill more efficient. Vogel writes that between 1880 and 1935, it is estimated that 6 ½ million windmills were sold in the United States. Peak sales of water-pumping windmills occurred in the 1930s and tapered off after that.

Although electricity was common for city dwellers by the early 1900s, it was prohibitively expensive for utility companies to build transmission lines to sparsely populated areas. Windmills used to generate electricity began to appear in rural areas. Farmers, some of whom were also able machinists, could modify their existing water-pumping windmill to an electricity generating windmill (Vogel notes that the patent for the first electricity generating windmill was obtained in 1860 by Moses Farmer. Unfortunately, Farmer's device was viewed as more of a novelty rather than a useful invention at the time he received his patent).

Experience with different types of blades demonstrated that two or three blades generated electricity more efficiently than other blade configurations. The first electricity generating windmills were useful for powering radios or lights, but did not generate enough power for larger applications. In 1935, Congress established the Rural Electrification Administration (REA). Congress intended the REA to finance the local development of power distribution groups. After World War II, with the advent of more western U.S. hydropower projects and rural electrification, electricity generating windmills were relegated to extremely remote locations, or to the few independents who did not want to rely on anyone else for power.

Components of a wind system

Most windmills you see today in North Dakota are the old, wooden windmills that are commonly seen at abandoned farmsteads. Today's windmills are much more modern, and more efficient, than their predecessors. Today's windmills are more appropriately called wind energy conversion systems, or WECS, and are a far cry from the windmill of our grandfather's generation, or even our father's generation.

Of the sources I've used for this article, Vogel most clearly describes the basic components of a WECS:

> Typically, a wind-driven generator system has six important components or sub-systems. A rotor, turned by the wind takes energy from the wind. A transmission may be used to match the rotor's speed to that needed by the generator. A generator converts rotational energy into electricity. A speed or power control limits power at high wind speeds and "turns off" the rotor when wind speeds are too high for safe operation or too low for efficient operation. A tower is required to safely anchor the rotor in the windstream. And finally, there is the electrical distribution system, with all its switches and means of using (or storing) the electricity produced (p. 5).

Blades on the rotor can have a diameter of about 160 feet and spin in winds as low as 9.3 miles per hour. (There are plans in Denmark to build 2,000 wind turbines in the North Sea and the Baltic that would have blades as long as 197 feet mounted on towers 180 feet high). If wind speeds are much lower than 9.3 miles per hour, the WECS owner will need a supplemental source of energy if they are not connected to a local power utility. If, however, a WECS is connected to the power grid, the owner may sell the excess electricity generated back to the local power utility. The buy-back rate is generally based on the cost of the avoided fuel, says Doug Mork, Director of Member Services at Capitol Electric Cooperative in Bismarck.

Mork states that Capitol Electric Cooperative has a standard policy regarding WECS and the use of alternative energy sources. The procedure for a customer with a wind turbine to connect to the power grid is relatively simple. First, the customer must already be receiving power from Capitol Electric Cooperative. Capital Electric Cooperative provides the meters, and the customer must pay installation costs of the WECS. The meters are installed to measure the flow of power either into or out of the customer's box. In that way, customers are reimbursed the cost of the power sold back to their electric cooperative. Therefore, persons who have an operating wind turbine pay extremely low rates for their electricity, to the tune of pennies per kilowatt hour. The low cost of the power, however, may be offset by the relatively high cost of installation, maintenance, and insurance of a WECS. Private WECS owners must do a careful evaluation of their power needs, and the available wind resource. The State Energy Office has various booklets and brochures that describe how to calculate the economic efficiency of a WECS.

How is wind power evaluated?

To understand how wind power is evaluated, it may be necessary to understand how wind is created in the first place. I am again quoting from Vogel (1987), as he offers the best description of how wind is created:

> Atmospheric winds are the results of two separate forces. Pressure gradients, produced by uneven solar heating, accelerate the air. The rotation of the earth also produces an additional, but separate, acceleration on the moving air. The action of these two forces creates the wind.... The principal result of wind is the transfer of atmospheric energy to offset the effects of uneven solar heating (p. 16).

Once the nature of wind is understood, it is easy to see why wind can be so variable according to the time of day, time of season, and even from year to year. According to U.S. Department of Energy research done for North Dakota, daily maximum wind speed occurs between 11 AM and 6 PM. The peak is more pronounced during the warmer months and is less noticeable during the winter months. Minimum daily wind speed is generally in the early morning hours. The time of year also matters; statewide, the highest mean monthly wind speed typically occurs in May and the lowest in July. It may be no surprise that the highest mean monthly wind speeds in North Dakota occur from December through May.

Wind speed also varies according to terrain. Rough terrain has frictional forces that can decrease wind speed. The highest wind speeds in the state are generally recorded over smooth terrain, such as an elevated plateau, or lake, where friction is low. In North Dakota, the Missouri escarpment, Pembina escarpment, and the Turtle Mountains have average wind speeds of 6 – 6.4 m/s at a height of 10 meters off the ground, the highest speeds in the state (Figure 1 and Table 1).

Wind speed and wind density are used to determine the wind power class. There are seven wind power classes. North Dakota has the most area of any state with wind power class 4 and above (Figure 2).

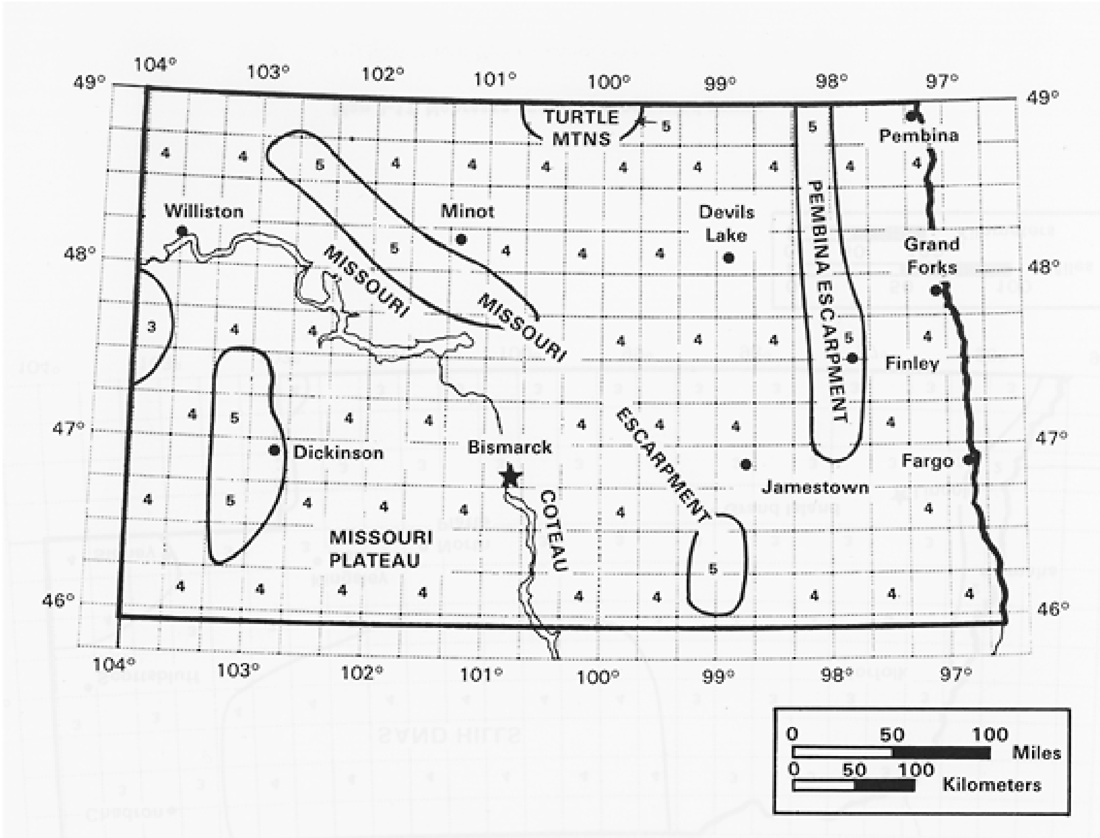

Figure 1*. North Dakota annual average wind power. Numbers shown are wind power classes. (See Table 1) (Source, U.S. DOE, 1986)*

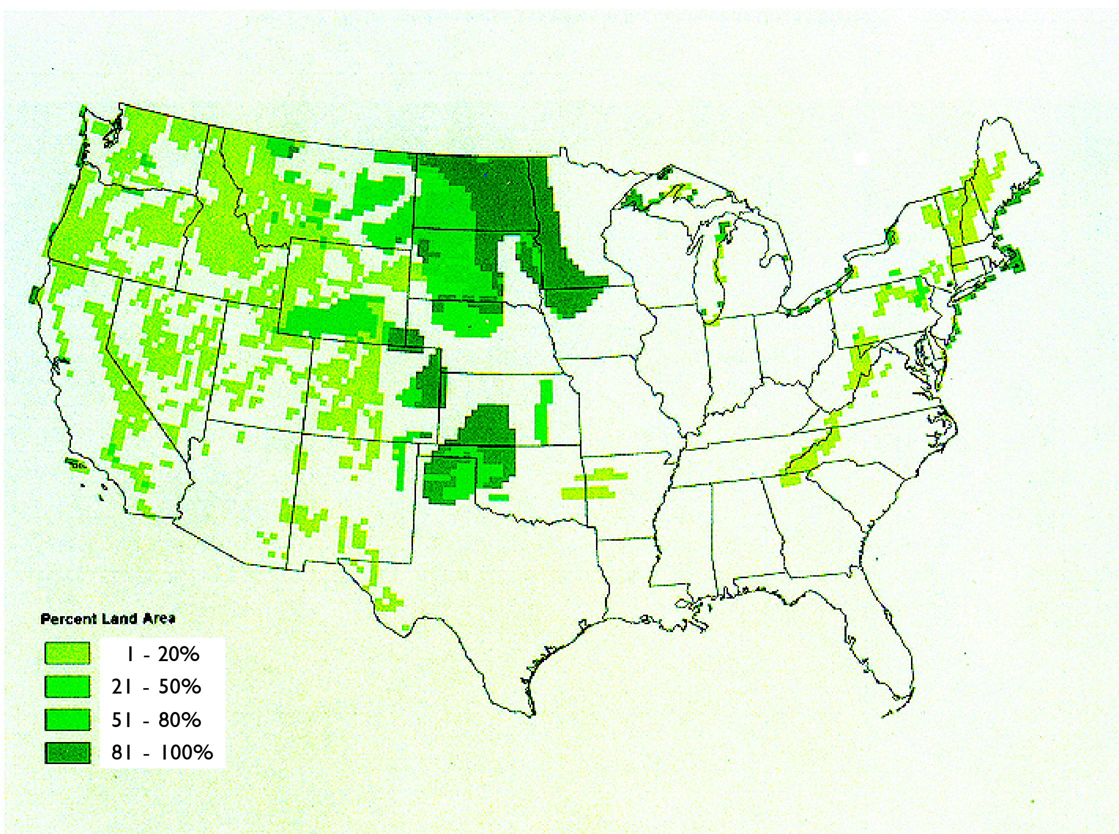

Figure 2*. Percent of the land area estimated to have a class 4 or higher wind power in the contiguous United States. (Source, U.S. DOE, 1986)*

Table 1. Classes of Wind Power Density at 10 meters and 50 meters (a)

Wind Power Class *	10 m (33 feet)		50 m (164 feet)	
	Wind Power Density (W/m^2)	Speed (b) m/s (mph)	Wind Power Density (W/m^2)	Speed (b) m/s (mph)
1	0	0	0	0
	100	4.4 (9.8)	200	5.6 (12.5)
2				
	150	5.1 (11.5)	300	6.4 (14.3)
3				
	200	5.6 (12.5)	400	7.0 (15.7)
4				
	250	6.0 (13.4)	500	7.5 (16.8)
5				
	300	6.4 (14.3)	600	8.0 (17.9)
6				
	400	7.0 (15.7)	800	8.8 (19.7)
7				
	1000	9.4 (21.1)	2000	11.9 (26.6)

a) Vertical extrapolation of the wind speed based on the 1/7 power law, which provides for wind power densities at 50 m that are twice the wind power densities at 10 m.

b) Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density.
Wind speed is standard for sea-level conditions. To maintain the same power density, speed increases 3% per 1000 m (5% /5000 ft) elevation.

* Each wind power class should span two power densities. For example, the Wind Power Class 6 represents the wind power density range from 300 to 400 W/m^2.

Source: U.S. Department of Energy, 1986.

The wind resource maps produced by the federal government estimate the resource in terms of wind power classes (Table 1). Wind power classes range from class 1 (the lowest) to class 7 (the highest). Each class represents a range of mean wind power density (in units of W/m^2) or equivalent mean wind speed at the specified height(s) above ground. Areas designated class 3 or greater are suitable for most wind turbine applications, whereas class 2 areas are marginal. Class 1 areas are generally not suitable, although a few locations (for example, exposed hilltops) with adequate wind resource for wind turbine applications may exist in some class 1 areas.

How much energy (and money) is generated by the wind?

North Dakota has the greatest wind generating capacity of any state in the nation, yet it is the least utilized of all the renewable energy sources available to North Dakotans. According to figures from the State Energy Office, North Dakota currently has 788 kW of wind capacity that is attached to the power grid. Wind energy systems that have a capacity of 100 kW or greater are located at the Sacred Heart Monastery in Richardton, on land owned by the Spirit Lake Tribe in Devils Lake, and in Belcourt on land owned by the Turtle Mountain Tribe. There are a number of smaller capacity, privately-owned WECS that are also connected to the power grid. This figure, however, does not include the number of people that use wind energy as back-up power that are not attached to the power grid. For comparison, a total of 19,000,000 kW are produced from biomass at the Northern Sun plant in Enderlin and Basin Electric Cooperative's Neal Station in Velva. This pales in comparison to the 517,750,000 kW generated at Garrison Dam in Riverdale.

Globally, Germany leads the world in wind power production with 2,080 MW, so states a recent report by Trends in Renewable Energies (March 15, 1999) (1,000 kW = 1 MW; the average power demand for a normal household with gas or other non-electric heat in the U.S. is 1 kW, according to Vogel, 1987). The United States is the second biggest producer at 1,600 MW, Denmark with 1,120 MW, and India with 950 MW. A separate report states that the global market for turbines alone will be more than $7 billion until 2003 (Trends in Renewable Energies, May 17, 1999). Many countries are increasing development of their wind resources. The Danes, for example, plan to have half their country's energy generated by wind power by 2030. Two thousand large turbines, (mentioned earlier) located in a series of offshore wind farms in the North Sea and the Baltic will be built to meet this goal.

According to a report prepared for the Office of Intergovernmental Assistance (Pan Aero Corporation, 1999), North Dakota is positioning itself to become a major developer in both the wind energy distribution and manufacturing markets.

How can the NDGS help?

The NDGS can supply companies who are interested in wind energy with the necessary information about the bedrock geology on which the WECS will be built. How deep is bedrock at a particular site? Are there any particular geologic hazards in the area that the developer should be aware of, such as landslides, subsidence, or springs?

Prospective wind energy developers need general information about the terrain of North Dakota. The NDGS is also the official map dealer for U.S. Geological Survey topographic maps. Potential owners of wind energy systems may wish to obtain 7.5 minute topographic maps from which they can calculate slope angles of their potential wind energy site. NDGS staff can also help wind developers get in touch with personnel at the Office of Intergovernmental Assistance – State Energy office. Personnel at the State Energy office can answer questions for prospective wind energy system owners.

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