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UNITED STATES AREAL WIND RESOURCE ASSESSMENT

M. N. Schwartz
D. L. Elliot

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Pacific Northwest Laboratory
Richland, Washington 99352

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Estimates of the electricity that could potentially be generated by wind power and of the land area available for wind energy development have been calculated for the contiguous United States, in support of the U.S. Department of Energy's National Energy Strategy. These estimates were based on the wind resource data published in a national resource atlas (1). Estimates of the wind resource in this atlas are expressed in wind power classes ranging from class 1 to class 7, with each class representing a range of mean wind power density or equivalent mean speed at specified heights above the ground (Table 1). Areas designated class 4 or greater are suitable for most wind turbine applications. Power class 3 areas are suitable for wind energy development using tall (50-m hub height) turbines. Class 2 areas are marginal and class 1 areas unsuitable for wind energy development. A map of the areal (percentage of land area) distribution of the wind resource digitized in grid cells (1/4° latitude by 1/3° longitude; Figure 1) shows that exposed areas with moderate to high wind resource (class 3 and greater) are dispersed throughout much of the contiguous United States.

Several factors determine the amount of land area suitable for wind energy development within a particular grid cell in a region of high wind energy potential. The important factors include the percentage of land exposed to the wind resource and land-use and environmental restrictions. The land area exposed to the wind for each grid cell was estimated based on a landform classification and ranged from 90% for relatively flat terrain down to 5% for mountainous terrain. Estimates of land area excluded from wind energy development were made for various types of land-use (e.g., forest, agricultural, range, and urban lands). Environmental exclusion areas were defined as federal and state lands (including parks, monuments, wilderness areas, wildlife refuges, and other protected areas) where wind energy development would be prohibited or severely restricted. Finally, additional land exclusions were estimated to account for transportation right-of-ways, locally administered park land, privately administered areas, and proposed environmental lands.

The wind electric potential per grid cell was calculated from the available windy land area and the wind power classification assigned to each cell. The amount of potential electricity that can be generated is dependent on several factors, including the spacing between wind turbines, the assumed efficiency of the machines, the turbine hub height, and the estimated energy losses caused by wind turbine wakes.

A study in 1991 (2) used a variety of land exclusion scenarios to estimate the available windy land and resultant wind electric potential for several levels of wind resource, both for the contiguous United States as a whole and for each of the 48 contiguous states. Figure 2 shows the overall potential wind energy based on terrain exposure and several land exclusion scenarios. Even under the most restrictive (severe) land exclusion scenario, the wind energy potential for areas with power class 3 and above is greater than total U.S. electricity consumption was in 1990. Figure 3 shows the contribution that wind energy of each state could make to meet the total electrical needs of the nation. North Dakota alone has enough potential energy from windy areas of class 4 and higher to supply 36% of the total 1990 electricity consumption of the 48 contiguous states.

A study in 1992 (3) recalculated estimates of windy land area and wind electric potential based on a more accurate mapping of environmental exclusion areas and a moderate land exclusion scenario. These new estimates were about 1 to 2% higher than the preliminary estimates made in 1991 based on the same land exclusion scenario. Overall, even with land being excluded from wind energy development for environmental and land-use considerations, the amount of windy land available and potential electric power from wind energy is surprisingly large. The amount of windy land available for power class 4 and above is approximately 460,000 square kilometers, or about 6.0% of the total land area in the contiguous United States. The potential average power from areas with class 4 and higher is estimated at 500,000 MW. If advanced wind turbine technology is utilized to take advantage of areas with wind resource class 3 and higher, than the amount of windy land available is over 1,000,000 square kilometers, or almost 14% of the land area in the contiguous United States. Moreover, the estimates show that a group of 12 states in the midsection of the country have enough wind energy potential to produce nearly four times the amount of electricity consumed by the nation in 1990. This potential has not been tapped before because the wind turbine technology was not able to utilize this resource. However, during the past decade, increased knowledge of wind turbine behavior has led to more cost-effective wind turbines that are more efficient in producing electricity. The price of the electricity produced from wind by these advanced turbines is estimated to be competitive with conventional sources of power, including fossil fuels. Because of the increasing competitiveness of wind energy, wind resource assessment will become essential in incorporating wind energy into the nation's energy mix. For example, the 1992 study (3) also produced gridded maps of wind electric potential and windy land area for the 48 contiguous states that show the distribution of these features within individual states, thus enabling utilities and wind energy developers to identify promising areas for wind energy. The importance of accurate wind resource assessment is also recognized in other parts of the world.

Detailed wind resource assessments have been proposed or are being considered as part of a plan to increase the use of wind energy in Europe, Asia, Latin America, and other regions. The decreasing cost of wind power and the growing interest in renewable energy sources should ensure that wind power will become a viable energy source in the United States and worldwide.

Acknowledgments

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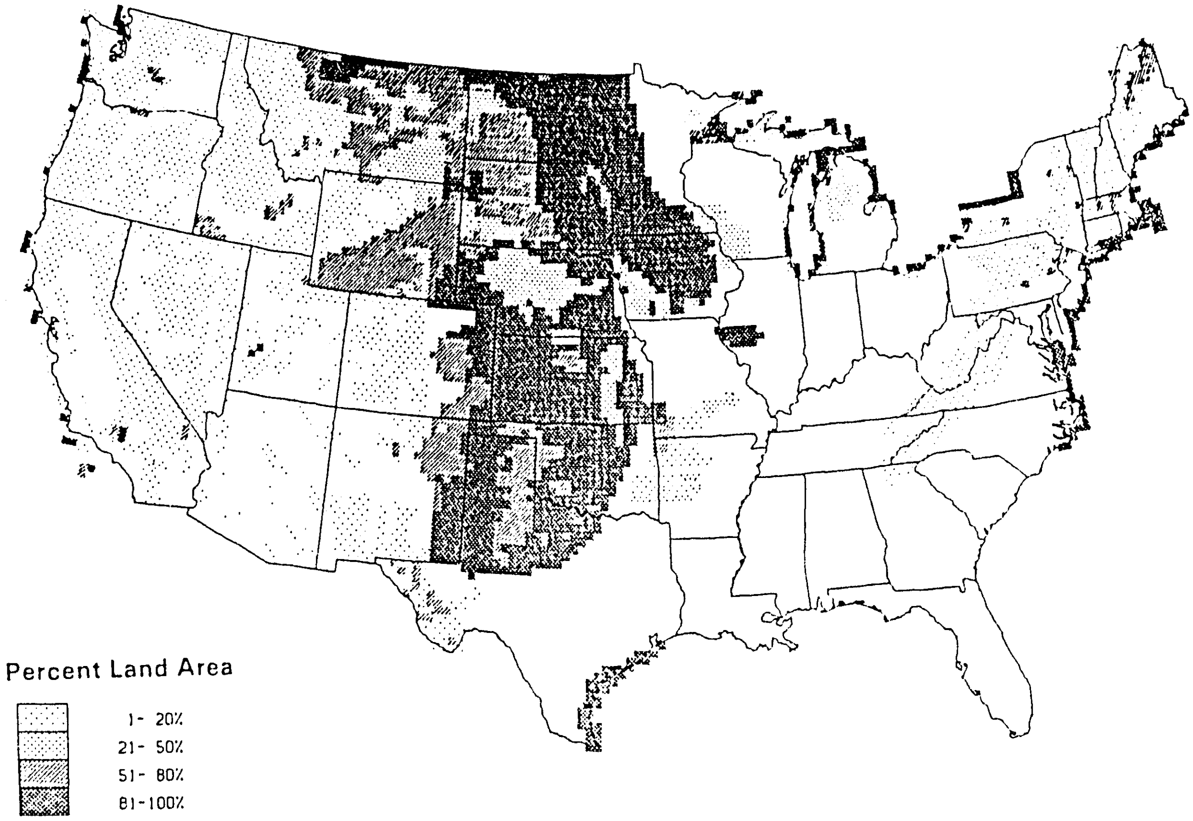
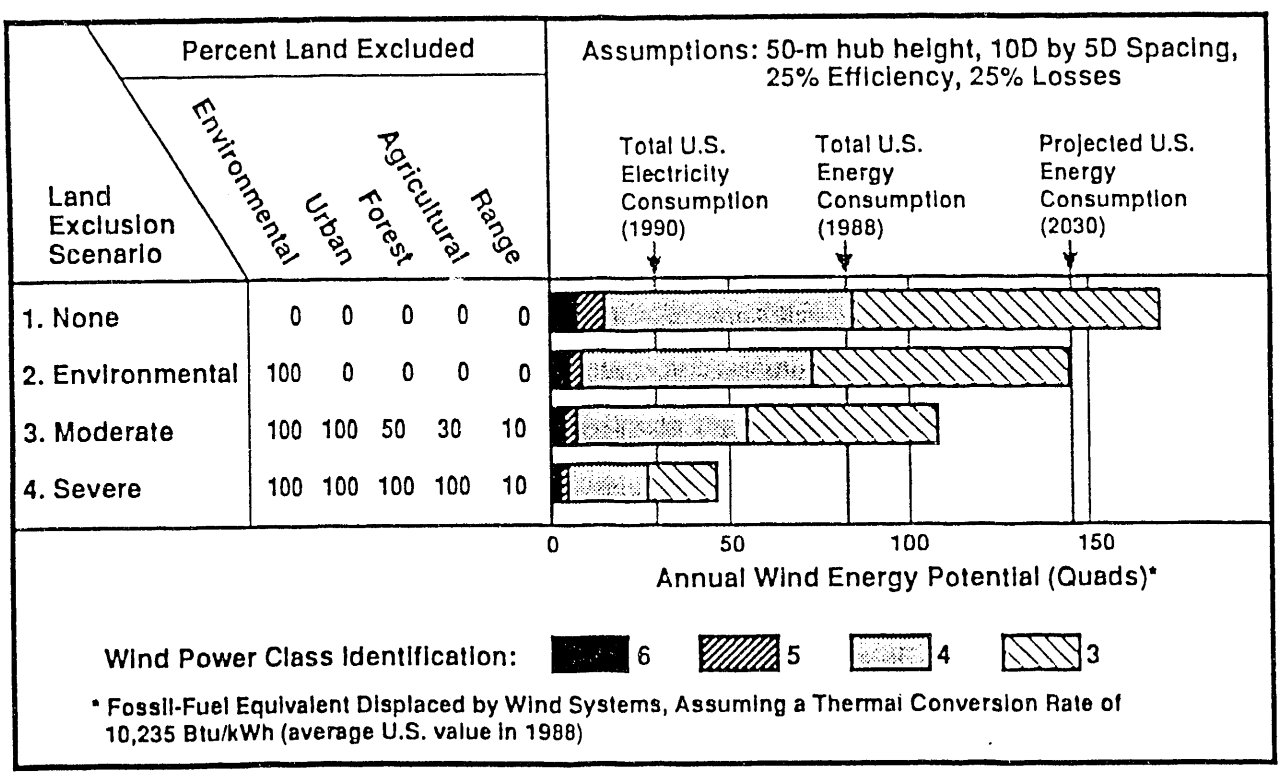


Fig. 1. Percentage of Land Area with Class 3 or Higher Wind Resource



Land Exclusion Scenario	Environmental	Urban	Forest	Agricultural	Range
1. None	0	0	0	0	0
2. Environmental	100	0	0	0	0
3. Moderate	100	100	50	30	10
4. Severe	100	100	100	100	10

Fig. 2. Wind Energy Potential of the Contiguous United States

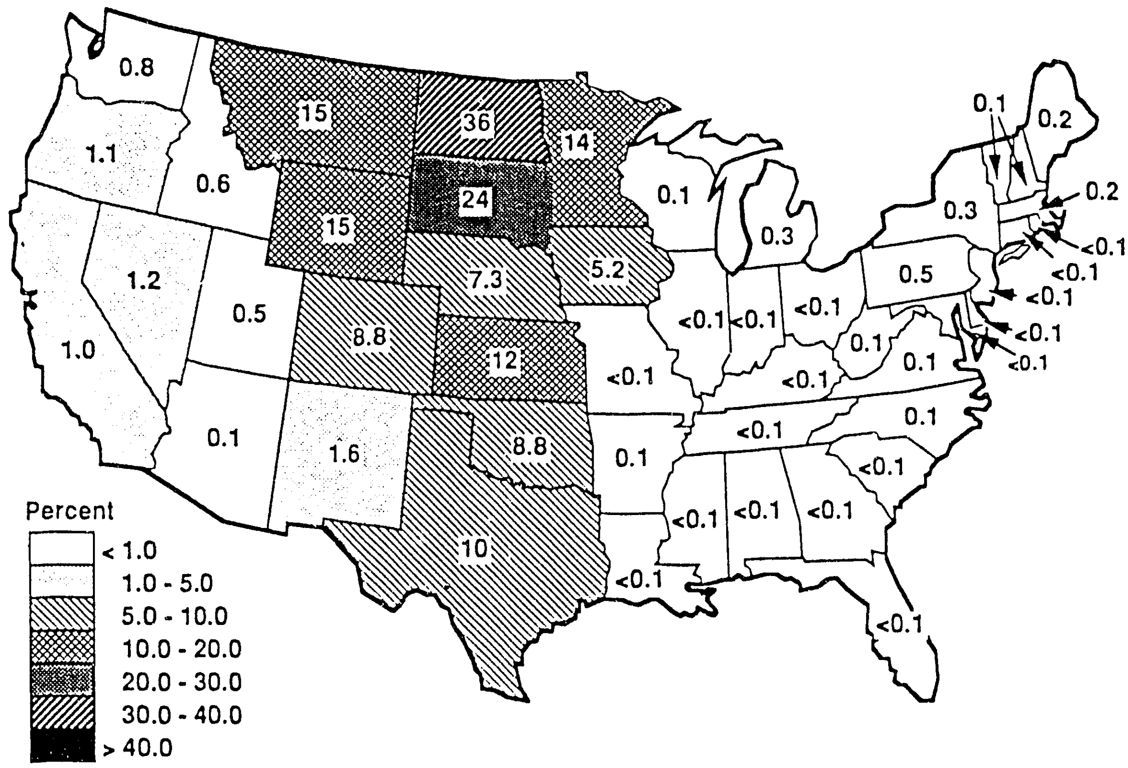


Fig. 3. Percentage of the Total 1990 Electricity Consumption of the Contiguous United States that Each State Could Produce (Assumptions: areas designated class 4 and above, hub height of 30 m, moderate land exclusion scenario)

Table 1. Classes of Wind Power Density

Wind Power Class	10 m (33 ft)[a] Wind Power Density, W/m²	10 m (33 ft)[a] Speed[b], m/s (mph)	30 m (98 ft)[a] Wind Power Density, W/m²	30 m (98 ft)[a] Speed[b], m/s (mph)	50 m (164 ft)[a] Wind Power Density, W/m²	50 m (164 ft)[a] Speed[b], m/s (mph)
	0	0	0	0	0	0
1						
	100	4.4 (9.8)	160	5.1 (11.4)	200	5.6 (12.5)
2						
	150	5.1 (11.5)	240	5.9 (13.2)	300	6.4 (14.3)
3						
	200	5.6 (12.5)	320	6.5 (14.6)	400	7.0 (15.7)
4						
	250	6.0 (13.4)	400	7.0 (15.7)	500	7.5 (16.8)
5						
	300	6.4 (14.3)	480	7.4 (16.6)	600	8.0 (17.9)
6						
	400	7.0 (15.7)	640	8.2 (18.3)	800	8.8 (19.7)
7						
	1000	9.4 (21.1)	1600	11.0 (24.7)	2000	11.9 (26.6)

[a] Vertical extrapolation of wind power density and wind speed are based on the 1/7 power law.
[b] Mean wind speed is estimated assuming a Rayleigh distribution of wind speeds and standard sea-level air density. The actual mean wind speed may differ from these estimated values by as much as 20%, depending on the actual wind speed distribution and elevation above sea level.

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