10. Wind

Introduction

Wind energy is a form of solar energy. Winds are created by uneven heating of the atmosphere by the sun, the irregularities of the Earth's surface, and rotation of the Earth. As a result, winds are strongly influenced and modified by local terrain, bodies of water, weather patterns, vegetative cover, and other factors. This wind flow, or motion energy, when "harvested" by wind turbines, can be used to generate electricity.

Recent studies have shown that there is sufficient wind resource in the United States potentially to develop electricity generating capacity roughly equivalent to twice the amount of existing U.S. generating capacity.[88] However, given economics, land use, the intermittent nature of wind energy, and other constraints, the usable portion of this resource is considerably less. Wind energy technology has progressed dramatically from the early days of California wind farms. Largely through a combination of improved design, accumulated operating experience, and better siting, wind turbines have established a track record of solid reliability and declining cost.[89] Yet the integration of wind capacity into electric utility systems continues to be hampered by a number of barriers, including the current and projected low cost of electricity from natural-gas-fired power plants, the intermittent nature of wind, the lack of data on viable wind resource areas, the distance of wind resources from demand centers, relatively high financing costs for wind energy projects, and overall reliability problems for individual utilities as wind capacity begins to increase its share of total generating capacity.

Background

Wind-based electricity generating capacity has increased markedly in the United States since 1970, although it remains a small fraction of total electric capacity. Technological improvements in wind turbines have helped reduce capital and operating costs. Some new turbines are reported to generate electricity for less than 5 cents per kilowatthour.[90] Although there are several constraints limiting wind energy's contribution to the U.S. energy supply, significant wind energy resources, some of which are currently economical, are located near existing high-voltage transmission lines, resulting in large potential wind energy capability.

Wind is an emerging renewable energy resource that produces no air or water pollution, involves no toxic or hazardous substances, and poses minimal threats to public safety. These and other potential benefits have prompted encouragement of wind energy projects by means of Federal and State tax credits, including a tax credit of 1.5 cents per kilowatthour established by the U.S. Congress as part of the Energy Policy Act of 1992 (EPACT).[91]

Major U.S. wind energy development to date has been in areas such as the Altamont and Tehachapi passes in California, which are characterized by favorable wind resources, relatively high-priced long-term power purchase contracts from utilities, and close proximity to existing electricity transmission corridors. In 1994, California had about 16,000 operating wind turbines, which produced approximately 3.5 billion kilowatthours of electricity.[92] As the cost of wind generating equipment declines and performance improves, interest in deploying significant amounts of wind energy elsewhere in the United States is expected to increase.

This chapter provides an overview of wind energy resources in the United States. Proximity of favorable sites to transmission lines and possible constraints on their use in the form of land-use restrictions and environmental exclusions are examined. State-level activity related to wind development initiatives is reviewed, and estimates of the potential usable resources and electric generation capability are presented in terms of land availability for wind development.

[88]J.P. Doherty, Energy Information Administration, "U.S. Wind Energy Potential: The Effect of the Proximity of Wind Resources to Transmission Lines," *Monthly Energy Review* (Washington, DC, February 1995), pp. vii-xiv.

[89]Union of Concerned Scientists, *Powering the Midwest: Renewable Electricity for the Economy and the Environment* (Washington, DC, 1993).

[90]Assuming 13-mile-per-hour winds and typical utility financing arrangements.

[91]Energy Policy Act of 1992, Public Law 102-485, Section 1212, 42 U.S.C. 13317, enacted October 24, 1992.

[92]Energy Information Administration, *Annual Energy Review 1994*, DOE/EIA-0384(94) (Washington, DC, July 1995).

Wind as a Renewable Energy Resource

Wind resources at particular sites are described in terms of wind power classes that range from class 1 (the least amount of energy) to class 7 (the greatest amount of energy). This classification scheme takes into account three factors that influence the energy available from the wind: the variability of wind speed (how widely and how often the wind speed varies), the average wind speed, and the average density of the air. The effect of these three factors is expressed as the wind power density (in watts per square meter of turbine rotor swept area) or its equivalent mean (average) wind speed (shown at hub heights of 10 and 50 meters in Table 30).[93]

Other things being equal, a site with steady winds may yield more energy than another location with the same average wind speed but more variable winds. Likewise, higher average wind speeds and air densities usually yield more energy than lower ones. Because air density decreases with altitude, somewhat higher average wind speeds are required at high altitudes to yield the same energy as lower altitude sites with lower average wind speeds. On the other hand, trees, plants, buildings, and topographical irregularities tend to impede the flow of air near the ground and thus reduce wind speed. Consequently, wind power turbines are mounted on towers to raise them well above ground level.

Wind resource maps usually identify areas by wind power class. In general, areas identified as class 4 and above are regarded as potentially economical for wind energy production with current technology. Nevertheless, some areas identified with class 3 wind resources are being developed in the United States.

Many regions of the country offer at least some usable wind resources. The Great Plains States have abundant wind resources, followed by other parts of the Midwest, the West, and the Northeast. Although there is some potential for wind energy development in the South, the wind resources there are not as significant as in the other regions of the United States.

Generating Power Potential and Land Available for Wind Development

The availability of wind resources for development in close proximity to transmission lines is plentiful. There is a total potential power output of 734,073 megawatts from wind available for development in the contiguous United States[94] on the 625,488 square kilometers of land in the contiguous United States having class 3 or greater wind resources and within 10 miles of transmission lines.

Table 30. Classes of Wind Power at Heights of 10 and 50 Meters

Wind Power Class	Wind Speed (meters per second)	Wind Power Density (watts per square meter of rotor-swept area)	Wind Speed (meters per second)	Wind Power Density (watts per square meter of rotor-swept area)
	10 Meters		50 Meters	
1	0.0-4.4	0-100	0.0-5.6	0-200
2	4.4-5.1	100-150	5.6-6.4	200-300
3	5.1-5.6	150-200	6.4-7.0	300-400
4	5.6-6.0	200-250	7.0-7.5	400-500
5	6.0-6.4	250-300	7.5-8.0	500-600
6	6.4-7.0	300-400	8.0-8.8	600-800
7	7.0-9.4	400-1,000	8.8-11.9	800-2,000

Source: Pacific Northwest Laboratory, *Wind Energy Resource Atlas of the United States*, DE86004442 (Golden, CO: Solar Energy Research Institute, October 1986), p. 3.

[93]Pacific Northwest Laboratory, *Wind Energy Resource Atlas of the United States*, DE86004442 (Golden, CO: Solar Energy Research Institute, October 1986), p. 2.

[94]National Renewable Energy Laboratory, *U.S. Wind Reserves Accessible to Transmission Lines*, Draft DOE Task 94-001 (Golden, CO, September 1994), supported by the Energy Information Administration.

In the North Central region, 318,813 megawatts of potential wind power output is available, assuming class 3 and above wind development, the highest for any region in the United States (Table 31). Kansas and Texas, followed by North Dakota, have the greatest potential power output for wind generating capability. The North Central region also has the most land (264,968 square kilometers) available for potential wind development within 10 miles of transmission lines. Texas, Kansas (South Central region), and Nebraska (North Central region) are the States with the greatest amount of land available within 10 miles of transmission lines for potential wind development.

Wind Energy in the U.S. Electricity Supply

Until 1970, facilities powered by wind were small, isolated, experimental, and/or disconnected from electric power networks. By the end of 1990, wind electric generation capacity in the United States had grown to 2,267 megawatts. In 1994, wind electric generation capacity dropped to 1,745 megawatts, largely because of the retirement of several wind turbines in California. The 1994 total was less than 2 percent of the total renewable electric generating capacity of 94,826 megawatts and less than 0.3 percent of U.S. total electric generating capacity in 1994. The American Wind Energy Association estimates that wind electric generation in the United States reached 3.5 billion kilowatthours in 1994, up more than 25 percent from 1992-1993, and double the output of the late 1980s. Among electric utilities, Pacific Gas & Electric is one of the largest purchasers of wind-generated electricity. That electricity is produced from 660 megawatts of nonutility-owned nameplate capacity.[95]

Improvements in Wind Energy Technology

Wind energy technology has improved considerably since the 1970s. Initial federally funded research focused on large machines of 1 to 5 megawatts capacity that operated at a constant speed as wind speed varied. The high unit costs of the machines and their unsatisfactory performance led to their gradual abandonment as the industry turned to smaller wind turbines, resulting in a dramatic decrease in the cost per kilowatt of wind capacity. The cost of wind energy, estimated at 50 cents per kilowatthour in 1980, dropped to a range of 5 to 7 cents per kilowatthour by the end of 1993.[96]

Today, installed grid-connected wind turbine capacity worldwide totals roughly 4,000 megawatts.[97] Installed capacity includes intermediate-size turbines (100 to 400 kilowatts) and some small turbines (1 to 50 kilowatts). Small turbines have proven to be reliable in off-grid applications and now compete in markets for remote power supply worldwide. These machines usually deliver direct current (DC) power for battery charging, water pumping, refrigeration, and other uses.

There are two types of wind turbine design: the horizontal-axis wind turbine, which resembles a windmill, and the vertical-axis wind turbine, which resembles an upright eggbeater. Horizontal-axis wind turbines, the most commonly used, capture the wind's energy with a rotor, usually consisting of two or three blades mounted on a shaft (Figure 22). The rotating shaft is connected to a generator to produce electricity. New wind turbines incorporating incremental improvements in design and construction have continued to reduce the cost of wind energy. Among these features are improved blades, variable-speed generation, simplified mechanisms, state-of-the-art controls, and aerodynamic braking to protect turbines in high winds. The new designs offer improved performance in the form of better energy capture, reduced stress on machine components, and longer life for turbine drive train hardware.

Wind Development Costs

Technological improvements have reduced the capital costs and operating and maintenance costs associated with wind energy development. Several of the new turbines, which range in capacity from 275 to 600 kilowatts, reportedly produce electricity for as little as 5 or less per kilowatthour.[98,99,100] The Electric Power Research Institute (EPRI) currently estimates that by the

[95]Information obtained from Pacific Gas & Electric Company by telephone, August 16, 1995.

[96]Costs for 1993 are estimated for 100 225-kilowatt wind turbines with operating lives of 30 years, total capital costs of $23.6 million ($1,049 per kilowatthour), and operating and maintenance costs of 1 cent per kilowatthour. For more information, see U.S. Department of Energy, *Wind Energy Program Overview Fiscal Year 1993*, DOE/CH10093-279 (Washington, DC, May 1994), p. 3; and U.S. Department of Energy, "Wind Technology Characterization," internal review document (December 9, 1993).

[97]International Energy Agency, *CADDET Mini Review: Wind Energy* (Oxford, United Kingdom, April 1995).

[98]"Competitive Wind Energy," *EPRI Journal*, Vol. 18, No. 8 (December 1993), p. 2.

[99]"Wind Systems for Electrical Power Production," *Mechanical Engineering* (August 1994), p. 75.

[100]Assuming 13-mile-per-hour winds and typical utility financing arrangements.

Table 31. Land Available for Potential Wind Development by Region and State, and Average Megawatts of Wind Generating Capability

Regions/States	Moderate Land Use and Environmental Restrictions, Within 10 Miles of Transmission	
	Area Exposed to Wind (square kilometers)	Potential Power Output at a 50-Meter Hub Height (megawatts)
Northwest	**79,311**	**101,383**
Idaho	1,667	2,151
Montana	37,028	43,753
Oregon	2,063	2,724
Washington	2,454	3,417
Wyoming	36,099	49,339
North Central	**264,968**	**318,813**
Iowa	42,425	46,898
Minnesota	43,520	54,020
Nebraska	67,614	72,510
North Dakota	59,125	81,342
South Dakota	52,284	64,043
Great Lakes	**14,524**	**14,990**
Illinois	5,753	5,926
Indiana	27	28
Michigan	3,915	4,063
Ohio	333	343
Wisconsin	4,496	4,631
Northeast	**14,721**	**16,099**
Connecticut	621	652
Maine	191	294
Massachusetts	2,096	2,225
New Hampshire	417	528
New Jersey	905	993
New York	6,116	6,432
Pennsylvania	4,001	4,491
Rhode Island	50	52
Vermont	324	432
East Central	**2,061**	**2,283**
Delaware	249	256
Kentucky	41	42
Maryland	235	256
North Carolina	249	308
Tennessee	140	159
Virginia	652	706
West Virginia	493	555
Southeast	**92**	**107**
Alabama	0	0
Florida	0	0
Georgia	51	62
Mississippi	0	0
South Carolina	41	44

See notes at end of table.

Table 31. Land Available for Potential Wind Development by Region and State, and Average Megawatts of Wind Generating Capability (Continued)

Regions/States	Moderate Land Use and Environmental Restrictions, Within 10 Miles of Transmission	
	Area Exposed to Wind (square kilometers)	Potential Power Output at a 50-Meter Hub Height (megawatts)
South Central	**213,085**	**236,423**
Arkansas	1,239	1,305
Kansas	78,369	88,406
Louisiana	0	0
Missouri	3,064	3,156
Oklahoma	50,562	56,270
Texas	79,851	87,285
South Rocky Mountain	**32,420**	**37,604**
Arizona	164	190
Colorado	19,067	23,350
New Mexico	12,754	13,262
Utah	435	803
Southwest	**4,306**	**6,371**
California	3,753	5,546
Nevada	553	826
Contiguous U.S. Total	**625,488**	**734,073**

Note: Potential generating capability is presented in average megawatts per square kilometer. Capacity denoted in average megawatts should not be confused with nameplate capacity in megawatts. The nameplate capacity rating represents peak output at the rated wind speed, while average megawatts is the normalized actual power production (average megawatts multiplied by 8,760 hours per year results in the annual energy production in kilowatthours per year).

Source: National Renewable Energy Laboratory, “U.S. Wind Resources Accessible to Transmission Lines” (August 5, 1994).

Figure 22. Wind Turbine Configurations

Source: U.S. Department of Energy, Office of Solar Technologies, *Five-Year Research Plan 1985-1990, Wind Energy Technology: Generating Power From the Wind*, DOE/CE-T11 (Washington, DC, January 1985), p. 2.

year 2005 the installed cost for total plant investment will be $620 per kilowatt of capacity, a decrease of $452 per kilowatt from the 1993 projection.[101] The Energy Information Administration's *Annual Energy Outlook 1995* also assumes that costs will continue to decline as new plants are built in the future.

Transmission Line Costs

In addition to the power plant construction and operating and maintenance costs, there are costs for connection to the transmission grid. The further a wind energy development project is from transmission lines, the higher the cost of connection to the transmission and distribution system (Tables 32 and 33).

The distance from transmission lines at which a wind developer can profitably build depends on the cost of the specific project. Consider, for example, the cost of construction and interconnection for a 115-kilovolt transmission line that would connect a 50-megawatt wind farm with an existing transmission and distribution network.[102] The cost of building 1 mile of 115-kilovolt line is assumed to be $286,000, the midpoint of the range for the relevant voltages (Table 32).[103] That amount includes the cost of the transmission line itself and the supporting towers. It also assumes relatively ideal terrain conditions, including fairly level and flat land with no major obstacles or mountains. (More difficult terrain would raise the cost of erecting the transmission line.) The cost of constructing a new substation for a 115-kilovolt transmission line is estimated at $1.08 million. The cost of connection for a 115-kilovolt transmission line with a substation is estimated at $360,000 (Table 33).

Representative costs of a wind energy project and connection to existing transmission lines are as follows: Assuming that a 50-megawatt wind farm costs $50 million, 10 miles of transmission line (at $286,000 per mile of line) adds $2.86 million to the total cost, construction of a new substation costs $1.08 million, and connection to an existing substation for a 115-kilovolt line is $360,000. These costs add 8 percent to the total cost.[104] The costs of construction of 10 miles of transmission line and interconnection to an existing substation would add 6 percent to the total cost.

Table 32. Estimated Costs of Single-Circuit Alternating Current Transmission Lines

Voltage (kilovolts)	December 1989 Installed Cost (thousand dollars per mile)
115	125-375
138	125-375
230	150-375
345	350-700
500	400-800

Source: Electric Power Research Institute, *Technical Assessment Guide: Electric Supply, 1989*, Vol. 1, Revision 6 (Golden, CO, November 1989), p. B-4.

Table 33. Estimated Costs for Substation Construction and Connection to Wind Energy Project

Voltage (kilovolts)	Construct New Substation	Connect With Substation
69	$750,000	$250,000
115	$1,080,000	$360,000
138	$1,200,000	$400,000
161	$1,410,000	$470,000
230	$1,770,000	$590,000
345	$2,820,000	$940,000
500	$4,380,000	$1,460,000

Source: Data calculated by National Renewable Energy Laboratory, based on Western Area Power Administration, 2 "Conceptual Planning and Budget Cost Estimating Guide," Internal Review Document (January 1, 1993).

Although 10 miles was chosen for purposes of illustration, a wind developer might economically build closer to or farther from transmission lines, depending on site-specific conditions, including the voltage of the transmission line constructed, cost of interconnection to higher voltage transmission lines, the project's overall capital costs, specific wind resource characteristics, and project economics. There are, however, land and environmental constraints on transmission line construction, such as the existence of densely populated urban areas,

[101]Estimation for 2005 is given in 1993 dollars. Cost does not include substation and interconnection. See Electric Power Research Institute, *Technical Assessment Guide, Electric Supply, 1993*, EPRI-102276-V1R7 (June 1993), pp. 8-106 and 8-108.

[102]The majority of circuit miles of overhead electric line of 115 kilovolts through 230 kilovolts in 1992 were 115-kilovolt lines. The cost assumptions for this analysis therefore considered 115-kilovolt transmission lines for construction and interconnection. See Edison Electric Institute, *Statistical Yearbook of the Electric Utility Industry 1992* (Washington, DC, October 1993), p. 97.

[103]Cost estimates are from Electric Power Research Institute, *Technical Assessment Guide, Volume 1, Electric Supply, 1989*, Revision 6 (Palo Alto, CA, November 1989), and are the most recent data available.

[104]Cost assumptions are based on information from National Renewable Energy Laboratory, *U.S. Wind Reserves Accessible to Transmission Lines*, Draft DOE Task 94-001 (Golden, CO, September 1994), supported by the Energy Information Administration.

national parks, reserves or recreation areas, national forests and grasslands, national scenic waterway and wilderness areas, wetlands, lakes, marshes, and terrain that is steeply sloped or inaccessible to roads. These factors, which were not considered in the above example, can also increase the cost of connecting to transmission lines. Although the costs for wind development in the United States are significant, efforts are being made to develop wind resources in some States.

Constraints on Integration of Wind Energy into Electric Utility Systems

Although there have been many improvements in wind technology and costs, there remain some constraints which affect the economic competitiveness of wind energy for integration into the electric utility systems. One is the intermittent nature of wind. Without storage capability, wind turbine systems can supply electricity only when the wind blows. The intermittency of wind energy, coupled with the fact that the times of peak availability of wind resources in a given location may not coincide with the times of peak demand for electricity, makes wind energy less attractive to electric utilities than power sources that are available at all times. However, if wind patterns tend to match load profiles (as in California), wind farms can earn capacity value.

Horizontal-axis wind turbines, developed by Enertech Corp. and the U.S. Department of Energy, located in Altamont Pass near Livermore, California.

Vertical-axis wind turbines in Altamont Pass.

Another constraint is financing for wind energy projects, which tends to be somewhat less readily available and more costly than financing for conventional energy facilities. Wind energy projects are typically developed by independent power producers, which obtain financing on the strength of power purchase agreements with electric utilities. At the current avoided cost for electricity (i.e., what the utility would have to pay for additional capacity using another fuel source), standard power purchase agreements are generally insufficient to support investment in wind farms. Only in very special cases can wind energy compete against conventional power. Also, lenders perceive risks in wind technologies and their performance. For example, if the technical estimates of the performance of a wind energy project prove overly optimistic, revenues may fall short of expectations, and the borrowing independent power producer may be unable to service its debt. To compensate for this risk, lenders typically charge comparatively high rates of interest for such projects and demand relatively large amounts of equity.[105] Investors demand higher rates of return on their equity. Overall capital costs may be moderately higher than for utilities or less risky power plant investments.

A third constraint on the integration of wind capacity into electric utility systems is the variability of wind energy potential by geographic region and daily weather conditions. Wind-driven electricity generating facilities must be located at specific sites to maximize the amount of wind energy captured and electricity generated. However, many good wind energy sites are on ridges or mountain passes, where siting and permitting difficulties, land restrictions, aesthetic objections, the potential for bird kills, and harsh weather conditions often constrain development. Further, transmitting electricity from good resource sites to population centers, where demand is greatest, can result in

[105]Lawrence Berkeley Laboratory, “Comparison of Financing Terms for Wind Turbine and Fossil Power Plants,” (Berkeley, CA, September 1994), supported by the Energy Information Administration.

higher costs. These obstacles, as well as those imposed by environmental exclusion areas, bear critically on the development of wind energy capacity in this country.

A fourth constraint on the integration of wind power into electric utility system applies once wind capacity exceeds about 15 to 20 percent of installed system capacity. At this level of penetration, utility system studies indicate that additional spinning reserve[106] and load-following generation may be needed. These forms of support are necessary to maintain system area control in the event of fluctuations in wind farm output. Because of these requirements, the value of wind power may decline markedly once wind system penetration exceeds about 15 to 20 percent of a utility system's installed capacity. No utility has reached this level of penetration thus far.

Finally, while wind power is considered to be environmentally benign relative to conventional energy technologies, it does face certain environmental hurdles. First, some consider large-scale commercial wind farms to be an aesthetic problem; second, high-speed wind turbine blades can be very noisy, although technological advancements continue to improve this problem; and third, differential pressure gradients around operating turbines can cause birds to be drawn into the path of the blades.

Outlook for Wind Power

Although there are constraints on wind energy development, a recent analysis[107] indicates that there are 240,000 square miles (625,000 square kilometers) of land with the potential for wind development within 10 miles of transmission lines to support wind energy development in the United States (Figure 23). Assuming class 3 and above wind resources and turbines with 50-meter hub heights centered on plots 10 rotor diameters by 5 rotor diameters in size,[108] that land area could potentially accommodate 734,000 average megawatts[109] of wind energy generation capability.[110] This is roughly equivalent to the installed capacity of all the power plants in the United States. Site-specific, transmission-related questions do remain, but the need for proximity to transmission lines does not overly constrain wind energy development in the United States.

The future of wind electricity is far from certain. Currently, planned additions to wind capacity will be built almost equally by utilities and nonutilities (Table 34). Of the five utility-planned units, two are located in Wisconsin and three in Texas. Completion dates of 2000 are scheduled by Wisconsin Electric Power Company and Wisconsin Public Service Corporation for both of that State's wind projects. In Texas, wind projects are scheduled for completion in 1999, 2003, and 2004 by Texas Utilities Electric Company.

In many cases, the planned projects were not selected because of their economic competitiveness, but were initiated because State governments or Public Utility Commissions provided additional incentives for development. Among the States with special incentives are California, New York, Wisconsin, Minnesota, Iowa, Rhode Island, and Massachusetts.

In addition, many utilities are contracting for small amounts of wind energy on an experimental basis because wind holds considerable promise over the long run, especially as turbine costs come down and fossil fuel prices potentially increase. Since renewables generally are not cost-competitive for utility applications, information about some State incentives is highlighted below. Examples of wind projects are discussed, with emphasis on the reasons for project selection.

[106]Spinning reserve refers to a generating unit (typically a combustion turbine) that is operating and synchronized with the transmission system but not supplying power to meet load. It is available to take on load on very short notice, for example, if a large generating unit goes off line unexpectedly. The greater the amount of capacity that can be lost, the greater the spinning reserve requirement.

[107]J.P. Doherty, Energy Information Administration, "U.S. Wind Energy Potential: The Effect of the Proximity of Wind Resources to Transmission Lines," *Monthly Energy Review* (Washington, DC, February 1995), pp. vii-xiv.

[108]For more information, see Pacific Northwest Laboratory, *An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States*, DE91018887 (Richland, WA, August 1991), p. 43.

[109]Potential generating capability is presented in average megawatts per square kilometer. Capacity denoted in average megawatts should not be confused with nameplate capacity in megawatts. The nameplate capacity rating represents peak output at the rated wind speed, while average megawatts is the normalized actual power production (average megawatts multiplied by 8,760 hours per year results in the annual energy production in kilowatthours per year).

[110]J.P. Doherty, Energy Information Administration, "U.S. Wind Energy Potential: The Effect of the Proximity of Wind Resources to Transmission Lines," *Monthly Energy Review* (Washington, DC, February 1995), pp. vii-xiv.

Table 34. Operable and Planned Wind Projects as of December 31, 1994

Ownership and Location	Operable		Planned[a]	
	Number	Megawatts	Number	Megawatts
Utility Owned				
Arkansas	3	0.03	0	0
California	1	6.80	0	0
Iowa	11	0.08	0	0
Kansas	2	0.05	0	0
Maine	8	0.32	0	0
Minnesota	3	0.20	0	0
Texas	0	0.00	3	300
Vermont	2	0.20	0	0
Wisconsin	1	0.04	2	15
Total	**21**	**7.72**	**5**	**315**
Nonutility Owned				
California	76	1,693	W	W
Other[b]	4	45	W	W
Total	**80**	**P1,738**	**7**	**P335**

[a]Utility plans, 1995 through 2004; nonutility plans, 1995 through 1997.
[b]Other includes Hawaii, Iowa, Maine, Minnesota, and New Hampshire.
P = preliminary data.
W = withheld to avoid disclosure of individual company data.
Source: Preliminary numbers for 1994 nonutility wind capacity from Energy Information Administration, Form EIA-867, "Annual Nonutility Power Producer Report."

State-Supported Wind Energy Programs

California

Although California is host to 97 percent of wind energy development in the United States, it contains less than 1 percent of total U.S. wind energy potential.[111] Sixteen States have a wind resource base greater than or equal to that of California,[112] and 37 States have defined potential for utility-scale wind energy development. Many of the California projects were built when natural gas prices were high and projected to go higher, and Federal and State tax incentives for wind were also high. These conditions made qualifying facilities (QFs) using wind power economical, given the electric utility's projected avoided cost.

The immediate outlook for renewables in California, however, is less favorable. Early in 1995, the Federal Energy Regulatory Commission (FERC) ruled that the Biennial Resource Plan Update of the California Public Utilities Commission (CPUC) improperly prevented nonrenewable resources from competing with renewable resources in the bidding for power purchase agreements. The FERC ruling prevents the CPUC from establishing rates for power supplied by QFs above the most broadly defined avoided cost—not just an avoided cost based on a preferred group of resources. By forcing California to open the power purchase bidding to all resources, renewable QFs are forced to compete with nonrenewable facilities, such as gas-fired power plants. Because this ruling is highly adverse to renewables and contrary to the State's intention to support renewables, the CPUC is considering measures to support renewables without mandating rates above avoided cost. Currently, the CPUC is considering mandating that utilities that sell at retail in the State obtain 12 percent of their energy from renewable resources. Such a ruling, which would have the effect of mandating the quantity of renewables instead of the price paid for renewables, is designed to circumvent the FERC order

[111]American Wind Energy Association in cooperation with the U.S. Department of Energy and the National Renewable Energy Laboratory, *Removing Barriers to Wind Energy: Directions for State Regulatory Action* (Washington, DC, 1993), pp. 5-6.
[112]Pacific Northwest Laboratories, *An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States*, DE91018887 (Richland, WA, August 1991), p. 43.

rejecting QF rates above avoided cost.[113] This issue is further discussed in the feature article "Renewable Resource Electricity in the Changing Regulatory Environment" in this report.

Wisconsin

The Wisconsin Public Service Commission has been a leader in environmental policies associated with electricity production. Since 1989, electric utilities in Wisconsin have been directed to incorporate environmental externality costs in their evaluation of demand and supply options. Because of the current low natural gas prices, however, renewables were not selected when Wisconsin Electric developed its 1994 plans based on least costs. Wisconsin Electric decided to incorporate renewable energy resources, including wind, in its plan in the belief that improvements in technology and cost could render renewables more attractive in the future.

Currently, Wisconsin is in the process of adopting incentives for wind. It is the only State that offers an incentive payment for electricity generated from renewables. Advance Plan 6, passed in 1992, provides for a payment of 0.75 cents per kilowatthour for qualifying wind power, solar thermal electric, or photovoltaic generation, and 0.25 cents per kilowatthour for all other qualifying renewable generation to shareholders of investor-owned Wisconsin utilities. The incentive payment applies to facilities that receive construction authority by December 31, 1998. It also applies to utility purchases of nonutility renewable power. The Wisconsin Commission recognized that utility ratepayers would ultimately cover the costs of these incentives but accepted the tradeoff in the interests of promoting renewable energy and obtaining the benefits of fuel diversity and emissions reduction.

The Wisconsin payments could be challenged, however, before the Federal Energy Regulatory Commission. In its ruling against the California Public Utility Commission on QF rates above avoided cost, FERC said that while a State could support renewables through broad tax or other mechanisms, it could not use environmental adders on rates. This rejection of the rate-based environmental adder (or externality) approach directly challenges the justification Wisconsin provides for its Advance Plan 6.

Minnesota

Minnesota has been working to promote the development of renewable energy since the early 1980s. Efforts in this area have intensified in recent years, resulting in a number of new incentives and renewable mandates within the State. Minnesota currently expects that over 30 percent of its new and refurbished capacity scheduled for construction between now and 2002 will utilize renewable resources.[114]

Minnesota recently mandated that Northern States Power (NSP) install or contract to purchase 425 megawatts of wind generation capacity and 125 megawatts of "closed loop, farm-grown" biomass capacity by 2002 as part of legislation authorizing the utility to store its spent nuclear fuel in an above-ground, dry cask storage facility. An additional 400 megawatts of wind capacity must be installed by 2002 if the Commission finds that wind is a least-cost resource, subject to Integrated Resource Plan requirements.[115] The mandates are set out in stages and NSP must achieve each stage in order to receive its next increment of nuclear waste storage casks.

NSP intends to install 143 turbines at a site near Lake Benton in southwestern Minnesota. Wind data collected since 1985 show that targeted areas of the State have an annual average wind speed of 16.1 miles per hour. At these speeds the project is expected to deliver wind energy to NSP for about 3 cents per kilowatthour averaged over the 30-year term of the power purchase agreement.[116]

Maine

In the Northeast region, Central Maine Power (CMP)[117] signed a 3-year contract, with options, to purchase 10 megawatts of power from a proposed wind plant development in the Boundary Mountains of Maine. The New England Electric System has already

[113]The Public Utilities Regulatory Policies Act of 1978 (PURPA), Section 210, requires utility companies to buy power from qualifying facilities, including renewable plants. There is a proposal to repeal this section of PURPA. The legislation has pitted some of the Nation's major utilities against independent producers. The utilities argue they are forced to subsidize sometimes uneconomical private producers at high cost to consumers, while the independent producers argue that the utilities are seeking to shore up a monopoly. The price for QF power, known as the "avoided cost," is based on how much money the utility would have spent to generate the same amount of energy that is supplied by the independent producer.

[114]B. Engelking, "Minnesota's Policy and Incentives for Renewable Energy," paper presented at NARUC-DOE Conference on Renewable and Sustainable Energy Strategies in a Competitive Market (Madison, WI, May 1995).

[115]1993 Renewable Energy and Integrated Resource Planning Act (Minnesota Laws 1993, Chapter 356).

[116]The cost of 3 cents per kilowatthour includes a tax credit of 1.5 cents per kilowatthour.

[117]NARUC Subcommittee on Renewable Energy, *State Renewable Energy News*, Vol. 4, No. 1 (Winter 1995).

signed a contract to purchase 20 megawatts of power from the project under its "Green RFP." The first phase of the project is expected to be on line by the end of 1996. Maine has 191 square kilometers for class 3 and above wind development, equal to a potential 294 megawatts of generating capacity.

The wind energy from this project will replace more expensive resources on cold winter days. The wind energy closely matches the utility's load during the winter season. CMP has been working to reduce its level of expensive QF purchases, and the price that the utility will pay for wind energy will be considerably lower than the average of its current QF contracts.

The staff of the Maine Public Utility Commission supported the utility proposal, noting that the projects represent a regulatory "insurance policy" because they add valuable diversity to the fuel mix, avoid more expensive fossil fuels, hedge against fuel price increases and more stringent environmental restrictions, and help to assure that future renewables applications will be cost-effective. The staff also noted that, even in the restructured utility industry, these "green" electric sources would have value both for environmentally conscious customers and for those seeking diversity.

Texas

Texas Utilities Electric has made a commitment to wind energy in anticipation of decreasing renewable energy costs over the next 10 years and as a hedge against potential future fuel price escalation and the possibility of changing environmental standards. A 40-megawatt nonutility-owned wind project is already in place, with startup expected in late 1996. In addition, the utility plans to build a total of 300 megawatts of wind electricity generation capacity, representing approximately 7 percent of its total resource additions over a 10-year period, as part of its 1995 Integrated Resource Plan.[118]

In early 1995, a U.S. company announced that it had signed contracts to develop and finance a project called Windplant™ in West Texas to sell electricity to the Lower Colorado River Authority. It will be the largest wind energy facility in the United States outside California. The company previously announced plans to develop up to 250 megawatts of wind capacity at the site.[119]

[118]NARUC Subcommittee on Renewable Energy, *State Renewable Energy News*, Vol. 4, No. 1 (Winter 1995).
[119]"Kenetech Announces Sale of West Texas Windplant," *Solar Letter* (January 25, 1995), pp. 24-25.

Wind Power Milestones

Early 1900s to 1950	Early wind power in the United States	Windmills were used to pump water and were also used for remote electricity generation.
1941	First grid-connected electricity	On a hilltop in Rutland, Vermont, "Grandpa's Knob" wind generator supplied power to the local grid for several months during World War II. The Smith-Putnam machine was rated at 1.25 megawatts in winds of about 30 miles per hour. It was removed from service in 1945.
1973	OPEC oil embargo	Oil and gas prices rose, increasing interest in alternative energy sources.
1974-1975	NASA's MOD-0 developed	The MOD-0, a horizontal axis wind turbine was developed at the NASA Lewis Research Center in Cleveland, Ohio.
1977-1981	MOD-0, MOD-1, and MOD-2 developed and tested	Four MOD-0As, rated at 200 kilowatts each, were placed at utility sites around the country for tests between 1977 and 1980. The MOD-1, with a 2-megawatt capacity rating, the first wind turbine rated over 1 megawatt, began operating in 1979.
1978	Public Utility Regulatory Policies Act (PURPA) enacted	PURPA mandated the purchase of electricity from qualifying facilities (QFs) meeting certain technical standards regarding energy source and efficiency. PURPA also exempted QFs from both State and Federal regulation under the Federal Power Act and the Public Utility Holding Company Act.
1979	Federal funding for wind power research and development (R&D) exceeds $50 million	U.S. Department of Energy (DOE) funding for wind power R&D was $59.6 million in fiscal year 1978 (current year dollars), marking the first time the funding level surpassed $50 million. It remained above $50 million until fiscal year 1982, when it was reduced to $16.6 million (current year dollars).
1980	Crude Oil Windfall Profits Tax Act	The Act increased the business energy tax credit to 15 percent. Combined with an investment tax credit passed earlier, the total Federal tax credit for a wind turbine was 25 percent. In addition, California had a 25-percent State tax credit in the early 1980s, bringing the effective tax credit to nearly 50 percent.

1983	Interim Standard Offer Number 4 (ISO4) contracts in California	Because of a projected capacity shortfall, California utilities contracted with facilities that qualified under PURPA to generate electricity independently. The ISO4 contracts set a price based on long-run costs avoided by not building the coal plants that had been planned. The contracts, combined with favorable tax incentives mentioned above, encouraged the installation of many hastily designed wind turbines in California in the early 1980s.
1985	California wind capacity at 1 gigawatt	Most of California's wind capacity, which totaled more than 1,000 megawatts in 1985, was installed on the Tehachapi and Altamont Passes.
1988	Decline in cumulative wind capacity	Many of the hastily installed turbines of the early 1980s were removed and later replaced with more reliable models.
1989	Low point in Federal funding for wind power	Throughout the 1980s, DOE funding for wind power R&D declined, reaching its low point in fiscal year 1989.
1990	California wind capacity in excess of 2 gigawatts	In 1990, more than 2,200 megawatts of wind energy capacity was installed in California—more than half of the world's capacity at the time.
1992	Energy Policy Act	The Act reformed the Public Utility Holding Company Act and many other laws dealing with the electric utility industry. It also authorized a performance tax credit of 1.5 cents per kilowatthour for wind-generated electricity.
1993	33M-VS commercially available	The 33M-VS was one of the first commercially available, variable-speed wind turbines. U.S. Windpower developed the 33M-VS over a period of 5 years, with final prototype tests completed in 1992. The $20 million project was funded mostly by U.S. Windpower, but also involved Electric Power Research Institute (EPRI), Pacific Gas & Electric, and Niagara Mohawk Power Company.
1995	FERC prohibition on QF contracts above avoided cost	In a ruling against the California Public Utility Commission, FERC refused to allow a bidding procedure that would have the effect of allowing rates above avoided cost from renewable QFs.
Mid-1990s	ISO4 contract rollover in California at lower rates	Ten-year QF contracts written during the mid-1980s at rates of 6 cents per kilowatthour and higher began rolling over at mid-1990s avoided costs of about 3 cents per kilowatthour. This " 11th-year cliff" creates financial hardship for most QFs on ISO4 contracts.

1995	DOE wind program lowers technology costs	DOE's advanced turbine program, funded at $49 million, has led to new turbines with energy costs of 5 cents per kilowatthour of electricity generated.