Renewable Energy: Wind Power

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1. Harnessing the Power of Wind

At the end of 2000 there was 2,554 MW of wind generation installed in the US. An American Wind Energy Association (AWEA) report published in May 2001 suggested that an additional 2000 MW was under development or expected to be completed by year end 2001[1]. Much of that capacity has come online; 2001 was a tremendous year for growth in the utility-scale wind industry. A total of 1,694 MW of capacity was installed, representing a 66% increase in total US capacity. In Section 3 of this paper we will take a more detailed look at projects coming online in 2001. Table 1 below shows the current top 10 states in terms of wind generation capacity as of January 11, 2002. Total US capacity is now 4,248 MW.

	MW
California	1,671
Texas	1,173
Iowa	324
Minnesota	319
Washington	178
Oregon	157
Wyoming	141
Kansas	118
Colorado	61
Wisconsin	53
Total	4,195

Table 1 Wind Capacity Top 10

2. US Wind Resource

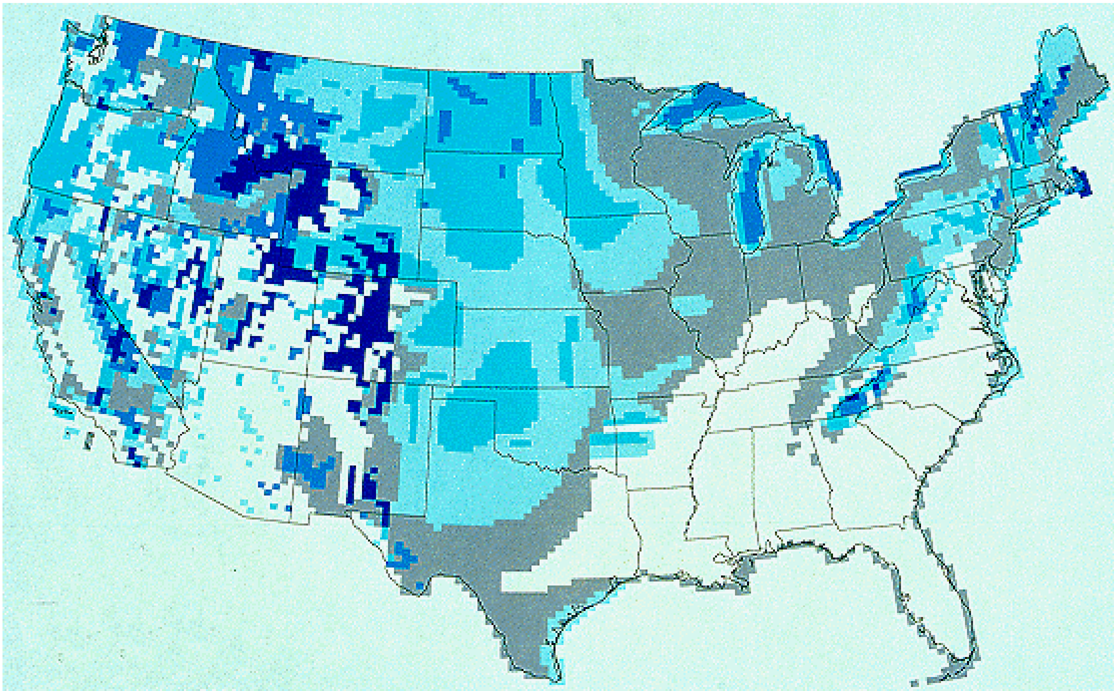
Wind power classes range from 1 to 7. Figure 1 shows annual average wind resource estimates for the contiguous United States[2].

A class 3 wind resource, which is not uncommon throughout much of the United States, is the minimum level suitable for wind most wind turbine applications. A class 4 wind resource or above is generally preferred for today's large wind farms. Factors such as those listed below influence the actual amount of land area available for development.

1) land form (flat vs. mountainous terrain)
2) land use (forest, agriculture, urban)
3) environmental exclusions (federal and state lands such as parks, monuments, wilderness areas)

[1] American Wind Energy Association, *Global Wind Energy Market Report*, May 2001
[2] Pacific Northwest Laboratory for US DOE, *Wind Energy Resource Atlas of the United States*, DOE/CH 10093-4, March 1987

4) other exclusions such as transportation right-of-ways, local parks, privately administered areas, and proposed environmental lands



Power Class	Wind Power (w/m²)	Wind Speed (m/s)
1	<200	<5.6
2	200-300	5.6-6.4
3	300-400	6.4-7.0
4	400-500	7.0-7.5
5	500-600	7.5-8.0
6	600-800	8.0-8.8
7	>800	>8.8

Figure 1 Annual Average Wind Resource Estimates

3. Utility-Scale Wind Technology: Current Applications

Utility-scale turbines typically range from 600 kW to 1500 kW. Larger turbines, in the 2 MW to 5 MW range, are being developed for offshore applications.

Table 2 provides a listing of all projects coming online in 2001[3]. Most notable from the RUS perspective is the Chamberlain, SD project, Prairie Winds. RUS provided it's first

[3] Wind Projects Data Base, AWEA, January 11, 2002

wind energy loan to support this joint project between Basin Electric Power and East River Electric Power.

Project / Location	Owner	Date Online	MW	Power Purchaser	Turbines (make / #)
Mountain View Power Partners 1 CA	PGE-NEG	Oct 2001	22.2	PG&E	Mitsubishi MWT 600 (37)
Mountain View Power Partners 2 CA	PGE-NEG	Oct 2001	44.4	PG&E	Mitsubishi MWT 600 (74)
Ponnequin Phase III CO	New Century (Xcel)	2001	9.9	New Century (Xcel)	Vestas (16)
Peetz Table Wind Farm CO	New Century (Xcel)	Sept 2001	29.7	New Century (Xcel)	NEG Micon (33)
Top of Iowa Wind Farm, Worth County, IA		Dec 2001	80.1	Northern Iowa Wind Power	NEG Micon (89)
Waverly III IA		2001	0.90	Waverly Light & Power	NEG Micon (1)
Spirit Lake IA		Dec 2001	0.75	Spirit Lake School Dist/Alliant	NEG Micon (1)
Montezuma KS	FPL Energy	Dec 2001	112.2	Utilicorp	Vestas V-47 (65)
Hull, MA	Town of Hull	Dec 2001	0.66	Hull Municipal Light Dept.	Vestas V-47 (1)
Mackinaw City MI		2001	1.8	Mackinaw City	NEG-Micon (2)
Ruthton Wind Farm MN	CHI Energy	Jan 2001	15.84	Northern States Power	Vestas V-47 (24)
Agassiz Beach MN	CHI Energy	Jan 2001	1.98	Northern States Power	Vestas V-47 (3)
Chandler Champepaden, Chandler Hills Phase II, MN	Great River Energy	Dec 2001	1.98	Great River Energy	Vestas V-47 (3)
Chandler Moulton, Chandler Hills Phase II, MN	Great River Energy	Dec 2001	1.98	Great River Energy	Vestas V-47 (3)
Metro Wind LLC MN	CHI Energy	Feb 2001	0.66	Northern States Power	Vestas V-47 (1)
Pipestone, MN Olsen Wind Farm	Olsen Farm	2001	1.5	Olsen Farm	NEG Micon (2)
Wilmont Hills MN	Alliant	Dec 2001	1.5		NEG Micon (1)

Project / Location	Owner	Date Online	MW	Power Purchaser	Turbines (make / #)
Hendricks/Lincoln County, MN Lakeview Ridge	Otter Tail Power	Dec 2001	0.9	Otter Tail Power	NEG Micon (1)
Pipestone County, MN Kas Farms	Kas Brothers	Dec 2001	1.5	Xcel	
Fenner Wind Project, NY	CHI Energy	Dec 2001	30.0	NY Power Pool	Enron TZ 1.5 (20)
Gilliam County Condon Wind Project OR		Dec 2001	24.6	BPA	Mitsubishi MWT600 (41)
Wasca (Klondike) OR	Northwest Wind Power	Dec 2001	24.0	Northwest Wind Power	Enron 1.5 MW (16)
Umatilla (Stateline Wind) OR	FPL Vansycle	Dec 2001	83.82	PacifiCorp	Vestas V-47 (127)
Somerset PA	Atlantic Renewable & Zilka Renewable Energy	Oct 2001	9.0	Exelon Power Team	Enron 1500 (6)
Mill Run Windpower PA	Atlantic Renewable & Zilka Renewable Energy	Oct 2001	15.0	Exelon Power Team	Enron 1500 (10)
Chamberlain SD	Basin Electric	Aug 2001	2.6	Basin / East River Electric	Nordex 1300 (2)
Hueco Mountain Wind Ranch, El Paso County, TX	Cielo Wind Power	Mar 2001	1.32	El Paso Electric	Vestas V-47 (2)
Woodward Mt. Pecos County, TX	FPL Energy	Apr 2001	159.7	TXU	Vestas V-47 (242)
King Mountain Wind Ranch / Austin TX	FPL Energy	July 2001	76.7	Austin Energy	Bonus 1300 (59)
Trent Mesa, Taylor County, TX	AEP	Nov 2001	150	AEP	Enron 1500 (100)
King Mountain Wind Ranch TX	FPL Energy	Dec 2001	278.2	Texas-New Mexico Power Co. / Reliant / Austin Energy	Bonus 1300 (214)

Project / Location	Owner	Date Online	MW	Power Purchaser	Turbines (make / #)
Pecos County Indian Mesa TX		Dec 2001	82.5	TXU LCRA	Vestas V-47 (125)
Pecos County Iraan TX	AEP	Dec 2001	160.5	City Public Services of San Antonio	Enron 1500 (107)
Llano Estacado Wind Ranch at White Deer TX		Nov 2001	80.0	SW Public Service	Mitsubishi 1000 (80)
Walla Walla (Stateline) WA	FPL Energy, Vansycle	Dec 2001	178.2	Pacificorp	Vestas-V47 (270)
Rock River I Arlington, WY	Shell Renewables	Oct 2001	50.0	Pacificorp	Mitsubishi MWT (50)
Monfort Wind Farm WI	Enron Wind Corp	July 2001	30	Wisconsin Electric / Alliant Energy	Enron 1500 (15)

Table 2 2001 Utility Scale Wind Projects

There is no typical sized wind generation project. For example, of the 22 projects currently operating in Minnesota, totaling 319 MW, the smallest is 0.225 MW and the largest is 107 MW. The two largest projects at 107 MW and 103 MW account for just over 2/3 of the states wind capacity. The remaining 20 projects total only 109 MW of capacity. This sort of dispersion does seem to be the norm for sates with a longer than average history in wind energy. However, newer entrants such as Washington, have jumped right in (see Table 2) with their first project exceeding 100 MW. Kansas also saw an increase in wind generation capacity from 1.5 MW to 113.5 MW with the addition of the Montezuma Project.

4. General Information Concerning Wind Energy Economics

Many factors come into play when considering the economics of a wind generation project. The discussion in this section is meant to provide a few generally accepted averages typically used in discussion of wind generation projects. This material pertains to onshore wind farms and much of the information is owed to the very useful website of the Danish Wind Industry Association.[4]

The cost of capital is always a significant factor in utility investments. At RUS wind projects are primarily being considered under the loan guarantee program. Current rates for this program can be found through the RUS website[5].

4 http://www.windpower.org
5 http://www.usda.gov/rus/electric/loans.shtml

Installed turbine prices generally tend to be in the neighborhood of $1000 per kW. One reason this tends to hold true across the range of the utility-scale turbines is that prices of turbines are much flatter above 600 kW than below. The two most significant factors affecting differences in turbine cost are tower height and rotor diameter. Installation cost typically come in at around 30% of the total turbine cost. Economies of scale are certainly possible if more than one turbine is installed. Scale economies often become evident at the 20-25 MW level.

Installation cost will generally include foundations, road construction, transportation, communications equipment, transformer and other interconnection or transmission related cost. These costs can vary considerably depending upon such factors as soil type, distance from other roadways, and the possible need for grid reinforcement or other interconnection related expenses.

Annual operating and maintenance cost for newer turbines tend to average 1.5% - 2.0% of turbine cost. Some analysts prefer to use an expense of $0.01 per kWh because wear and tear tends to increase with increased production. The design life of most onshore utility-scale turbines is 20 years or 120,000 hours. The actual lifetime of a wind turbine will depend both on the quality of the turbine and the local climatic conditions.

Availability factors for wind turbines are quite high. Availability factors of 98% are common for the best manufacturers. Capacity factors for wind turbines typically range from 25% to 30%.

5. Market Incentives

Many states and the federal government have established incentives or mechanisms to aid in wind and other renewable energy market development.

At the federal level, the Renewable Energy Production Incentive (REPI) was authorized under section 1212 of the Energy Policy Act of 1992. The program, which is administered through the Department of Energy, provides an annual payment of 1.5 cents per kWh for energy produced from an eligible facility during the first 10 years of operation. Eligible facilities are those owned by state or local governments, or not-for-profit cooperatives and they must have started operating between October 1, 1993 and September 30, 2003. Payments are subject to annual appropriations for each year of operation. Regulations for the administration of the REPI program can be found in 10 CFR 451.

The federal production tax credit (PTC) for wind and other renewables was also a product of the Energy Policy Act of 1992[6]. The PTC, enacted as Section 45 of the Internal Revenue Code provides a tax credit of 1.5 cents for every kWh produced for the first 10 years of a projects life, assuming the project came on line after December 31, 1993. The most recent (2nd) extension of the PTC expired December 31, 2001. Several attempts

[6] Section 1914

have been made to get an extension of the PTC passed; however this has not yet been successful. It is generally expected that the PTC will be extended; however the delay may certainly have an effect on the current industry momentum.

Renewable Portfolio Standards (RPS) is a public policy tool which typically requires an increasing share of renewable energy production within the portfolio of supply resources available to serve a state or country. To accomplish this in an efficient manner, the state or federal government would require of generators (or retailers) that they possess a number of Renewable Energy Credits at year end. The number of credits required is typically determined as a percentage of kWhs sold. For more information on credit trading, check out the National Wind Coordinating Committee website at http://www.nationalwind.org, for look at their new report on credit trading. Several states have already enacted such laws and most comprehensive federal energy proposals also include an RPS.

For a state by state look at incentives for renewable energy investment, visit AWEA's website at http://www.awea.org/pubs/inventory.html. Note that at the state level, not all incentives are targeted to utility scale investment.

6. Economic Development

The rural economic benefits of wind farms can be significant. Wind energy development is highly compatible with other land uses such as farming and ranching. Landowners can normally expect to receive lease fees of up to 2% of gross revenue or about $2000 per turbine annually.

Local property taxes bring in about $1 million per year for each MW of installed capacity[7]. During construction, an estimated two jobs per MW are added to the local economy when local contractors are used for foundations, roads, towers, and electrical systems. When construction is complete, as many as five permanent jobs are created for each 50-100 MW of installed capacity.

7. Environmental / Public Relations Issues

The obvious environmental plus with wind generation is the fact that no CO_2 or other greenhouse gases are emitted into the atmosphere. There is also minimal or no risk of soil or water contamination.

There are however environmental and other externalities associated with wind energy development. These include potential impacts to birds and other animal habitat, soil erosion, noise, electromagnetic interference, and aesthetics[8].

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[7] NREL for US Department of Energy, *Wind Power Today*, DOE/GO-102001-1325, May 2001
[8] NREL for US Department of Energy, *Wind Energy Information*, DOE/GO-10095-238, April 1996

The interaction between birds and wind turbines is an issue of current debate. It's often said that with careful sighting, this concern can be largely mitigated. The wind industry is currently working with other interested parties to address this important issue. The crux of the problem is the attractive nature (to birds) of the pasture and prairie lands where the best wind resources are located. The best advice is to carefully assess the potential for avian interaction in the early stages of project siting.

Wind turbines, like all mechanical systems do make noise. Turbines can create low frequency impulsive (thumping) and broadband (swishing) sounds. Design changes in recent years have done a great deal to lessen these noises. Much of the noise created by wind turbines is masked by the sound of the wind itself. At 250 meters the sound from a wind turbine is in the 45-50 decibel range. This is often compared to the sound of a typical household refrigerator.

Predictable levels of television interference have been associated with wind turbines, particularly in older machines with metal blades. Blades today are typically made with a composite material, which doesn't reflect television signals as much as past designs. However modern blades also tend to have lightning protection, on the surface of the blade, which tends to increase electromagnetic interference.

8. Power Supply Integration

Integrating wind energy into utility systems presents the potential for some familiar power quality related problems and some not so familiar issues for most utility engineers. These issues have been characterized as either interface (engineering) issues, or operational/planning issues[9].

Interface issues include harmonics, reactive power supply, voltage regulation, and frequency control. Power quality is obviously a major utility concern. Problems with power quality have been documented at various California wind farms built in the early 1980's. Modern turbines are equipped with more sophisticated power electronics than their predecessors. These newer systems have largely eliminated past problems associated with harmonics, reactive power supply, and frequency control. The extent to which voltage regulation is an issue of concern today appears to be largely a function of grid strength at the point of integration.

Operational/planning issues essentially deal with the intermittent power output inherent in wind generation. These issues include operating reserve requirements, unit commitment, economic dispatch, modeling, and valuation. When integrating wind power

[9] National Wind Coordinating Committee, Wind Energy Series, *Wind Energy Transmission and Utility Integration*, No 9, January 1997 (Much of this information is taken form a DOE sponsored report on wind system integration prepared by Robert J. Putnam Jr., of Electrotek Concepts, Inc. Mr. Putnam based his findings on interviews with system operators and dispatchers from Pacific Gas & Electric and S. California Edison.)

into a utility system, reserve margins must also account for the maximum probable decrease in wind plant output over a given period. At the time of the Putnam report (see footnote 9) the variability of wind plant output in California had not required any change in operating reserve requirements. It's suggested that wind penetration must exceed 5% of system capacity to have an adverse affect on reserve requirements.

In terms of unit commitment and dispatch, the most conservative approach to integration of an intermittent resource is to discount the contribution of the resource. Much attention within the research community currently is being paid to forecasting wind plant output. Not unlike the issue of unit commitment and dispatch, planning issues also center on the modeling and valuation of intermittent wind resources. Models, which can reflect the real-time variation in load and wind plant output, are necessary to address concerns over the operational impacts of changing wind plant output. Further, modeling capability of this nature will allow better quantification of wind outputs capacity, environmental, and other distributed benefits to the utility system.

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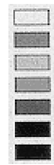
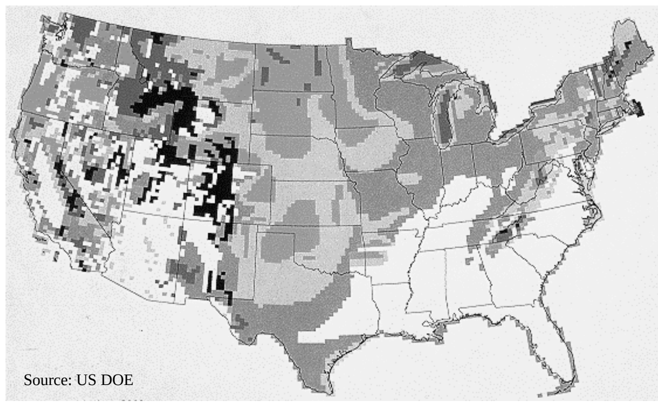
Current US Wind Power Capacity

- 2001 Projects Total 1,694 MW
- US Total = 4,248 MW
- 2001 Industry Leaders
- RUS Makes 1st Wind Loan

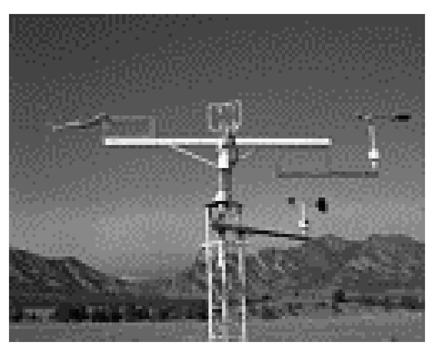
- ***California*** 1,671 MW
- ***Texas*** 1,173 MW
- ***Iowa*** 324 MW
- ***Minnesota*** 319 MW
- ***Washington*** 178 MW
- ***Oregon*** 157 MW
- ***Wyoming*** 141 MW
- ***Kansas*** 118 MW
- ***Colorado*** 61 MW
- ***Wisconsin*** 53 MW
- ***Total*** 4,195 MW

US Wind Resources





Wind Plant Cost / Analysis Factors



- Installed Turbine Cost
  - Installation
  - Scale Economies
- Design Life
- Availability
- Capacity Factor
- Operating and Maintenance

Market Incentives

- Renewable Energy Production Incentive (REPI)
- Federal Production Tax Credit (PTC)
- Renewable Portfolio Standard (RPS)
  - Renewable Energy Credits
- Other State Incentives

Economic Development

- Lease Fees and Rural Land Use
- Local Property Taxes
- Construction Related Employment
- Permanent Employment

Environmental Issues and Other Externalities

- Environmental Benefits
- Avian and other Habitat Issues
- Noise
- Electromagnetic Interference
- Aesthetics

Power Supply Integration

- Interface Issues
  - – harmonics
  - – reactive power supply
  - – voltage control
  - – frequency control
- Operational Issues
  - – reserve margins
  - – unit commitment / dispatch
- Planning Issues
  - – modeling and valuation of wind resources