

Strong Winds on the Horizon: Wind Power Comes of Age

RANDALL SWISHER, CHRISTINE REAL DE AZUA, AND JULIE CLENDENIN

Invited Paper

Wind power has been the fastest growing energy technology in the world for the last decade, and U.S. wind capacity is expected to increase by 50% by the end of 2001. What are the factors driving that growth?

- 1) *Wind energy's increasingly attractive economics is perhaps the most important factor, with the costs of wind having declined almost 90% since the early 1980s. Technology changes have played a critical role in driving down costs. Today, major wind projects are being built in Texas that will generate electricity at costs competitive with those of a new natural gas plant.*
- 2) *State policy leadership has played a key role in moving wind into the U.S. market, and Minnesota, Iowa, and Texas have been the three states that have contributed the most new wind capacity over the last decade.*
- 3) *Competition in the electric industry has driven more and more utilities to recognize that many customers care about the environmental attributes of electric power. More than 190 utilities or power suppliers are now offering a wind-energy based electricity product.*
- 4) *The electric utility industry's perspective on wind has become more favorable as wind has been more widely deployed around the country. While California and Hawaii were the only states with significant wind capacity in the mid-1980s, there are 26 states with at least pilot utility-scale wind installations now planned or in place.*
- 5) *Wind and gas are complementary resources, but wind is emerging as perhaps the most promising nongas alternative for the electric industry. Gas has been the electric industry fuel of choice in recent years, but as the price of gas has soared over the past year, a growing number of utilities are finding it attractive to diversify their portfolio with wind.*
- 6) *Finally, the wind production tax credit is now scheduled to expire at the end of 2001. Many utilities that are favorably disposed toward wind are moving to ensure that their planned projects come on line prior to the expiration of the credit.*

Small wind turbines, which range in size from 300 W to 100 kW of capacity, have also been enjoying a steadily increasing market. Small wind turbines, which have many applications ranging from off-grid to grid-connected to hybrid systems, are cost-competitive with diesel systems while offering substantial environmental advantages.

The barriers to increased wind deployment are limited. Siting is not too difficult, particularly in the areas of the Great Plains where so much of the wind resource is to be found. Perhaps the most significant barrier is transmission simply because the wind resource is typically found at a distance from load centers. But states like Texas have helped facilitate wind development through policy decisions that ensure that the transmission system does not discriminate against wind because it is a variable resource.

Perhaps the greatest current barrier facing wind energy technology is an information barrier: the fact that so many key decision makers—electric industry, financial community, and public policy-makers—have not kept up with wind power's enormous progress over the last decade. But, as wind continues to double in global capacity every three years, that problem appears to be slowly fading. Clearly, wind energy's future is bright.

Keywords—*Electricity, electric utilities, energy policy, renewable energy, wind energy.*

Wind energy in the U.S. is turning in a dazzling performance in 2001, showing that our nation's abundant winds can provide a cost-competitive, clean energy solution to its electricity needs. The amount of electricity generated from wind in the U.S. is expected to surge this year, establishing 2001 as the best ever for the industry. Proposals for well over 2000 new megawatts of wind generating capacity were in the works as of April 2001. Of that amount, 1250 MW is expected to be completed in 2001, almost twice the previous record of 732 MW, set in 1999.

By the end of 2001, wind farms across the country will generate about 10 billion kilowatt-hours (kWh) annually, enough electricity to power one million average American households. Even though that is still less than 1% of U.S. electricity production, at that level, wind will displace, every year, 8 million tons of carbon dioxide, based on the average U.S. electricity fuel mix. An area of 4000 square miles of forest, larger than the states of Rhode Island and Delaware combined, would be needed to absorb that amount of carbon dioxide.

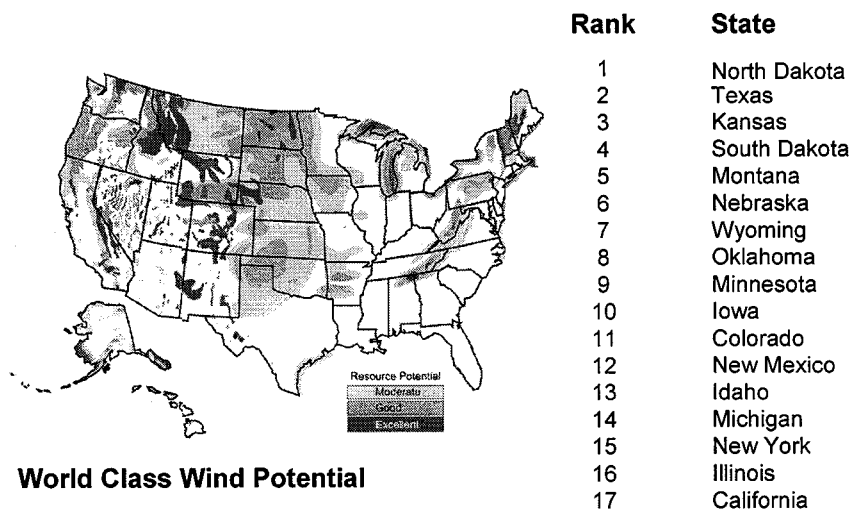
We have barely begun to tap the power of this gigantic, invisible river of air. America's wind energy potential is ample enough to meet more than twice the total current U.S. con-

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An All American Resource



World Class Wind Potential

Germany's Potential: 100 GW
 North Dakota's Potential: 250 GW

Fig. 1. U.S. Department of Energy map of wind resources in the U.S.

sumption of electricity, according to federal estimates. Development of only a fraction of that potential would allow the U.S. to boost its electricity supply by 10%–20% without sacrificing environmental standards or accelerating the depletion of natural resources.

As Fig. 1 demonstrates, the U.S. is blessed with an enormous wind resource. Although Germany is today the world's leader in installed wind capacity, North Dakota alone has two and a half times as much wind potential. The state of Texas, which ranks just behind North Dakota, has enough wind potential to provide about 40% of total U.S. electric demand. California, despite being the state that is the current leader in installed U.S. wind capacity, ranks only 17th in wind potential, demonstrating the important role played by state policy leadership in opening markets for new renewable technologies such as wind.

The year 2001 is seeing wind projects of record size in development. At least seven projects in the 100–200 MW range and three projects in the 200-plus MW range are expected to be installed in the U.S. this year and next. The Bonneville Power Administration (BPA), a federal power marketing agency in the Pacific Northwest, issued in February a request for proposals (RFP) for 1000 MW of wind energy, the largest wind RFP ever from a single entity, and received proposals for more than 2500 MW of capacity in response. There are substantial economies of scale in larger wind plants, and these new projects will realize those economies, cutting the cost of wind to very attractive levels. Large projects, when sited in a strong wind resource area, are resulting in optimum wind energy economics.

I. WHAT ARE THE DRIVING FORCES BEHIND THE SURGING MARKET FOR WIND ENERGY IN THE U.S.?

- **Competitive Cost:** The cost of wind-generated electricity has declined about 90% over the last 20 years.

Today, large new wind farms at excellent wind sites generate electricity at a cost of 3 to 4 cents per kWh (which includes the value of the wind production tax credit). That places the cost of power from the country's most efficient wind farms in a range that is competitive with that of electricity from new conventional power plants.

- **Stable Price:** While the cost of wind power has continued to decline, the cost of electricity from new natural gas plants has gyrated sharply in the last year. Natural gas was the utility fuel of choice in the 1990s, with about 95% of planned new capacity devoted to gas projects. The volatility in the price of natural gas has highlighted for utilities the fact that wind energy is impervious to fuel price hikes because its fuel—the wind—is free. Wind power plants generate electricity at a predictably constant price over the life of their wind turbines.
- **State Policy:** A growing number of states have adopted Renewables Portfolio Standards (RPS) or have required utilities in the state to include a certain percentage of renewables in their generation mix. Perhaps the best examples are Minnesota, Iowa, and Texas. In Texas, the 1999 state restructuring legislation included an RPS requirement of 2000 MW of new renewable energy capacity by 2009. The response to utility RFP's stunned the state's electric suppliers—the wind bids came in at record low rates, making wind the least cost new resource in the state. With that, the utilities moved toward overcompliance with the requirements of the law, and there are now about 900 MW of new wind projects moving toward completion in the state. Other states that are now implementing an RPS policy are Massachusetts, New Jersey, Connecticut, Maine, Wisconsin, Nevada, and Arizona,

and the policy is under discussion in California and Minnesota.

- **Electric Industry Competition:** As electric utilities move toward a more competitive environment, a growing number of companies are offering a Green electricity product as a means of differentiating their service and winning customer loyalty. Wind, because of its superior economics and strong consumer appeal, has emerged as the star of the Green Market. Today, more than 190 electric utilities (including many distribution cooperatives) offer a premium-priced Green electricity product that includes wind power as a major component. Although the Green Market represents only a modest amount of added capacity at this point, it will grow over time.
- **Resource Diversity/Insurance Against Electricity Shortages:** The 300-MW Stateline project along the Washington-Oregon border and the 1000 MW of wind power requested by the Bonneville Power Administration will help diversify the region's resource mix and complement hydro resources from local dams, extending water supplies in the region at a time when precipitation has been lower than normal and planners are concerned about electricity shortages.
- **Utility Experience and Perspective:** As wind energy technology has matured, a growing number of electric utilities have learned that the past negative experiences with wind were just that—a thing of the past. Despite the bad “lessons” of the mid-1980s, wind energy technology now performs reliably and cost-effectively when properly sited and developed. Modern wind turbines typically have availabilities exceeding 98%, and perform with capacity factors of 35%–40% in good wind resource areas.
- **Production Tax Credit Deadline:** The wind production tax credit provides 1.5 cents per kWh (adjusted for inflation) through the first ten years of a project's operation. This incentive is currently scheduled to expire at the end of 2001 and has driven the timing of project decision-making since developers don't want to lose the value of the incentive. Legislation to extend the PTC for five years has been introduced in both the House and the Senate, and a three-year extension has been included in the budget proposed by the Bush Administration.

II. IMPROVEMENTS IN TECHNOLOGY DRIVE THE COST OF WIND DOWN

Wind energy technology has evolved in dramatic ways over the past two decades. There are five major technology changes that have translated into reduced cost of energy. Those improvements include the following.

- 1) *Increasing wind turbine size*, including substantially larger rated generating capacity, much larger wind turbine rotor diameters, and increased tower heights. This is perhaps the single most obvious change in the technology over the last few decades. In 1990, the average

turbine size was 100 kW, while close to 40% of wind turbines installed globally last year were 1 MW or larger in capacity (which requires blades larger than 50 m long).

- 2) Although wind turbines are much larger than in the past, as they are trending larger designers are also trying to take some of the weight out of the machines. *Reduced wind turbine weight* lowers the cost of the turbine since it reduces the raw materials requirements for the product.
- 3) *Manufacturing economies of scale* are now starting to be achieved as production of wind turbines is nearing 5000 MW annually on a global basis.
- 4) *Improvements in power electronics and control systems* have meant that wind-generated electricity can be more easily integrated into modern electric utility systems.
- 5) *Improvements in blade design*, using airfoils especially designed for wind turbine operating requirements, has resulted in greater energy capture. The National Wind Technology Center, based in Golden, CO, has played a key role partnering with industry in all of the technology improvements noted above.

Fig. 2 highlights the dramatic changes in wind turbine size and how that has translated directly into increased energy capture and enhanced cost-effectiveness.

III. OPTIMIZING THE ECONOMICS OF WIND ENERGY

There are two primary factors that influence the cost of wind from a wind farm: the wind resource at the site and the size of the project.

The power in the wind is determined using the following formula:

$$P = \frac{1}{2} \times \text{efficiency} \times \text{air density} \times \text{swept rotor area} \times (\text{wind speed})^3.$$

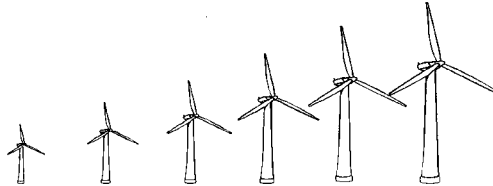
One of the key lessons from wind farm development in California in the early 1980s was just how important it is to understand the wind speed at the potential project site. Some first generation projects were developed with inadequate wind resource data. When the projects did not perform as expected, projects sometimes lost money. Subsequently, developers learned to invest money up front in intensive wind resource monitoring. Because the formula for calculating the power in the wind involves the cubic function of the wind speed, even small variations in wind speed make a major difference in power output. For example, a 12 mph wind has 70% more power than a 10 mph wind.

Fig. 3 demonstrates the difference in expected cost per kWh for a 51 MW project at three different wind speeds. As the figure reveals, a difference of slightly more than 2 m/s results in an 84% increase in the cost of energy.

The other critical factor in regard to the cost of energy from wind projects is the size of the project. There are economies of scale from developing large projects. The two projects that are compared in Fig. 4 are 51 MW and 3 MW in size, but

Economies of Scale Drive Down Wind Cost:

20 Years of Wind Technology Development

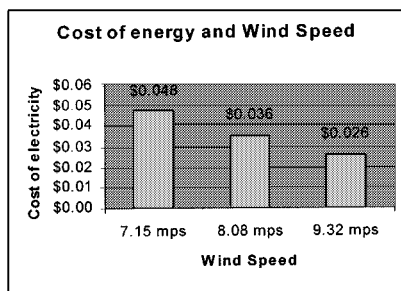


	1981	1985	1990	1996	1999	2000
Rotor (Meter)	10	17	27	40	50	71
KW	25	100	225	550	750	1,650
Total Cost, k	\$65	\$165	\$300	\$580	\$730	\$1,300
Cost/kW	\$2,600	\$1,650	\$1,333	\$1,050	\$950	\$790
MWh	45	220	550	1,480	2,200	5,600

Bottom Line: 1981-2000 = 124 x the energy at 20 x the cost

Fig. 2. Economies of scale and technology development drive down wind costs.

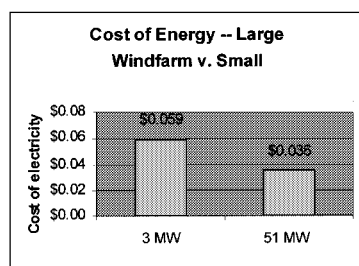
Acquiring Wind Least-Cost: Wind Speed Matters



Assuming the same size project, the **better** the wind resource, the **lower** the cost

Fig. 3. Impact of wind speed on cost per kWh.

Acquiring Wind Least-Cost: Project Size Matters



Assuming the same wind speed of 8.08 M/S, a large wind farm is more economical

Fig. 4. Impact of project size on cost per kWh.

both projects will bear many of the same transaction costs. The larger project, with substantially more output, simply has many more kWh of production over which to spread those costs, resulting in electricity that is 64% less expensive than the smaller project.

Large and Small are Different

- Large Turbines – 100 kW to 2 MW**
- Installed in "wind farm" arrays
 - Provide bulk power to utilities
 - Require 13 mph average wind sites

- Small Turbines – 0.3 to 100 kW**
- Installed in off-grid and facility-specific on-grid applications
 - Provide power using back-up generation or storage
 - Designed for reliability, low maintenance
 - Require 9 mph average wind sites



Fig. 5. Large and small wind turbines have different characteristics and markets.

IV. SURGE IN SALES OF SMALL WIND SYSTEMS FOR HOME AND BUSINESS

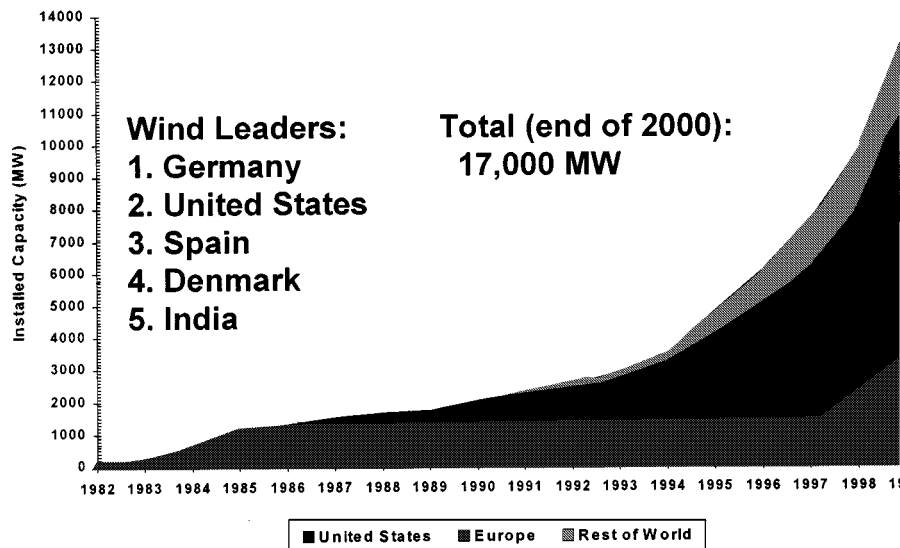
Although there has been growing attention given to wind energy in the press in the last few years, most of the focus has been upon utility-scale wind farm development. However, there is another element of the wind industry that has great potential and is starting to see substantial growth: small wind turbines to serve residential or distributed applications.

Small wind turbines are fundamentally different from utility-scale turbines in a number of different ways (see Fig. 5).

California's prolonged electricity crisis has raised customer concerns with rate shock and spurred consumer interest in home and small business wind energy generators. Bergey Windpower Co., Inc., a leading manufacturer of residential wind turbines, sold 40 home units in California in January of this year, compared with just six in all of 2000 and 12 in all of 1999 (when Y2K fears boosted sales).

Sales have benefited from a rebate of up to 50% on the purchase price of a home wind energy system, offered by the

Wind Power Taking Off Worldwide



Based on information supplied by International Energy Agency.

Fig. 6. Wind capacity growth in major markets worldwide.

California Energy Commission to customers of the state's major utilities. A typical 10-kW home wind system costs about \$16 000 to install after the state rebate, and produces an average of 900–1500 kWh of electricity per month. Homeowners recoup their investment in six to ten years. The policy is proving worthwhile for California, as each home or small business running on wind energy helps cut overall electricity demand and reduces the need for new power plants and transmission lines.

Rebates are emerging as one of the most effective policies states can adopt if they hope to stimulate a market for small wind turbines, as the relatively high first cost of a wind turbine is the biggest single market barrier. Illinois offers a rebate similar to that of California, and New Jersey and New York have recently approved funding for renewable energy including small wind systems. With looming concerns over electricity costs and supply, the market for small wind systems is likely to remain vibrant in the years to come.

V. STRONG GROWTH IN INTERNATIONAL WIND ENERGY MARKETS

European nations, led by Germany, Spain, and Denmark, installed 3200 MW of new wind generation in 2000. Europe's wind energy market is expanding at such a strong and steady rate that the European Wind Energy Association (EWEA) has raised its goal for the region by 50%, from 40 000 MW to 60 000 MW of installed capacity by 2010—enough to provide two-thirds of California's entire electricity demand (see Fig. 6).

Wind farms are sprouting along the Mediterranean rim from Spain and Italy to Morocco, Turkey, and Egypt. Spain's investments in wind energy—its capacity at the end of 2000 reached 2250 MW, just behind the U.S. total of 2554 MW—have caught the attention of at least one Latin

American country. Argentina has announced its intention of developing some 3000 MW of wind energy through an agreement with two Spanish firms.

Despite the Bush Administration's position on the Kyoto Protocol on global warming, the stall in negotiations is not affecting wind energy's current worldwide expansion. Wind energy's projected growth rate of 39% for 2001 has been made possible by the technology's competitiveness, growing demand for electricity, and effective renewable energy policies in countries such as Germany and Spain. World wind power generating capacity is expected to sail well past the 20 000-MW mark in the course of 2001.

VI. WIND POWER IS MOVING OFFSHORE IN EUROPE

Improved offshore wind data, megawatt-sized turbines, and reduced construction costs are generating a new wave of interest in offshore wind power.

For decades, academics and wind experts on both sides of the Atlantic Ocean have viewed offshore wind as an energy resource with huge potential. Now, developers in Europe are acting on the science, constructing water-based wind plants that are highly efficient and cost competitive.

The wind industry's timing couldn't be better. With world power demand increasing at unprecedented rates and growing consumer interest in clean power options, the industry can provide reliable large-scale (1.5-MW and 2.0-MW) turbines and high-tech components that make offshore wind a practical energy choice.

Western Europe has led the way in offshore wind, fueled by the desire to develop clean energy options without overwhelming the subcontinent's limited open land. According to the German Wind Energy Institute, five countries bordering the North Sea (Germany, the United Kingdom, the Netherlands, Belgium, and Denmark) have offshore wind resources

equal to three times their total electricity consumption. All five of these nations are aggressively developing offshore wind. A number of successful demonstration projects are already producing reliable electricity, and several developers are building or operating commercial-scale wind plants.

Denmark, for example, plans to install 4100 MW of offshore wind power capacity by 2030. That amounts to roughly U.S. \$7 billion in investment. The new offshore capacity is expected to provide about 13.4 billion kWh of electricity each year—roughly 40% of Denmark's annual electricity consumption. The Danish Wind Turbine Manufacturers Association (DWTMA) reports 750 MW of offshore wind capacity in the planning stages.

Denmark is a prime candidate for offshore wind.

- Its high population density creates large demand for electricity.
- Danish consumers are remarkably "green," and its energy policies reflect that.
- Open tracts of land are rare in Denmark, so the nation has sought generating capacity that does not consume precious acreage.
- Finally, its shorelines are relatively shallow (5–10 m, or 16–33 feet deep), a characteristic well suited to offshore wind plants.

In fact, Denmark built the world's first multi-turbine offshore wind project in 1991 near the port city of Vindeby. Vindeby's 5-MW demonstration facility "has been performing flawlessly," with electricity production about 60% higher than on comparable land sites, according to ELKRAFT, the power pool that operates the plant.

Wind equipment installed offshore has a longer lifetime due to lower turbulence in ocean winds, and the turbines can produce an average of 40%–60% more electricity than their land-based counterparts because ocean winds are generally stronger and more consistent than land-based winds. Increased power production achieved by offshore wind farms thus mitigates much of their higher installation costs, according to many experts. An October 2000 analysis by Greenpeace estimated that grid extension and foundation costs for offshore projects are roughly 60% higher than for land-based wind plants. "We will build . . . large parks offshore mainly because wind resources are better than [on] land," said Joern Lemming of the Danish Energy Ministry.

The Danish WTMA estimates the cost of installing 1 MW of offshore wind capacity at 12 million DKK (roughly U.S. \$1.7 million). The Association explains, "Since there is substantially more wind at sea than on land, however, we arrive at an average cost of electricity of 0.36 DKK/kWh [about 5 cents/kWh in U.S. currency]." Further, if the cost is spread over a 25-year equipment lifetime (rather than the usual 20 years), average costs come down even further—to 4.5 cents/kWh.

The United Kingdom's first commercial offshore wind plant is generating electricity for 5 pence/kWh, according to the British Wind Energy Association (BWEA). BWEA is bullish about the U.K. market for offshore wind. It predicts another 1300 2-MW turbines, or 2600 MW of capacity, will

be installed in its waters by 2005, satisfying nearly one-fifth of its 2010 renewable energy requirement.

Other countries are also moving ahead in regard to offshore wind development. Offshore wind plants are being planned or developed in Germany, Sweden, Holland, Italy, Belgium, and France. Eurowind AB is a leading developer in the field, with projects planned in France and Italy and a 72-MW wind plant being built off the coast of Sweden. Its Swedish facility will consist of 48 1.5-MW wind turbines, and will be the largest offshore wind plant in the world. Eurowind's chairman, Magnus Rosenback, is optimistic about the future. "There is a lot of interest in offshore wind," he said recently, noting that the next several years will be key for the growing European market.

As Europe leads the way, the United States is beginning to assess its offshore wind resources and even starting to scope out plans for actual development. Significant interest exists in some regions of the country, especially New England, where population density is high, energy demand is stretching existing supplies, and air pollution threatens quality of life. According to Jim Manwell, director of the Renewable Energy Research Lab at the University of Massachusetts, his state is on the cutting edge due to several key factors, including:

- a high wind resource in offshore areas that are close to major electrical loads;
- difficulty developing onshore projects in populated areas;
- the state's Renewables Portfolio Standard and Renewable Energy Trust Fund, which are spurring interest in renewables.

Massachusetts "has significant offshore wind resources with class 4, 5, and 6 winds located along the coast," Manwell recently wrote. The University of Massachusetts estimates that projects sited off the coast could supply 54.7 billion kWh of electricity, about 116% of the state's energy demand. "The resource is large, but not well characterized," he explained, noting that the estimate is confined to offshore waters shallower than 60 feet. Developers in Europe are now considering areas as deep as 130 feet, which opens up a great deal more resource potential. Nor is there currently any development of floating structures, which were the original concept of offshore pioneer William Heronemus, although such an approach is now receiving serious consideration. "If floating structures do become a reality," says Manwell, "then the potential for offshore wind in all of the U.S. is vastly greater."

VII. MARKET PROJECTIONS

Market growth has generally surpassed projections. For example, in 1995 the American Wind Energy Association conservatively projected a worldwide market of 18 500 MW by 2005. That total is in fact being surpassed in 2001. On a global basis, BTM Consult now projects almost 39 000 MW of new wind capacity to be installed in the five-year period of 2001–2005, with a worldwide installed capacity of more than 140 000 MW by the end of 2010.

Market Barriers:

Is Noise An Issue?

How Much Noise Do Wind Turbines Make?
45 decibels
at 350 meters

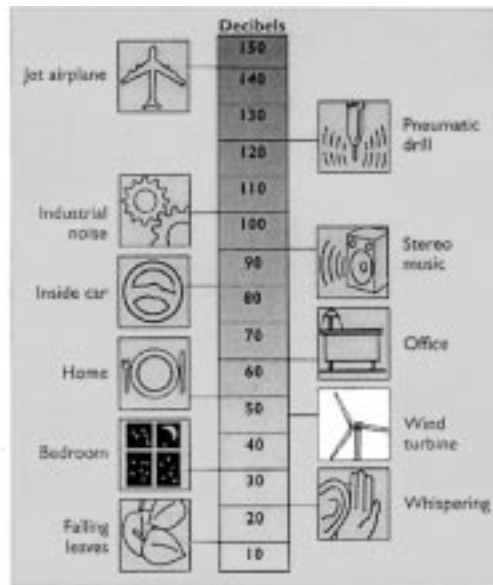


Fig. 7. How much noise do wind turbines make?

In the U.S., the Department of Energy established a realistic and achievable goal for wind to provide 5% of the country's electricity by 2020—approximately 80 000 MW. In Europe, however, the European Wind Energy Association has put forward a more expansive vision: “Wind Force 10—A Blueprint to Achieve 10% of the World's Electricity from Wind Power by 2020.” The analysis includes country by country projections of how the 10% target could be achieved, and adds extensive detail on both the environmental and economic development benefits of such a significant wind market. Finally, the EWEA puts forward policy recommendations that could help facilitate the market for wind.

Wind is now starting to see substantial penetration in a number of different markets. In Denmark, wind now provides about 13% of the nation's electricity, in Germany's northernmost Schleswig-Holstein province wind exceeds 15% of the generation, and in the Spanish province of Navarra, wind provides about 23% of electric generation. European nations are thus learning to integrate substantial amounts of variable wind generation into their electric systems. But there is growing attention to the potential, in a post-petroleum world, to the impact of a hydrogen-based energy economy. Wind could be used to generate hydrogen whenever the wind blew, diminishing the concern in regard to wind's availability on peak. At that point the practical limitations on wind's role in our energy mix would be dramatically reduced.

VIII. MARKET BARRIERS FACING WIND POWER

Despite wind energy's bright future, it does face a variety of challenges, including a number of issues related to siting as well as variability.

In regard to siting, there are three common issues that are raised:

- potential impacts of wind development on birds and other wildlife;
- noise;
- visual impact.

Despite the extensive press coverage of the issue of birds and wind turbines, the attention appears more related to the novelty of an “environmental technology” being discovered to actually have real environmental impacts. Despite the public attention, wind energy does not present a threat to bird populations in general. In virtually all wind plants, the number of bird collisions is small and has no biological significance. The one exception to this statement to date in the U.S. is Northern California's Altamont Pass, where wind plants were installed in the early 1980s in an area of high year-round raptor use, and the number of golden eagles killed annually does appear to present a long-term threat to that species' population in the area. Industry is actively working on a mitigation plan in Altamont Pass, which involves removing or moving wind turbines that appear to be disproportionately responsible for eagle deaths.

To the extent that it exists, the problem of wind energy and birds is a problem of specific species at specific sites. At this point, the Altamont Pass situation appears to be an anomaly. It is possible for a similar problem to arise in the future if wind turbines are sited in an area with high concentrations of birds, or where there are populations of threatened and endangered species. To avoid this, industry and other experts now recommend that a thorough evaluation of prospective wind energy sites be carried out before wind turbines are installed so that sites that may be problematic can be avoided.

The “noise issue” also appears to be poorly understood by the public. As anyone who has visited a wind farm can testify, wind turbines produce less noise that one would expect. Wind turbines do produce some noise, but as Fig. 7 demonstrates, at a distance of 350 m the noise from wind turbines is at the level of background noise, and very few people actually live within 350 m of a wind farm.

IX. CONCLUSION

Wind technology has made huge advances over the last few decades, and, with the availability of the federal wind production tax credit providing tax parity with subsidies for fossil fuels, is now cost-competitive in class 6 wind resources for large-scale projects (50 MW and larger). This has led to record-breaking growth in the U.S. market for wind. But there is 20 times more land with class 4 wind potential in the U.S. than class 6 land. And the average distance between the top 40 load centers in the country and our class 6 lands is 500 miles, while the average distance for class 4 lands is 100 miles. While wind power is one of the great technology success stories of the last few decades, it would be a mistake to rest on our laurels. By continuing to improve the technology through aggressive research and development, the objective is to achieve cost-competitive wind projects in more moderate wind regimes, which would open up much greater market opportunity. Given past progress, this is an achievable goal, but it will take continuing partnership between public and private sectors if we hope to see wind energy technology achieving its full potential in the U.S.



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He has served as Executive Director of the American Wind Energy Association since 1989. Prior to that, he worked as Legislative Representative for the American Public Power Association and as Energy Program Director for the National Association of Counties. He has also worked as Professional Staff for the House

Interior Committee's Energy and Water Subcommittee and as Executive Director for the D.C. Public Interest Research Group, where he first became involved with renewable energy advocacy in 1975. Between 1976 and 1981, he served as an Adjunct Professor at Georgetown University and Georgetown University Law Center, where he taught courses on energy policy.

Christine Real de Azua received the degree in political science and economics from the Institut d'Etudes Politiques de Paris, France, and the B.A. degree from Swarthmore College, Pennsylvania.

She joined the American Wind Energy Association as communications coordinator and international policy analyst in 1999. Prior to joining AWEA, she launched and directed Accounting for the Environment, a nonprofit project calling for improved accounting for natural resources and environmental quality in the way which nations measure their economic performance. The project worked with other nonprofit organizations, with the White House, and with members of Congress to establish a "green Gross Domestic Product" in the U.S. system of national accounts, and with the United Nations and the World Bank to promote the establishment and use of such a measure in all nations' systems of national accounts. From 1991 to 1993, she worked with a coalition of conservation organizations on the Earth Summit in Rio de Janeiro. She has also served as assistant editor for *World Press Review* and for *One World*, an international supplement on development issues carried by major dailies in several countries.

Julie Clendenin received the B.A. degree in political science from Gettysburg College in 1989.

She served as Communications Manager for the American Wind Energy Association from 1993 to 1997. She has since managed her own communications company, and in that capacity serves as editor of *The Windletter*, AWEA's monthly newsletter. Prior to working with AWEA, she was employed by the Edison Electric Institute for four years, first as Legislative Assistant and then as Environmental Activities Coordinator.