Surpassing Expectations: State of the U.S. Wind Power Market

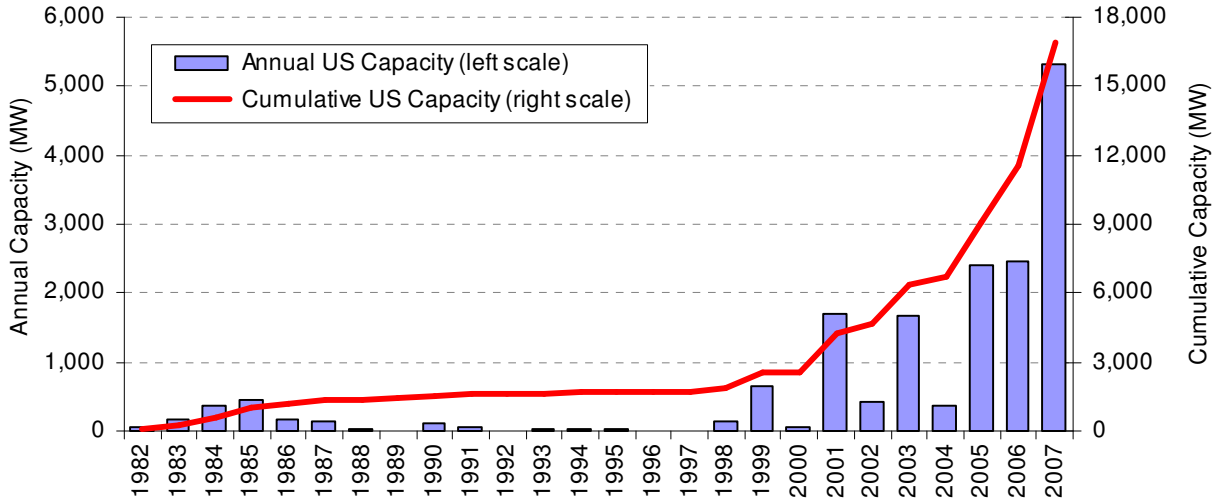
Intro Sidebar: The U.S. wind industry experienced unprecedented growth in 2007, surpassing even optimistic projections from years past. **Mark Bolinger** and **Ryan Wiser** present highlights from the U.S. Department of Energy's second *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends*.

The wind power industry in the U.S. has been on a growth binge in recent years, and the rapid pace of development has made it difficult to keep up with trends in the marketplace. Yet the need for timely, objective information on the wind industry and its progress has never been greater. This article, excerpted from a longer report from the U.S. Department of Energy, attempts to fill this need by providing a comprehensive, yet detailed, overview of key developments in the U.S. wind power market, with a particular focus on 2007.

This summary includes information on wind project installation trends, industry developments, and, perhaps most interestingly, project-level installed cost and pricing information that has not otherwise been widely reported. The article concentrates on larger-scale wind applications, defined here as projects utilizing turbines that exceed 50 kW in size. In many cases, the data reported here represent only a sample of all wind projects installed in the United States; furthermore, the data vary in quality. As such, emphasis should be placed on overall trends in the data, rather than on individual data points.

Growth Surge

The U.S. added roughly 5,300 MW of new wind power capacity in 2007 – more than twice the previous record set in 2006 – bringing the cumulative total to more than 16,900 MW (Figure 1). This growth translates into roughly $9 billion (real 2007 dollars) invested in wind project installation in 2007. No country, in any single year, has added the volume of wind capacity that was added to the U.S. electrical grid in 2007.



Source: AWEA

Figure 1. Annual and Cumulative Growth in U.S. Wind Power Capacity

For the third straight year, the United States led the world in wind capacity additions (Table 1), capturing roughly 27% of the worldwide market. In cumulative terms, the United States ended the year with 18% of worldwide capacity, in second place behind Germany. So far this decade, cumulative wind power capacity has grown an average of 27% per year in the United States, equivalent to the same 27% growth rate in worldwide capacity.

Table 1. International Rankings of Wind Power Capacity

Incremental Capacity (2007, MW)		Cumulative Capacity (end of 2007, MW)	
U.S.	**5,329**	Germany	22,277
China	3,287	**U.S.**	**16,904**
Spain	3,100	Spain	14,714
Germany	1,667	India	7,845
India	1,617	China	5,875
France	888	Denmark	3,088
Italy	603	Italy	2,721
Portugal	434	France	2,471
U.K.	427	U.K.	2,394
Canada	386	Portugal	2,150
Rest of World	2,138	*Rest of World*	13,591
TOTAL	**19,876**	**TOTAL**	**94,030**

Source: BTM Consult; AWEA project database for U.S. capacity

Within the United States, new large-scale wind turbines were installed in 18 states in 2007; ten of these states added more than 100 MW each (Table 2 and Figure 2). Texas dominated other states in terms of new capacity, with more than 1,708 MW installed in 2007 alone. On a cumulative basis, after surpassing California in 2006, Texas continued to build on its lead in 2007, with a total of 4,446 MW of wind capacity installed by the end of the year. In fact, Texas has more installed wind capacity than all but five countries worldwide (Tables 1 and 2).

Table 2. United States Wind Power Rankings: The Top 20 States

Incremental Capacity (2007, MW)		Cumulative Capacity (end of 2007, MW)		Estimated Percentage of In-State Generation	
Texas	1,708	Texas	4,446	Minnesota	7.5%
Colorado	776	California	2,439	Iowa	7.5%
Illinois	592	Minnesota	1,298	Colorado	6.1%
Oregon	444	Iowa	1,271	South Dakota	6.0%
Minnesota	403	Washington	1,163	Oregon	4.4%
Washington	345	Colorado	1,067	New Mexico	4.0%
Iowa	341	Oregon	882	North Dakota	3.8%
North Dakota	167	Illinois	699	Oklahoma	3.0%
Oklahoma	155	Oklahoma	689	Texas	3.0%
Pennsylvania	115	New Mexico	496	Washington	2.8%
California	63	New York	425	California	2.8%
Missouri	57	Kansas	364	Kansas	2.3%
New York	55	North Dakota	345	Hawaii	2.3%
South Dakota	54	Pennsylvania	294	Montana	1.9%
Maine	33	Wyoming	288	Wyoming	1.7%
Hawaii	21	Montana	147	Idaho	1.5%
Massachusetts	2	South Dakota	98	Illinois	0.8%
Montana	2	Idaho	75	Maine	0.8%
		Nebraska	73	New York	0.7%
		West Virginia	66	Nebraska	0.7%
Rest of U.S.	0	*Rest of U.S.*	277	*Rest of U.S.*	0.05%
TOTAL	**5,329**	**TOTAL**	**16,904**	**TOTAL**	**1.1%**

Source: AWEA project database, EIA, Berkeley Lab estimates

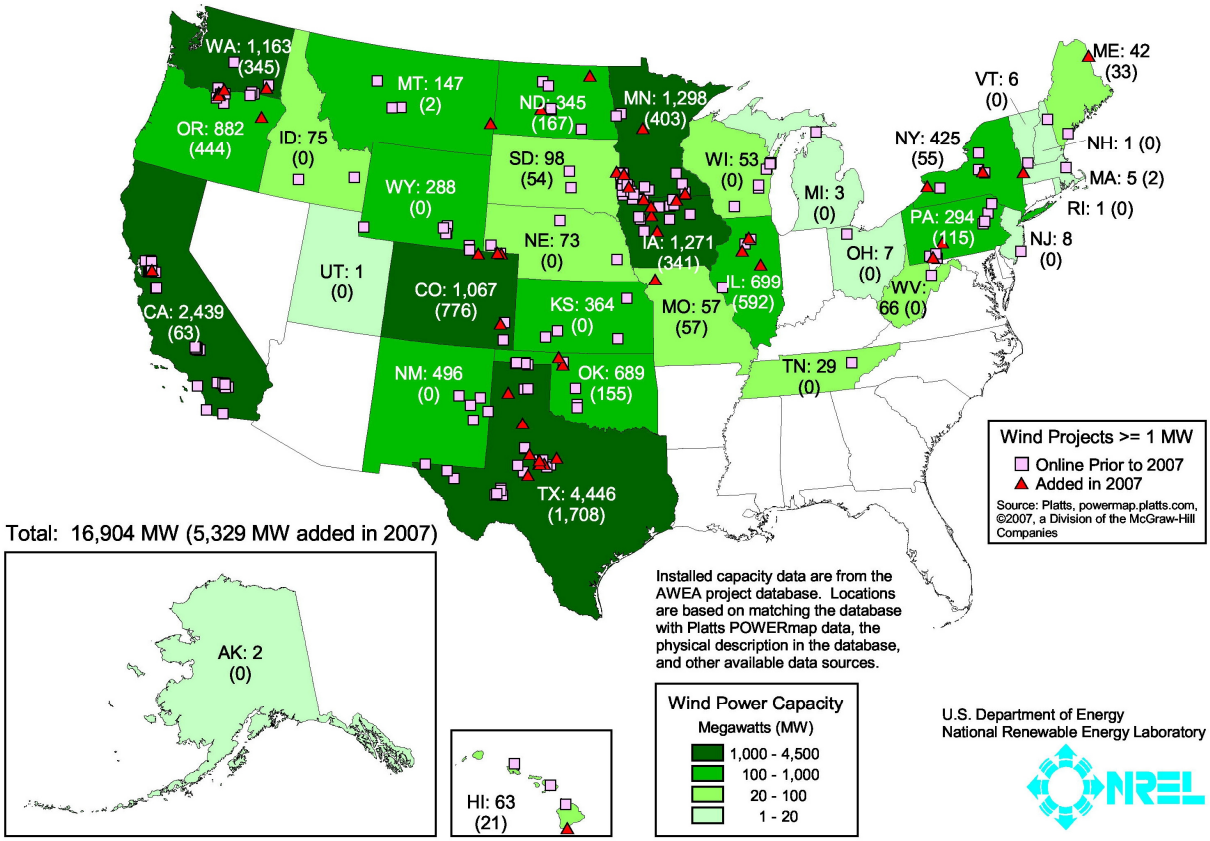


Figure 2. Location of Wind Power Development in the United States

Interestingly, the average size of installed wind projects has grown substantially in recent years. Projects installed in the U.S. in 2007 averaged nearly 120 MW, roughly double that seen in the 2004-05 period and nearly quadruple that seen in the 1998-99 period. These larger project sizes reflect an increasingly mature energy source that is beginning to penetrate into the domestic electricity market in a significant way.

Wind Becoming a Significant Contributor

Several countries are beginning to achieve relatively high levels of wind power penetration in their electricity grids. Focusing only on the 20 countries with the most installed wind capacity, Figure 3 shows that end-of-2007 installed wind is projected to supply roughly 20% of Denmark's electricity demand (somewhat less than last year), 12% of Spain's (up by 2.2% from last year), 9% of Portugal's (up by 1.6%), 8% of Ireland's (up by 0.4%), and 7% of Germany's (also up by 0.4%). In contrast, the cumulative wind capacity installed in the United States at the end of 2007 would, in an average year, be able to supply just 1.2% of the nation's electricity consumption (up by 0.4% from last year) – the same as wind's estimated 1.2% contribution to electricity consumption on a worldwide basis.

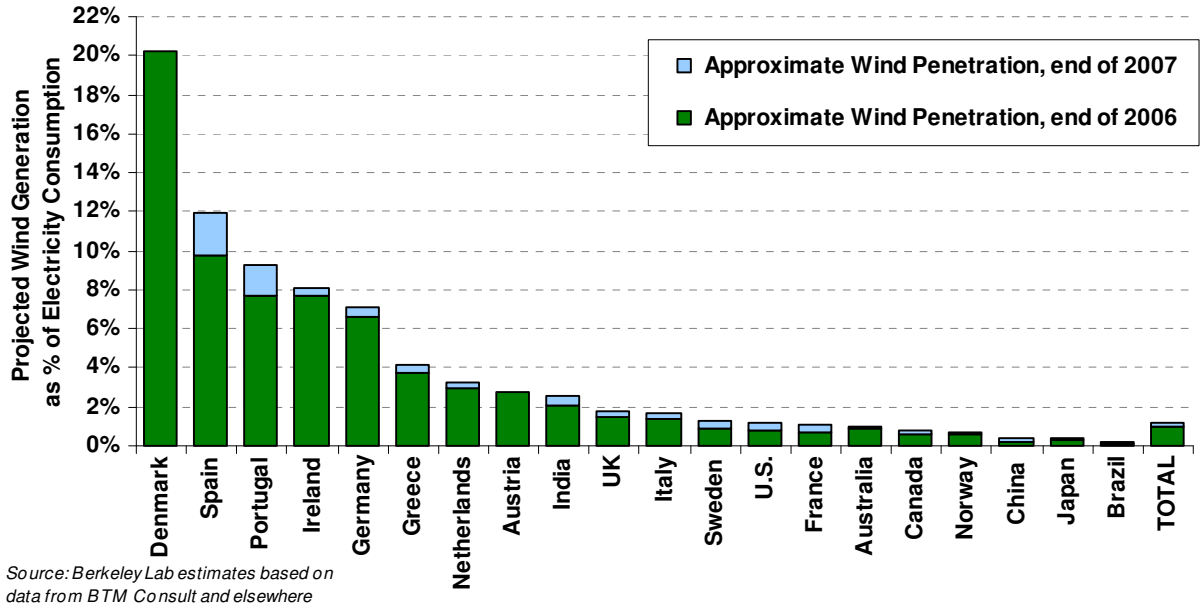
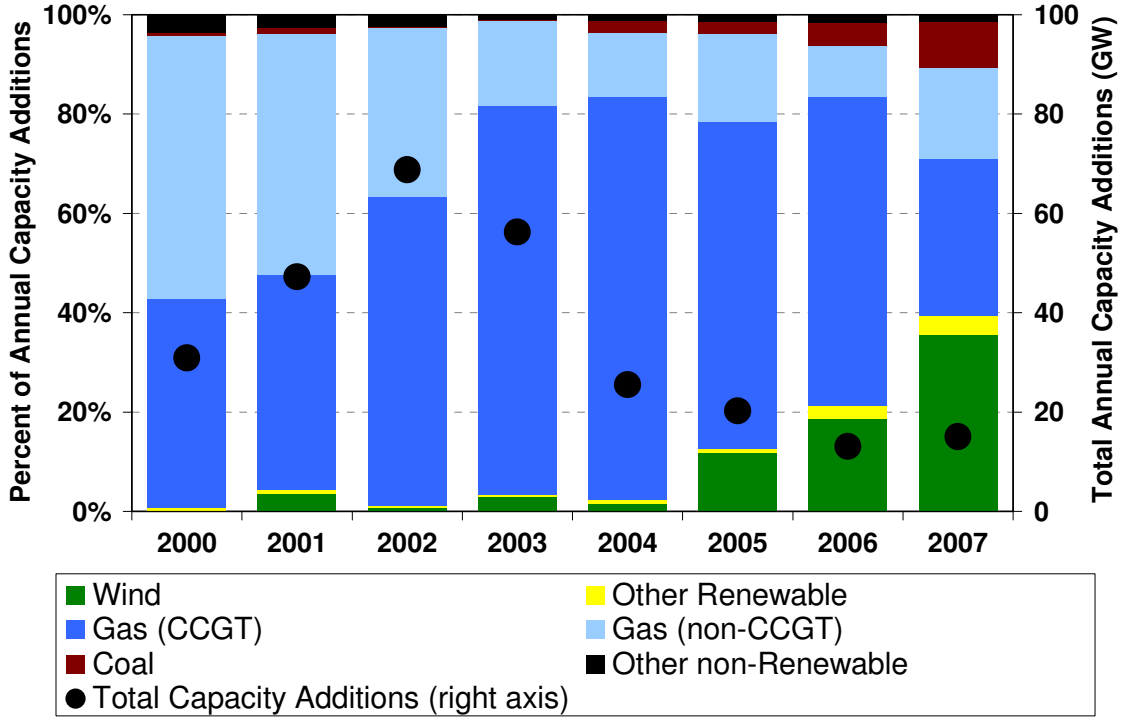


Figure 3. Approximate Wind Power Penetration in the Twenty Countries with the Most Installed Wind Capacity

Within the U.S., however, some individual states are beginning to realize relatively high levels of wind penetration. Minnesota and Iowa lead the nation in terms of estimated wind power as a percentage of total in-state generation, at 7.5% each (Table 2). Four additional states – Colorado, South Dakota, Oregon, and New Mexico – surpass the 4% mark by this metric. Though not shown in Table 2, some individual utilities are achieving even higher levels of wind penetration – greater than 10% in some cases – into their individual electric systems.

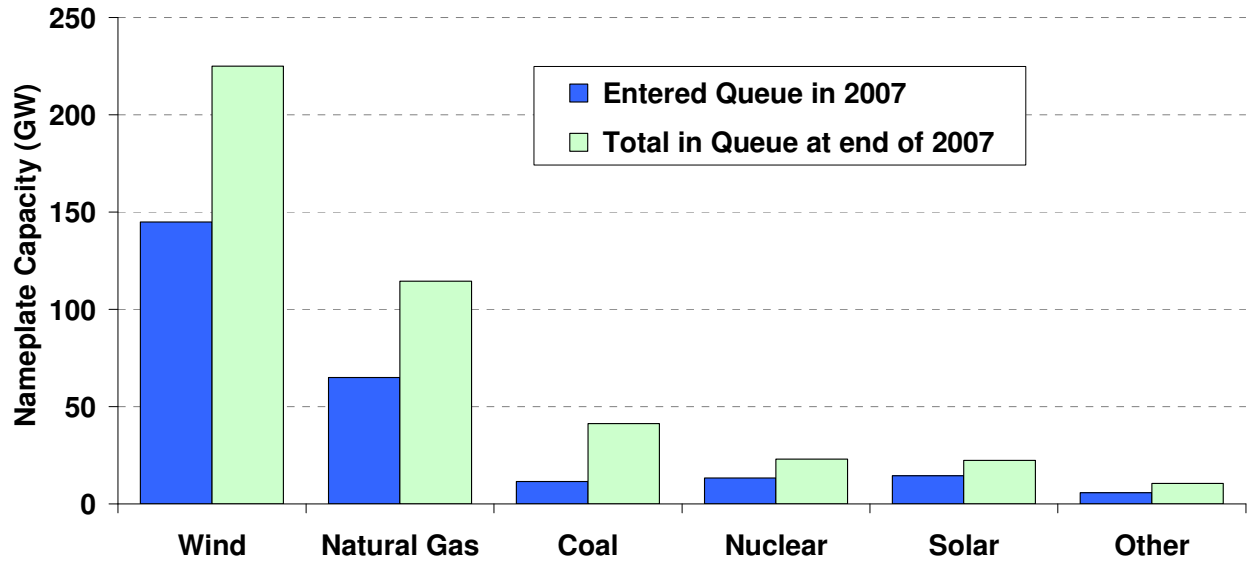
Wind has also made great strides in terms of becoming a significant contributor to the nation's resource mix. For the third consecutive year, wind power was the second-largest new resource added to the U.S. electrical grid in terms of nameplate capacity, behind the 7,500 MW of new natural gas plants, but ahead of the 1,400 MW of new coal. New wind plants contributed roughly 35% of the new nameplate capacity added to the U.S. electrical grid in 2007, compared to 19% in 2006, 12% in 2005, and less than 4% from 2000 through 2004 (Figure 4).



Source: EIA, Ventyx, AWEA, IREC, Berkeley Lab

Figure 4. Relative Contribution of Generation Types in Annual Capacity Additions

Based on the amount of wind power capacity currently working its way through eleven of the major transmission interconnection queues across the country, this trend is expected to continue (Figure 5). At the end of 2007, there were 225 GW of wind power capacity within these interconnection queues – more than 13 times the installed wind capacity in the U.S. Moreover, this wind capacity represents roughly *half* of all generating capacity within these queues at that time, and is *twice as much* capacity as the next-largest resource in these queues (natural gas). Although many of these planned projects are still very early in the development process, and a large number are unlikely to achieve commercial operations any time soon (if at all), the 225 GW figure is nevertheless astounding, and provides an indication of the increasingly important role that wind may play within the nation's power mix.

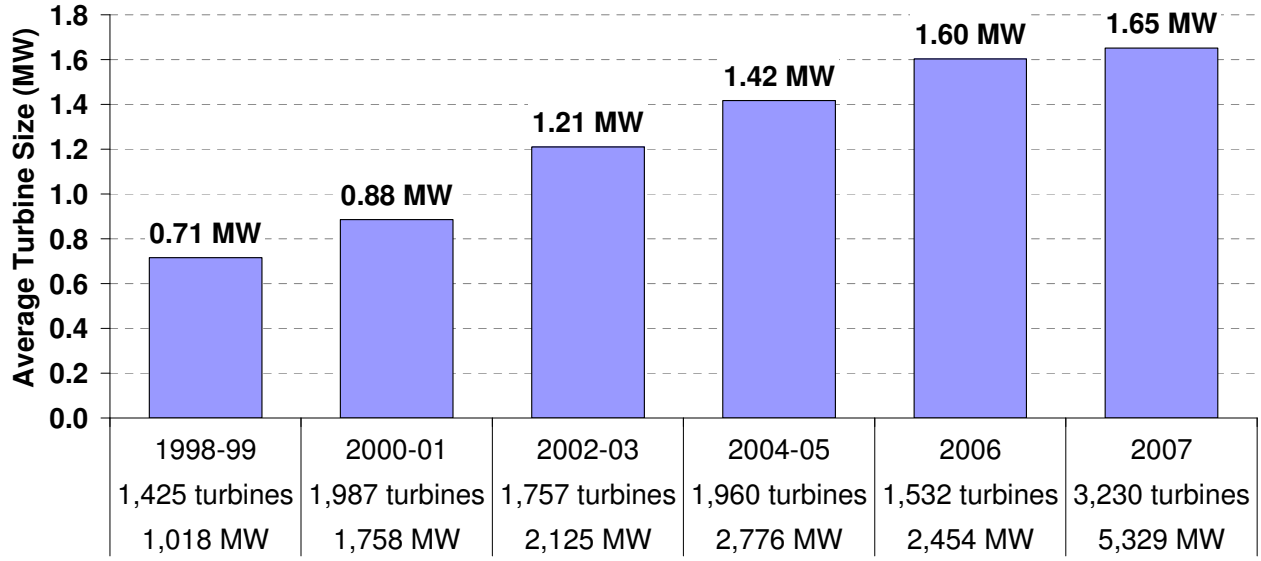


Source: Exeter Associates review of interconnection queues

Figure 5. Nameplate Resource Capacity in Eleven Major Interconnection Queues

Trends Among Turbines and Turbine Vendors

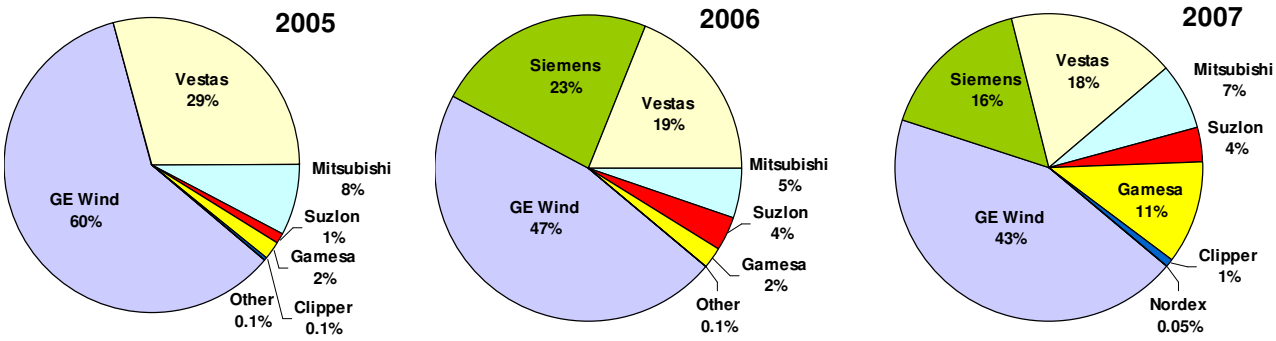
The average size of wind turbines installed in the United States in 2007 increased to roughly 1.65 MW, from 1.60 MW in 2006 (Figure 6). Since 1998-99, average turbine size has increased by 130%. The distribution of turbine size has also shifted over time; 40% of all turbines installed in 2007 had a nameplate capacity in excess of 1.5 MW, compared to 34% in 2006, 24% in 2004-2005, and 13% in 2002-2003.



Source: AWEA project database

Figure 6. Average Turbine Size Installed During Period

GE Wind remained the dominant manufacturer of wind turbines supplying the U.S. market in 2007, with 44% of domestic turbine installations (in MW terms), down from 47% in 2006 and 60% in 2005. The other two market leaders, Vestas (18%) and Siemens (16%), also lost market share in 2007, while Gamesa increased its market share from 2% in both 2005 and 2006 to 11% in 2007 (Figure 7). Of course, in a rapidly growing market, percentage market share can be misleading: every turbine vendor active in the U.S. market saw installations of its turbines grow between 2006 and 2007, in many cases dramatically.



Source: AWEA project database

Figure 7. Annual U.S. Market Share of Wind Manufacturers by MW, 2005-2007

As domestic demand for wind turbines continues to surge, a growing number of foreign turbine and component manufacturers have begun to localize operations in the United States. Manufacturing by U.S.-based companies is also starting to expand.

Among the list of wind turbine and component manufacturing facilities opened or announced in 2007 are three owned by major international turbine manufacturers: Vestas (blades in Colorado), Acciona (turbine assembly in Iowa), and Siemens (blades in Iowa). These plants are in addition to facilities recently opened by several other international turbine manufacturers in previous years, including: Gamesa (blades, towers, and nacelle assembly Pennsylvania), Suzlon (blades and nose cones in Minnesota), and Mitsubishi (gearboxes in Florida). More recently, in 2008, Fuhrlander announced its decision to build a turbine assembly plant in Montana, Vestas announced it would open an R&D center in Texas, and Siemens announced an R&D center in Colorado.

Among U.S.-based wind turbine manufacturers, GE maintains a significant domestic turbine manufacturing presence, while three newer U.S.-based turbine manufacturers continue to scale-up their activities:

- **Clipper Windpower** is in the process of significant expansion, with 137 of its 2.5 MW Liberty turbines produced in 2007, up from eight in 2006. Clipper expects to produce over 300 turbines in 2008 at its Iowa manufacturing facility, and cumulative firm turbine orders equaled 825 at the end of January 2008.
- **CTC/DeWind** commissioned its first 2 MW D8.2 turbine in the United States in March 2008. CTC acquired DeWind in 2006, and turbine production commenced in December 2007 at a TECO Westinghouse manufacturing facility in Texas, with an initial capacity of 400 turbines per year and an order backlog of $140 million by the end of January 2008.

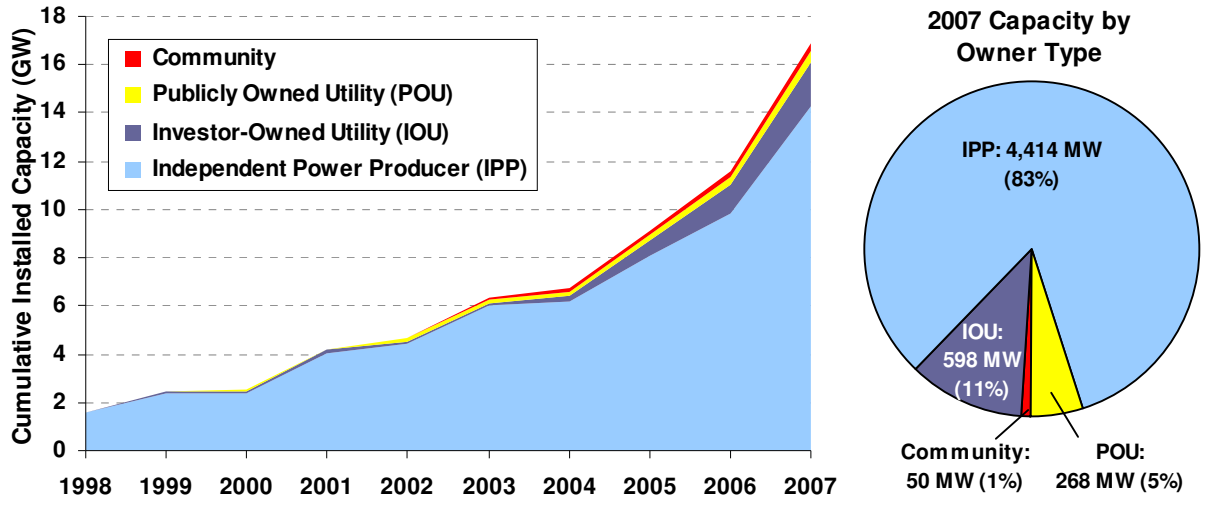
- **Nordic Windpower**, a manufacturer of two-bladed turbines, announced that Goldman Sachs made a significant investment in the company in 2007. Nordic subsequently announced the opening of its North American headquarters in California, and in early 2008 announced the location of a planned manufacturing facility in Idaho.

Trends Among Project Developers, Owners, and Offtakers

Consolidation on the development end of the wind business continued the strong trend that began in 2005, and that has been motivated, in part, by the increased globalization of the wind sector and the need for capital to manage wind turbine supply constraints. At least 11 significant developer acquisition and investment transactions involving roughly 37 GW of wind project "pipeline" were announced in 2007, consistent with 2006 acquisition and investment activity of 12 transactions with a total 34 GW in the pipeline.

Particularly striking in recent years has been the entrance of large European energy companies into the development side of the U.S. market. The two largest U.S. developer acquisitions in 2007, for example, were the purchase of Horizon Wind by Energias de Portugal (from Portugal) and the acquisition of Airtricity North America by E.ON AG (from Germany), summing to nearly $4 billion in aggregate.

In terms of project ownership, private independent power producers (IPPs) continued to dominate the wind industry in 2007, owning 83% of all new capacity (Figure 8). In a continuation of the trend begun several years ago, however, 16% of total wind additions in 2007 are owned by local electrical utilities, split between investor-owned utilities (IOUs) and publicly owned utilities (POUs) roughly two-to-one. Community wind power projects – defined here as projects using turbines over 50 kW in size and completely or partly owned by towns, schools, commercial customers, or farmers, but excluding publicly owned utilities – constitute the remaining 1% of 2007 projects. Of the cumulative installed wind capacity at the end of 2007, IPPs owned 84%, with utilities contributing 14% and community ownership just 2%.



Source: Berkeley Lab estimates based on AWEA project database

Figure 8. Cumulative and 2007 Wind Capacity Categorized by Owner Type

Investor-owned utilities continued to be the dominant purchasers of wind power, with 48% of new 2007 capacity and 55% of cumulative capacity selling power to IOUs under long-term contract (Figure 9). Publicly owned utilities have also taken an active role, purchasing the output of 17% of new 2007 capacity and 15% of cumulative capacity.

The role of power marketers – defined here as corporate intermediaries that purchase power under contract and then re-sell that power to others, sometimes taking some merchant risk – in the wind power market has increased dramatically since 2000, when such entities first entered the wind sector. In 2007, power marketers purchased the output of 20% of new wind power capacity and 17% of cumulative capacity.

Increasingly, owners of wind projects are taking on some merchant risk, meaning that a portion of their electricity sales revenue is tied to short-term contracted and/or spot market prices (with the resulting price risk commonly hedged over a 5- to 10-year period via financial transactions). The owners of 15% of the wind power capacity added in 2007, for example, are accepting some merchant risk, bringing merchant/quasi-merchant ownership to 12% of total cumulative U.S. wind capacity. The majority of this activity exists in Texas and New York – both states in which wholesale spot markets exist, where wind power may be able to compete with these spot prices, and where additional revenue is possible from the sale of renewable energy certificates (RECs).

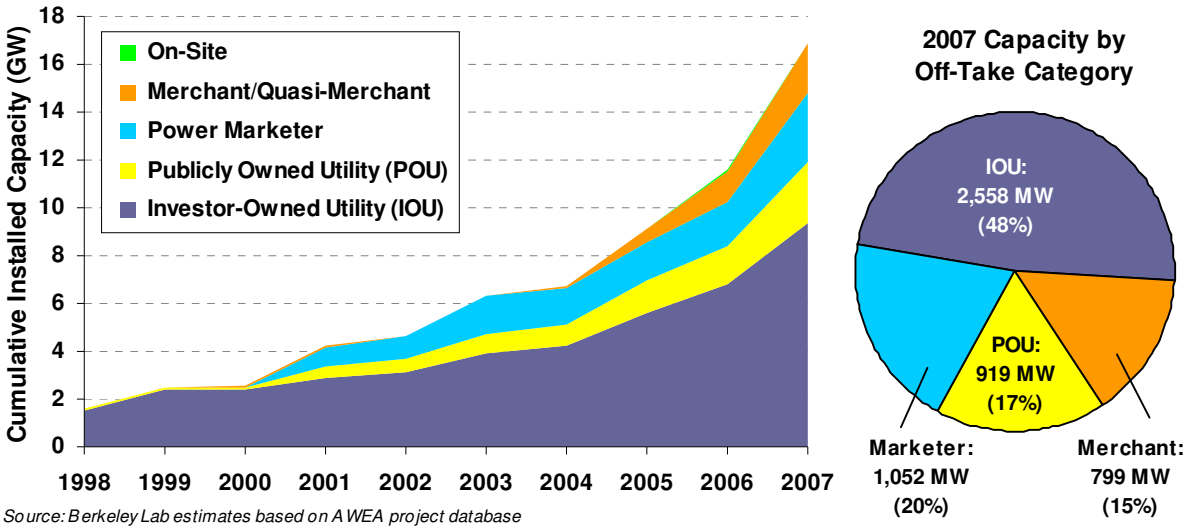
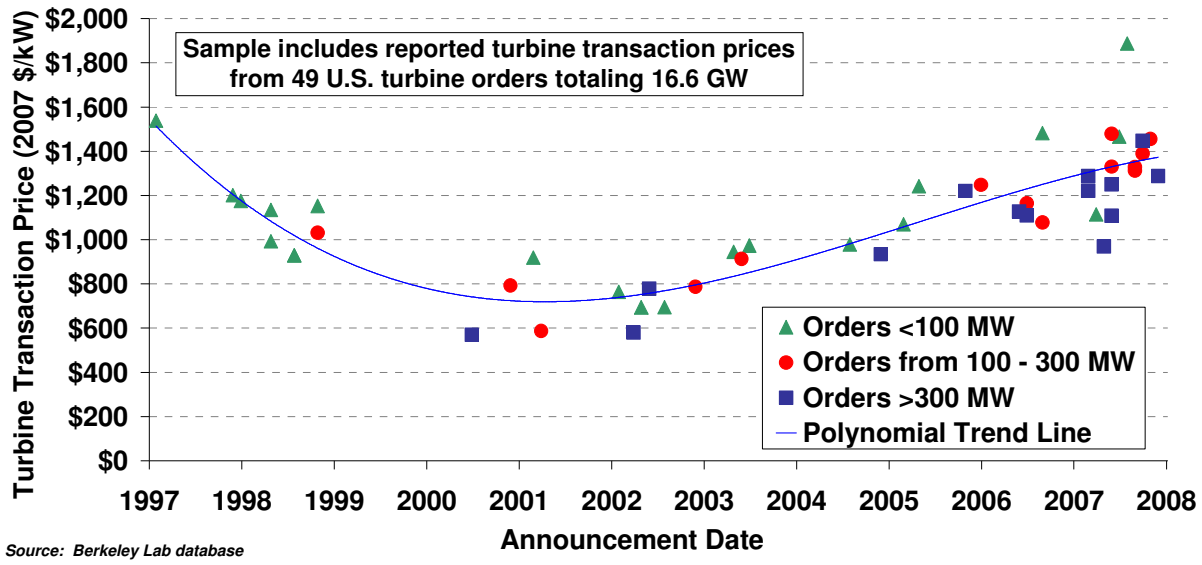


Figure 9. Cumulative and 2007 Wind Capacity Categorized by Power Off-Take Arrangement

Increasing Cost Pressures

Although the wind industry appears to be on solid footing, the weakness of the dollar, rising materials costs, a concerted movement towards increased manufacturer profitability, and a shortage of components and turbines continued to put upward pressure on wind turbine costs, wind project costs, and wind power prices in 2007.

Since hitting a nadir of roughly $700/kW in the 2000-2002 period, wind turbine prices appear to have increased by approximately $600/kW (85%), on average (Figure 10). U.S. wind turbine transactions announced in 2007, for example, had a capacity-weighted average price of $1,240/kW.

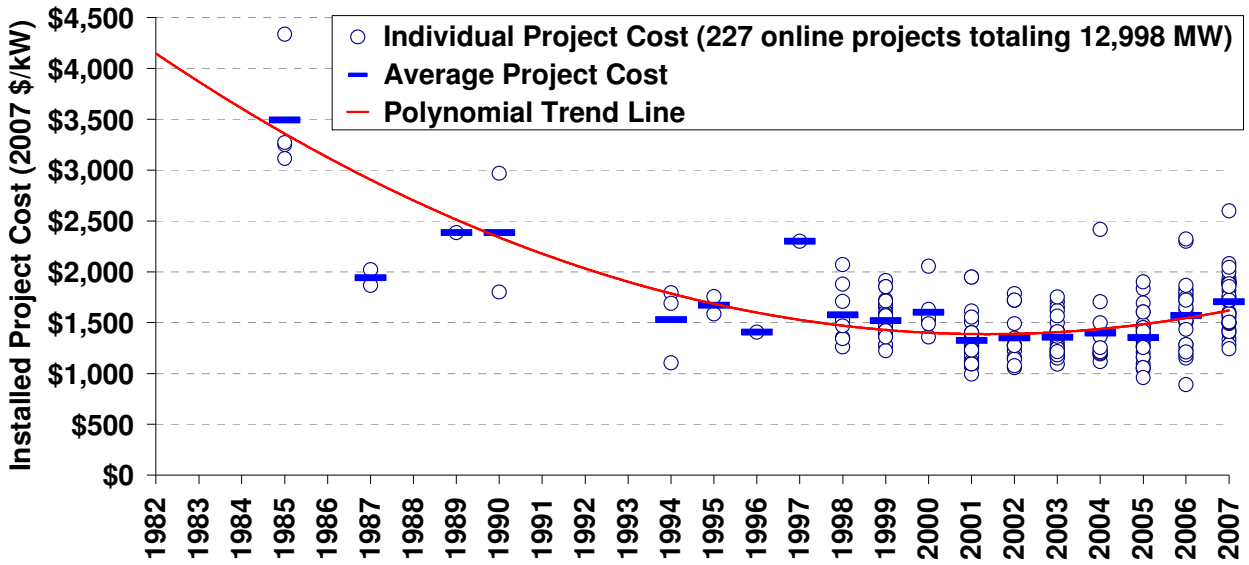


Source: Berkeley Lab database

Figure 10. Reported U.S. Wind Turbine Transaction Prices Over Time

With turbines accounting for as much as 75%-80% of total project costs, higher turbine prices have unavoidably led to higher installed project costs. Among a sample of 36 wind projects installed in 2007 and totaling 4,079 MW (77% of the wind power capacity installed in the U.S. that year), installed costs range from $1,240/kW to $2,600/kW, with an average cost of $1,710/kW (Figure 11). This average is up $140/kW (9%) from the average cost of installed projects in 2006 ($1,570/kW), and up roughly $370/kW (27%) from the average cost of projects installed from 2001 through 2003.

Moreover, there is reason to believe that recent increases in turbine costs had not fully worked their way into installed project costs in 2007, and therefore that even higher installed costs can be expected in the near future. For example, the average cost estimate for 2,950 MW of *proposed* projects (not shown in Figure 11, but most of which are expected to be built in 2008) is $1,920/kW, or $210/kW higher than for projects completed in 2007.



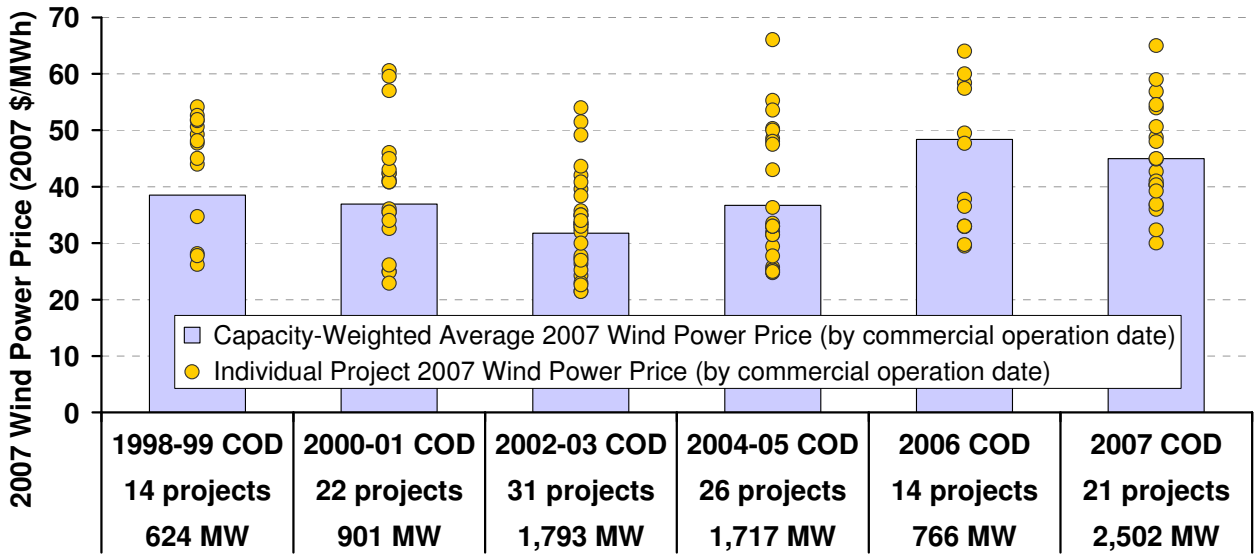
Source: Berkeley Lab database (some data points suppressed to protect confidentiality)

Figure 11. Installed Wind Project Costs Over Time

Wind Prices Rise, but Remain Competitive with Wholesale Power

Higher installed project costs eventually translate into higher wind power prices. Figure 12 shows average wind power sales prices in the year 2007 for a sizable sample of U.S. wind projects, grouped by each project's initial commercial operation date (COD). The general trend exhibited by the capacity-weighted-average prices within this sample (i.e., the blue columns) suggests that, following a general decline since 1998, prices from newly built wind projects bottomed out for projects built in 2002 and 2003, and have since risen significantly.

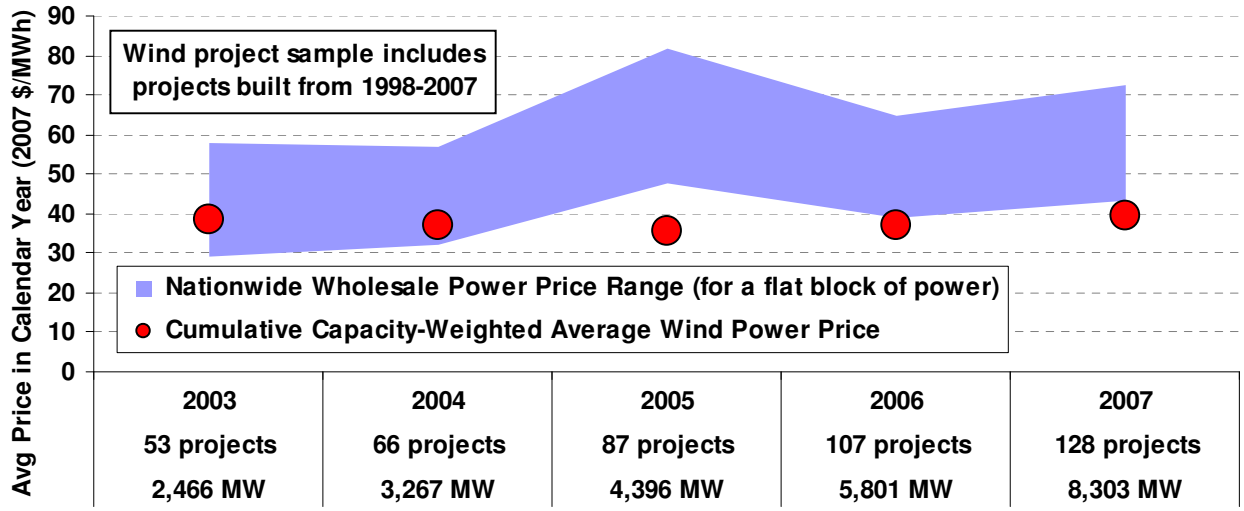
Specifically, the capacity-weighted average 2007 sales price for projects in the sample built in 2007 was roughly $45/MWh (with a range of $30 to $65/MWh, including the value of the Federal production tax credit, or PTC). Although this price is (somewhat surprisingly) slightly *less* than the average of $48/MWh for the sample of projects built in 2006, it is still higher than the average price of $37/MWh for the sample of projects built in 2004 and 2005, as well as the average price of $32/MWh for the sample of projects built in 2002 and 2003. Moreover, because ongoing turbine price increases have not yet fully worked their way through the development pipeline, prices from projects being built in 2008 and beyond will likely be higher still.



Source: Berkeley Lab database

Figure 12. 2007 Wind Power Prices by Commercial Operation Date (COD)

It is important to recognize that wind is not alone in facing increasing cost pressures – other types of power plants have seen similar increases in construction costs in recent years, and fuel prices (natural gas, coal, oil, and uranium) have also increased sharply. In fact, a simple comparison of wind power prices to recent wholesale power prices throughout the United States demonstrates that, despite mounting cost pressures, wind power has remained competitive in wholesale power markets over the past few years. Specifically, Figure 13 shows the cumulative capacity-weighted average wind power price from our sample in each calendar year from 2003 through 2007, plotted against the range of average nationwide wholesale power prices in each year. Presented this way (which differs from how prices were presented in Figure 12), average wind power prices (which include the value of the Federal PTC) have consistently been at or below the low end of the wholesale power price range since at least 2003.



Source: FERC 2006 and 2004 "State of the Market" reports, Berkeley Lab database, Ventyx

Figure 13. Average Cumulative Wind and Wholesale Power Prices Over Time

Coming Up in 2008

Though transmission availability, siting and permitting conflicts, and other barriers remain, 2008 is, by all accounts, expected to be another banner year for the U.S. wind industry. Another year of capacity growth in excess of 5 GW appears to be in the offing, and past installation records may again fall as developers rush to complete projects prior to the scheduled year-end expiration of the PTC. Local manufacturing of turbines and components is also anticipated to continue to grow, as previously announced manufacturing facilities come on line and existing facilities reach capacity and expand.

All of this is likely to occur despite the fact that wind power pricing is projected to continue its upwards climb in the near term, as increases in turbine prices make their way through to wind power purchasers. Supporting continued market expansion, despite unfavorable wind pricing trends, are the rising costs of fossil generation, the mounting possibility of carbon regulation, and the growing chorus of states interested in encouraging wind power through policy measures.

If the PTC is not extended, however, 2009 is likely to be a difficult year of industry retrenchment. The drivers noted above should be able to underpin some wind capacity additions even in the absence of the PTC, and some developers may continue to build under the assumption that the PTC will be extended and apply retroactively. Nonetheless, most developers are expected to "wait it out," re-starting construction activity only once the fate of the PTC is clear.

Mark Bolinger and Ryan Wiser conduct research on renewable energy economics, markets, and policies at Lawrence Berkeley National Laboratory. Their work on this article was funded by the Wind & Hydropower Technologies Program, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007,* on which this article is based, is downloadable from http://eetd.lbl.gov/ea/ems/reports/lbnl-275e.pdf