Attachment A

OBAMA BIDEN
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BARACK OBAMA AND JOE BIDEN: NEW ENERGY FOR AMERICA

America has always risen to great challenges, and our dependence on oil is one of the greatest we have ever faced. It's a threat to our national security, our planet and our economy. For decades, Washington has failed to solve this problem because of partisanship, the undue influence of special interests, and politicians who would rather propose gimmicks to get them through an election instead of long-term solutions that will get America closer to energy independence.

Our country cannot afford politics as usual – not at a moment when the energy challenge we face is so great and the consequences of inaction are so dangerous. We must act quickly and we must act boldly to transform our entire economy – from our cars and our fuels to our factories and our buildings.

Achieving this goal will not be easy. Energy independence will require far more than the same Washington gimmicks and continued dependence on costly and finite resources. It will require a sustained and shared effort by our government, our businesses, and the American people. But America has overcome great challenges before. With clarity of direction and leadership, there is no question that we possess the insight, resources, courage and the determination to build a new economy that is powered by clean and secure energy.

Barack Obama and Joe Biden have a comprehensive energy plan that provides immediate relief to struggling families. It also summons the nation to face one of the great challenges of our time: confronting our dependence on foreign oil, addressing the moral, economic and environmental challenge of global climate change, and building a clean energy future that benefits all Americans.

The Obama-Biden comprehensive New Energy for America plan will:

- Provide short-term relief to American families facing pain at the pump
- Help create five million new jobs by strategically investing $150 billion over the next ten years to catalyze private efforts to build a clean energy future.
- Within 10 years save more oil than we currently import from the Middle East and Venezuela combined
- Put 1 million Plug-In Hybrid cars – cars that can get up to 150 miles per gallon – on the road by 2015, cars that we will work to make sure are built here in America
- Ensure 10 percent of our electricity comes from renewable sources by 2012, and 25 percent by 2025
- Implement an economy-wide cap-and-trade program to reduce greenhouse gas emissions 80 percent by 2050

Figure C-4. Total economic impacts of 20% Wind Energy by 2030 on a relative basis

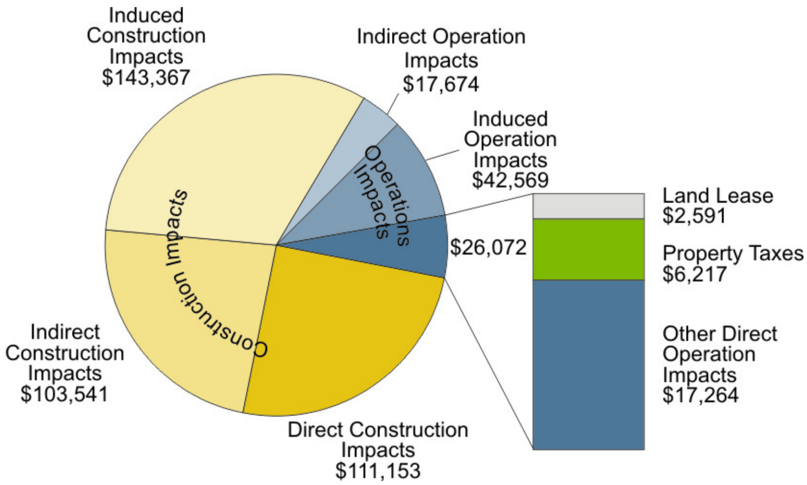


Figure C-5. In the following sections, employment impacts in the wind industry are divided into three major industry sectors: manufacturing, construction, and operations. Each sector is described during the year of its maximum employment supported by the wind industry.

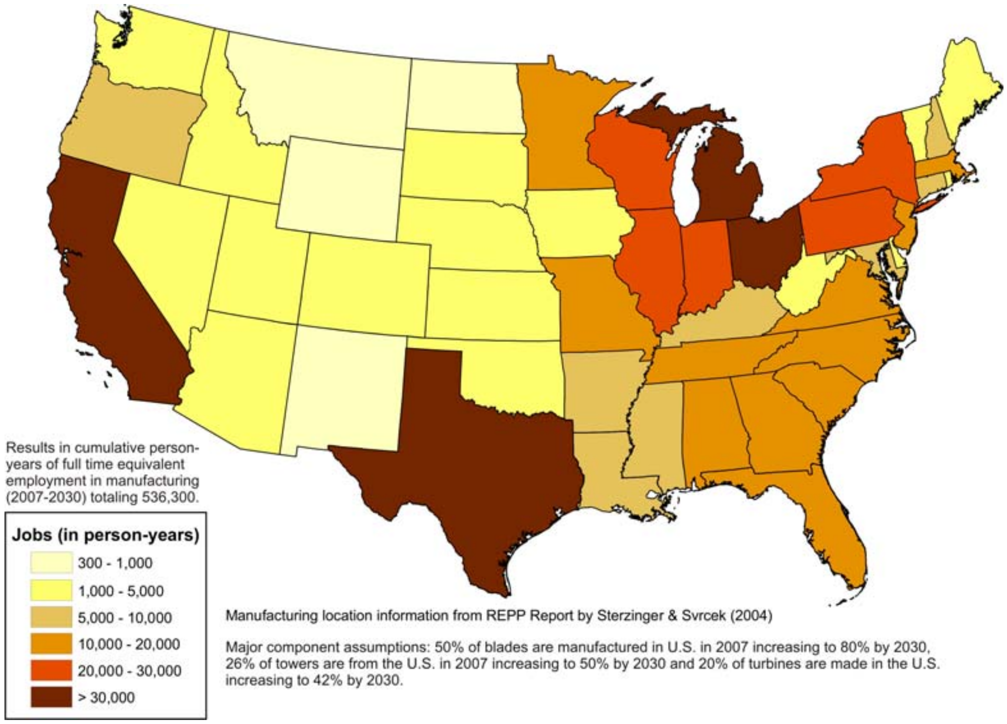
The JEDI model estimates the number of jobs supported by one project throughout the economy, as well as the total economic output from the project. Results from the JEDI model do not include macroeconomic effects; instead, the model focuses on jobs and impacts supported by specific wind projects. In other words, the employment estimates from the JEDI model look only at gross economic impacts from this 20% Wind Scenario.

C.4 Manufacturing Sector

The 20% Wind Scenario includes the prospect of significantly expanding wind power manufacturing capabilities in the United States. In 2026, this level of wind development supports more than 32,000 U.S. manufacturing full-time workers in land-based and offshore wind projects. These employment impacts are directly related to producing the major components and subcomponents for the turbines, towers, and blades installed in the United States. Although the level of domestic wind installations declines after 2021 in the scenario modeled, the manufacturing and construction industries have the potential to maintain a high level of employment and expand further to meet increasing global demand.

To estimate the potential location for manufacturing jobs, data from a non-governmental organization, Renewable Energy Policy Project (REPP), report were used (Sterzinger and Svrcek 2004). The REPP report identified existing U.S. companies with the technical potential to enter the wind turbine market. The map in Figure C-5 was created using the percentages of manufacturing capability in each state and JEDI's manufacturing jobs output. Again, these potential manufacturing jobs from the REPP report are based on technical potential existing in 2004, without assuming increased productivity or expansion over time. The data also assume that existing facilities that manufacture components similar to wind turbine components are modified. Most of the manufacturing jobs in this scenario are located in the

Figure C-5. Potential manufacturing jobs created by 2030



Great Lakes region, where manufacturing jobs are being lost. Even states without a significant wind resource can be impacted economically from new manufacturing jobs (e.g., southeastern US).

C.5 Construction Sector

The year 2021 represents the height of the wind plant construction period, with 16.7 GW of wind having been brought online. In that year, more than 65,000 construction industry workers are assumed to be employed and $54.5 billion is generated in the U.S. economy from direct, indirect, and induced construction spending.

To reach the 20% Wind Scenario, today's wind power industry would have to grow from 9,000 annual construction jobs in 2007 to install 3 GW, to 65,000 new annual construction jobs in 2021 to install more than 16 GW. Construction jobs could be dispersed throughout the United States. Assuming the 16 GW/year capacity can be maintained into the future, including the replacement of outdated wind plants, the industry could maintain 20% electricity from wind as demand grows. In this scenario, the construction sector would experience the largest increase in jobs, followed by the operations sector, and then by the manufacturing sector. Figure C-6 shows the direct employment impact on the construction sector, the manufacturing sector and the operations sector (plant workers only).

Figure C-7 shows employment impacts during the same years, but adds the indirect and induced jobs. The bottom three bars (manufacturing, construction, and operations—including plant workers and other direct jobs) are direct jobs only. This chart depicts the large impact from the indirect and induced job categories, compared to the initial direct expenditures in the direct categories.

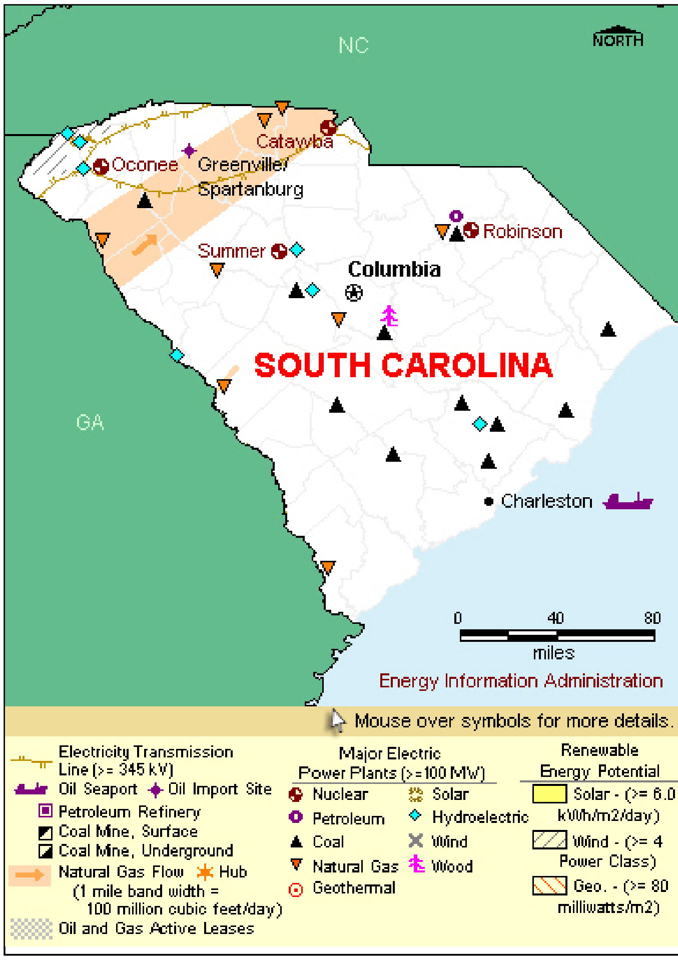
Attachment C

South Carolina

STATE ENERGY PROFILES

Last Update: November 06, 2008
Next Update: November 13 , 2008

Print Full Report



South Carolina Quick Facts

- South Carolina's four nuclear power plants typically supply more than half of the State's electricity generation.
- South Carolina receives most of its coal from Kentucky.
- Industry is the State's largest energy-consuming sector, accounting for roughly two-fifths of total energy consumption.
- If licensing and construction go as planned, four new nuclear reactors could come online in South Carolina by 2015.
- Per capita electricity use in South Carolina is higher than the nationwide average due in part to high air-conditioning demand during hot summer months and the widespread use of electricity for home heating during generally mild winter months.

Overview

Resources and Consumption

South Carolina's only substantial energy resource is its system of rivers and lakes, which offers potential for hydroelectric power generation. Driven in part by the energy-intensive chemical manufacturing industry, South Carolina's industrial sector accounts for approximately two-fifths of State energy consumption.

Petroleum

South Carolina receives petroleum products shipments at the Port of Charleston and via the Colonial and Plantation pipelines from the Gulf Coast. The Dixie Pipeline, also originating in the Gulf Coast, supplies the State's propane demand. South Carolina's total petroleum consumption is near the national median,, and South Carolina is one of the few States that allow the statewide use of conventional motor gasoline. (Most States require the use of specific gasoline blends in non-attainment areas due to air-quality considerations.)

Natural Gas

South Carolina's natural gas supply is transported from the Gulf Coast by two major interstate pipeline systems. Although more than one-fourth of households in South Carolina use natural gas as their main energy source for home heating, winters are generally mild and overall demand is relatively low.

Coal, Electricity, and Renewables

Nuclear power accounts for more than one-half of South Carolina's electricity generation. With four active nuclear power plants, South Carolina is among the top nuclear power producers in United States. Coal fuels about two-fifths of net electricity generation. South Carolina has no coal mines, and coal-fired power plants rely on supplies shipped from Kentucky, and, to a lesser extent, West Virginia and Tennessee. South Carolina produces hydroelectric power from facilities located in several river and lake basins. Per capita electricity consumption in South Carolina is among the highest in the United States. The State's high per capita electricity consumption is due to high industrial use, high demand for electric air-conditioning during hot summer months, and the widespread use of electricity for home heating during typically mild winter months. Nearly three-fifths of South Carolina households use electricity as their primary energy source for home heating.

Data

Economy

Population and Employment	South Carolina	U.S. Rank	Period
Population	4.4 million	25	2007
Civilian Labor Force	2.2 million	24	2007
Per Capita Personal Income	$31,013	48	2007
Industry	**South Carolina**	**U.S. Rank**	**Period**
Gross Domestic Product by State	$152.8 billion	28	2007
Land in Farms	4.8 million acres	38	2002
Market Value of Agricultural Products Sold	$1.5 billion	35	2002

Prices

Petroleum	South Carolina	U.S. Avg.	Period
Domestic Crude Oil First Purchase	—	$112.83/barrel	Aug-08
No. 2 Heating Oil, Residential	—	$3.872/gal	Aug-08
Regular Motor Gasoline Sold Through Retail Outlets (Excluding Taxes)	$3.174/gal	$3.25/gal	Aug-08
State Tax Rate on Motor Gasoline (other taxes may apply)	$0.16/gal	$0.2159/gal	Aug-08
No. 2 Diesel Fuel Sold Through Retail Outlets (Excluding Taxes)	—	$3.751/gal	Aug-08
State Tax Rate on On-Highway Diesel (other taxes may apply)	$0.16/gal	$0.2214/gal	Aug-08
Natural Gas	**South Carolina**	**U.S. Avg.**	**Period**
Wellhead	—	$6.40/thousand cu ft	2006
City Gate	$11.28/thousand cu ft	$10.16/thousand cu ft	Aug-08
Residential	$28.11/thousand cu ft	$19.62/thousand cu ft	Aug-08
Coal	**South Carolina**	**U.S. Avg.**	**Period**
Average Open Market Sales Price	—	$26.20/short ton	2007
Delivered to Electric Power Sector	$ 3.31/million Btu	$ 2.09 /million Btu	Jul-08
Electricity	**South Carolina**	**U.S. Avg.**	**Period**
Residential	10.24 cents/kWh	12.09 cents/kWh	Jul-08
Commercial	8.66 cents/kWh	11.08 cents/kWh	Jul-08
Industrial	5.66 cents/kWh	7.75 cents/kWh	Jul-08

See more Price data for all States

Reserves & Supply

Reserves	South Carolina	Share of U.S.	Period
Crude Oil	—	—	2006
Dry Natural Gas	—	—	2006
Natural Gas Liquids	—	—	2006
Recoverable Coal at Producing Mines	—	—	2007
Rotary Rigs & Wells	**South Carolina**	**Share of U.S.**	**Period**
Rotary Rigs in Operation	0	0.0%	2007
Crude Oil Producing Wells	0	0.0%	2007
Natural Gas Producing Wells	—	—	2006
Production	**South Carolina**	**Share of U.S.**	**Period**
Total Energy	661 trillion Btu	1.0%	2005
Crude Oil	—	—	Jun-08
Natural Gas - Marketed	—	—	2006
Coal	—	—	2007
Capacity	**South Carolina**	**Share of U.S.**	**Period**
Crude Oil Refinery Capacity (as of Jan. 1)	—	—	2008
Electric Power Industry Net Summer Capability	22,782 MW	2.3%	2006
Net Electricity Generation	**South Carolina**	**Share of U.S.**	**Period**
Total Net Electricity Generation	10,031 thousand MWh	2.5%	Jul-08
Petroleum-Fired	6 thousand MWh	0.2%	Jul-08
Natural Gas-Fired	694 thousand MWh	0.7%	Jul-08
Coal-Fired	4,287 thousand MWh	2.3%	Jul-08
Nuclear	4,885 thousand MWh	6.6%	Jul-08
Hydroelectric	138 thousand MWh	0.5%	Jul-08
Other Renewables	164 thousand MWh	1.7%	Jul-08
Stocks	**South Carolina**	**Share of U.S.**	**Period**
Motor Gasoline (Excludes Pipelines)	988 thousand barrels	1.6%	Aug-08
Distillate Fuel Oil (Excludes Pipelines)	858 thousand barrels	0.9%	Aug-08
Natural Gas in Underground Storage	—	—	Aug-08
Petroleum Stocks at Electric Power Producers	823 thousand barrels	2.0 %	Jul-08
Coal Stocks at Electric Power Producers	2,581 thousand tons	1.8%	Jul-08

Production Facilities	South Carolina
Major Coal Mines	None
Petroleum Refineries	None
Major Non-Nuclear Electricity Generating Plants	Bad Creek (Duke Energy Carolinas • LLC) • Cross (South Carolina Pub Serv Auth) • Winyah (South Carolina Pub Serv Auth) • John S Rainey (South Carolina Pub Serv Auth) • Broad River Energy Center (Calpine Operating Services Company Inc)
Nuclear Power Plants	Oconee (Duke Energy Carolinas • LLC) • Catawba (Duke Energy Carolinas • LLC) • V C Summer (South Carolina Electric&Gas Co) • H B Robinson (Progress Energy Carolinas Inc)

See more Reserves and Supply data for all States

Distribution & Marketing

Distribution Centers	South Carolina
Oil Seaports/Oil Import Sites	Charleston • Greenville-Spartanburg.
Natural Gas Market Centers	None
Major Pipelines	**South Carolina**
Crude Oil	None
Petroleum Product	Colonial • Plantation.

Liquefied Petroleum Gases	Dixie		
Interstate Natural Gas Pipelines	Southern Natural Gas Co. • Transcontinental Gas Pipeline Co.		

Fueling Stations	South Carolina	Share of U.S.	Period
Motor Gasoline	3,677	2.2%	2007
Liquefied Petroleum Gases	27	1.2%	2007
Compressed Natural Gas	3	0.4%	2007
Ethanol	55	3.9%	2007
Other Alternative Fuels	73	6.3%	2007

See more Distribution and Marketing data for all States

Consumption

per Capita	South Carolina	U.S. Rank	Period
Total Energy	398 million Btu	15	2005

by Source	South Carolina	Share of U.S.	Period
Total Energy	1,694 trillion Btu	1.7%	2005
Total Petroleum	109,208 thousand barrels	1.4%	2006
Motor Gasoline	61,779 thousand barrels	1.8%	2006
Distillate Fuel	21,812 thousand barrels	1.4%	2006
Liquefied Petroleum Gases	3,243 thousand barrels	0.4%	2006
Jet Fuel	1,805 thousand barrels	0.3%	2006
Natural Gas	174,805 million cu ft	0.8%	2006
Coal	17,288 thousand short tons	1.6%	2006

by End-Use Sector	South Carolina	Share of U.S.	Period
Residential	359,549 billion Btu	1.7%	2005
Commercial	255,375 billion Btu	1.4%	2005
Industrial	651,129 billion Btu	2.0%	2005
Transportation	428,294 billion Btu	1.5%	2005

for Electricity Generation	South Carolina	Share of U.S.	Period
Petroleum	13 thousand barrels	0.2%	Jul-08
Natural Gas	5,005 million cu ft	0.6%	Jul-08
Coal	1,737 thousand short tons	1.8%	Jul-08

for Home Heating (share of households)	South Carolina	U.S. Avg.	Period
Natural Gas	26%	51.2%	2000
Fuel Oil	5%	9.0%	2000
Electricity	58%	30.3%	2000
Liquefied Petroleum Gases	9%	6.5%	2000
Other/None	2%	1.8%	2000

See more Consumption data for all States

Environment

Special Programs	South Carolina		
Clean Cities Coalitions	Palmetto State		

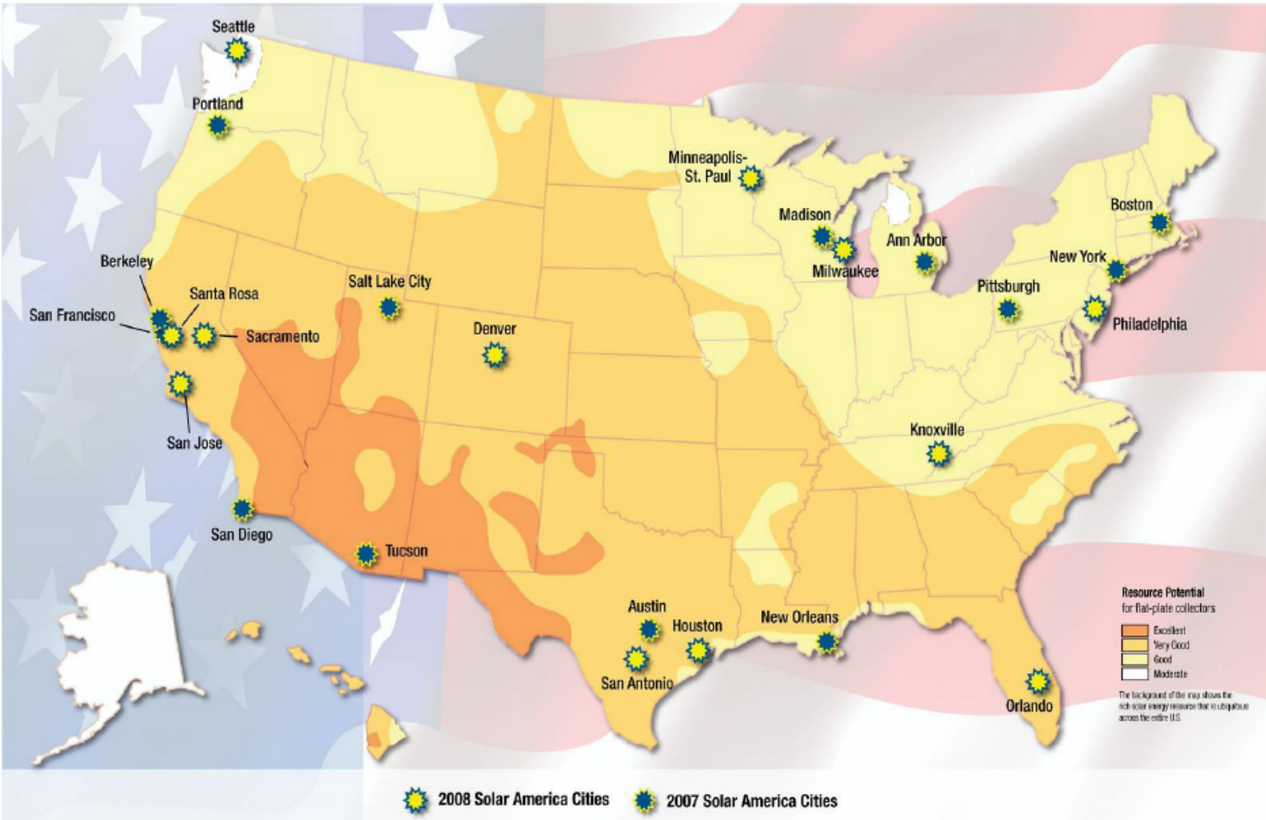
Alternative Fuels	South Carolina	Share of U.S.	Period
Alternative-Fueled Vehicles in Use	9,642	1.6%	2006
Ethanol Plants	0	0.0%	2008
Ethanol Plant Capacity	0 million gal/year	0.0%	2008
Ethanol Use in Gasohol	0 thousand gal	0.0%	2004

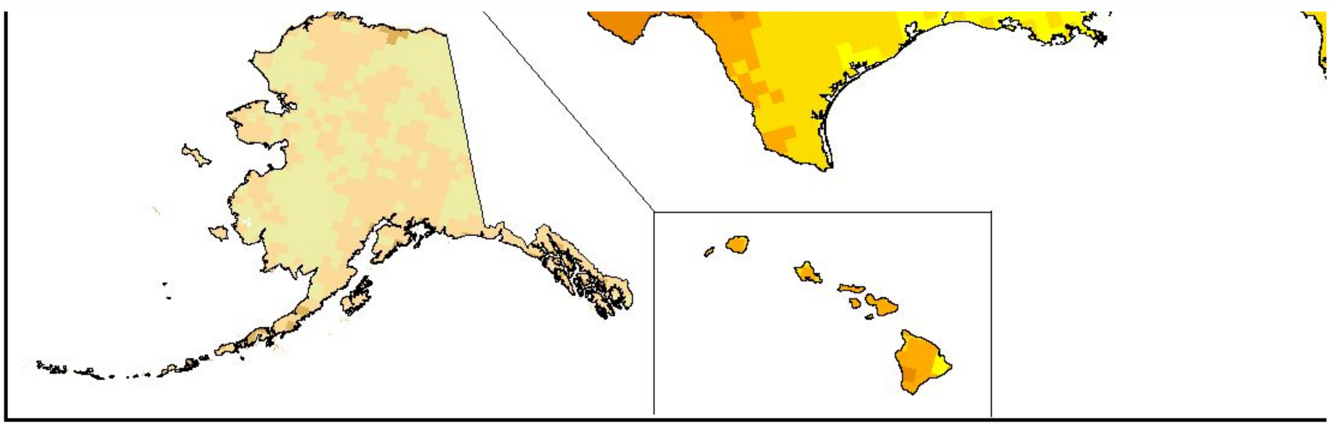
Electric Power Industry Emissions	South Carolina	Share of U.S.	Period
Carbon Dioxide	40,847,197 metric tons	1.7%	2006
Sulfur Dioxide	218,658 metric tons	2.3%	2006
Nitrogen Oxide	49,251 metric tons	1.3%	2006

See more Environment data for all States

Attachment D

Solar America Cities





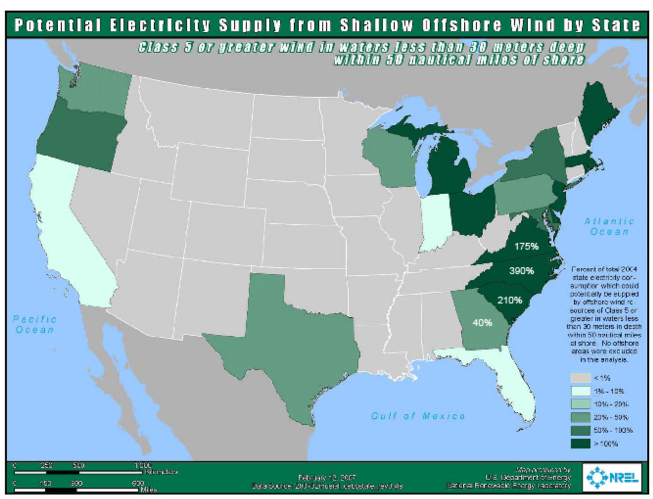
Attachment E

The Offshore Wind Industry

The wind industry has emerged as one of the fastest growing energy markets in the world. Offshore wind farms have been generating clean, home-grown electrical energy in Europe since 1991 with 1250 megawatts in operation, 1500 megawatts under construction and over 20,000 megawatts permitted throughout the region (1000 megawatts of wind energy is enough to power well over 300,000 homes). Current European targets for wind generated power aim to supply 25% of projected electrical demand by 2030. To achieve this goal, more than $25 billion will be invested annually. When completed the annual fuel cost savings and reduction in trade deficit are estimated to be more than $45 billion.

A new study recently released by the United States Department of Energy shows that 20% of the nation's power needs can be met by wind power with:

- continued technology improvement,
- upgrades to transmission infrastructure,
- improved ancillary services and
- development of offshore wind power along the Atlantic and Pacific seaboards.



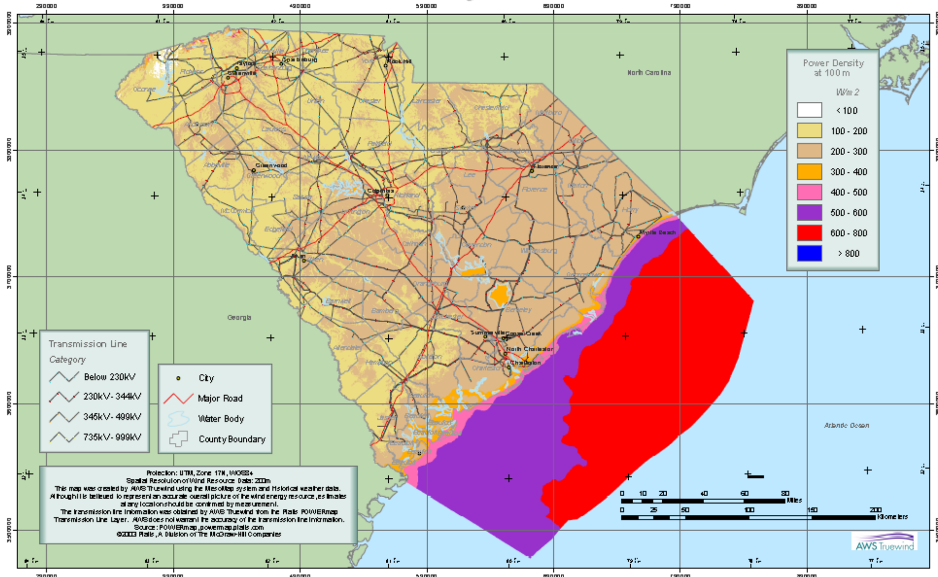
This scenario includes more than 50,000 megawatts of offshore wind power along the northeastern and southeastern coasts of the United States, representing a market in excess of $170 Billion.

As the lessons learned from the rapidly expanding offshore wind market in Europe are transferred to the United States, a domestic offshore wind industry is emerging. Growth will be concentrated along the Atlantic coast due to its large demand centers, excellent wind resources and shallow waters.

Signs of this growth are already evident. Delmarva Power recently signed a Purchase Price Agreement (PPA) for power from a proposed 200 megawatts offshore wind farm. The project will make Delaware the first to build an offshore wind farm in the United States. Rhode Island and New Jersey have quickly followed with Requests for Proposals (RFPs) for offshore wind farms. Despite political delays in Massachusetts, permitting of an offshore wind farm in that state continues to proceed.

Closer to home, the United States Department of Energy has identified South Carolina as one of the states along the Atlantic Coast with a strong offshore wind potential. According to the National Renewable Energy Laboratory, South Carolina has more than twice as much untapped offshore wind capacity as is presently installed throughout the entire state. Further, with the development of offshore wind projects in North America, and along the East Coast in particular, industrial hubs must emerge to support these large projects.

Mean Annual Wind Power Density of South Carolina at 100 Meters



Second, as the offshore wind market emerges along the East Coast of the United States and land-based turbines continue to grow in size, South Carolina is strategically positioned to serve as an industrial hub from this growing industry. For example, Vestas, the world leader in wind turbine manufacturing, established their industrial hub to service land-based wind farm development in Denver, CO due to its rail infrastructure, access to the Midwest markets and manufacturing base. This model will emerge to support the offshore wind industry targeted to grow along the Atlantic seaboard. As larger turbines continue to be introduced into the market, access to port facilities for transporting large components will become increasingly important driving new manufacturing hubs to be established along the coast and Great Lakes.

The Charleston area already exhibits many of the characteristics necessary for a successful wind manufacture and distribution center. These include:

- outstanding port facilities,
- established large scale ship rebuilding facilities, which are transferable to wind component fabrication,
- local steel manufacturing,
- a favorable manufacturing environment,
- excellent research institutions, and
- existing key industry players including General Electric and Fluor Corporation.

Add to this a demonstrated entrepreneurial spirit, and South Carolina – and the Charleston area in particular – emerge as a leading candidate to incubate an offshore wind energy hub that services not only the Atlantic coast of the United States but also the growing European market.

It is important for South Carolina to strategically market its strengths to both US and European manufacturers before the opportunity is lost. Key industry, academic, environmental and community leaders must come together now to form an alliance to attract this emerging industry to the state.

Madsen (2005) describe how databases can be used for managing O&M and improving future designs.

In mature industries, O&M management tools are available to help maximize maintenance efficiency. Achieving this efficiency is a key factor in minimizing the COE and maximizing the life of wind plants, thereby increasing investor confidence. Unlike central generation facilities, wind plants require maintenance strategies that minimize human attention and maximize remote health monitoring and automated fault data diagnosis. This requires intimate knowledge of healthy plant operating characteristics and an ability to recognize the characteristics of very complex faults that might be unique to a specific wind plant. Such tools do not currently exist for the wind industry, and their development will require RD&D to study wind plant systems interacting with complex atmospheric conditions and to model the interactions. The resultant deeper understanding will allow expert systems to be developed, systems that will aid operators in their quest to maximize plant performance and minimize operating costs through risk mitigation. These systems will also produce valuable data for improving the next generation of turbine designs.

2.5 Offshore Wind Technology

Offshore wind energy installations have a broadly dispersed, abundant resource and the economic potential for cost competitiveness that would allow them to make a large impact in meeting the future energy needs of the United States (Musial, 2007). Of the contiguous 48 states, 28 have a coastal boundary. U.S. electric use data show that these same states use 78% of the nation's electricity (EIA 2006). Of these 28 states, only 6 have a sufficient land-based wind energy resource to meet more than 20% of their electric requirements through wind power. If shallow water offshore potential (less than 30 m in depth) is included in the wind resource mix, though, 26 of the 28 states would have the wind resources to meet at least 20% of their electric needs, with many states having sufficient offshore wind resources to meet 100% of their electric needs (Musial, 2007). For most coastal states, offshore wind resources are the only indigenous energy source capable of making a significant energy contribution. In many congested energy-constrained regions, offshore wind plants might be necessary to supplement growing demand and dwindling fossil supplies.

Twenty-six offshore wind projects with an installed capacity of roughly 1,143 MW now operate in Europe. Most projects were installed in water less than 22 m deep. One demonstration project in Scotland is installed in water at a depth of 45 m. Although some projects have been hampered by construction overruns and higher-than-expected maintenance requirements, projections show strong growth in many European Union (EU) markets. For example, it is estimated that offshore wind capacity in the United Kingdom will grow by 8,000 MW by 2015. Similarly, German offshore development is expected to reach 5,600 MW by 2014 (BSH & BWEA).

In the United States, eight or nine offshore project proposals in state and federal waters total to a capacity of more than 1,500 MW. Two of these proposed projects are being treated separately by the Minerals Management Service (MMS) because the permits were submitted before MMS authority was established by the Energy Policy Act (EPAct) of 2005 (MMS). Two other projects in Texas state waters have already received state approval.

2.5.1 Cost of Energy

The current installed capital cost of offshore projects is estimated in the range of $2,400 to $5000 per kW (Black & Veatch, forthcoming 2008, Pace Global 2007). Because offshore wind energy tends to take advantage of extensive land-based experience and mature offshore oil and gas practices, offshore cost reductions are not expected to be as great as land-based reductions spanning the past two decades. However, offshore wind technology is considerably less mature than land-based wind energy, so it does have significant potential for future cost reduction. These cost reductions are achievable through technology development and innovation, implementation and customization of offshore oil and gas practices, and learning-curve reductions that take advantage of more efficient manufacturing and deployment processes and procedures.

2.5.2 Current Technology

Today's baseline technology for offshore wind turbines is essentially a version of the standard land-based turbine adapted to the marine environment. Although turbines of up to 5 MW have been installed, most recent orders from Vestas (Randers, Denmark) and Siemens (Munich, Germany), the two leading suppliers of offshore wind turbines, range from 2.0 MW to 3.6 MW.

The architecture of the baseline offshore turbine and drivetrain comprises a three-bladed upwind rotor, typically 90 m to 107 m in diameter. Tip speeds of offshore turbines are slightly higher than those of land-based turbines, which have speeds of 80 m/s or more. The drivetrain consists of a gearbox generally run with variable-speed torque control that can achieve generator speeds between 1,000 and 1,800 rpm. The offshore tower height is generally 80 m, which is lower than that of land-based towers because wind shear profiles are less steep, tempering the advantage of tower height.

The offshore foundation system baseline technology uses monopiles at nominal water depths of 20 m. Monopiles are large steel tubes with a wall thickness of up to 60 mm and diameters of 6 m. The embedment depth varies with soil type, but a typical North Sea installation must be embedded 25 m to 30 m below the mud line. The monopile extends above the surface where a transition piece with a flange to fasten the tower is leveled and grouted. Its foundation requires a specific class of installation equipment for driving the pile into the seabed and lifting the turbine and tower into place. Mobilization of the infrastructure and logistical support for a large offshore wind plant accounts for a significant portion of the system cost.

Turbines in offshore applications are arranged in arrays that take advantage of the prevailing wind conditions measured at the site. Turbines are spaced to minimize aggregate power plant energy losses, interior plant turbulence, and the cost of cabling between turbines.

The power grid connects the output from each turbine, where turbine transformers step up the generator and the power electronics voltage to a distribution voltage of about 34 kilovolts (kV). The distribution system collects the power from each turbine at a central substation where the voltage is stepped up and transmitted to shore through a number of buried, high-voltage subsea cables. A shore-based interconnection point might be used to step up the voltage again before connecting to the power grid.

2

Shallow water wind turbine projects have been proposed and could be followed by transitional and finally deepwater turbines. These paths should not be considered as mutually exclusive choices. Because there is a high degree of interdependence among them, they should be considered a sequence of development that builds from a shallow water foundation of experience and knowledge to the complexities of deeper water.

2.5.3 Technology Needs and Potential Improvements

Offshore, wind turbine cost represents only one-third of the total installed cost of the wind project, whereas on land, the turbine cost represents more than half of the total installed cost. To lower costs for offshore wind, then, the focus must be on lowering the balance-of-station costs. These costs, which include those for foundations, electrical grids, O&M, and installation and staging costs, dominate the system COE. Turbine improvements that make turbines more reliable, more maintainable, more rugged, and larger, will still be needed to achieve cost goals. Although none of these improvements is likely to lower turbine costs, the net result will lower overall system costs.

The commercialization of offshore wind energy faces many technical, regulatory, socioeconomic, and political barriers, some of which may be mitigated through targeted short- and long-range RD&D efforts. Short-term research addresses impediments that are preventing initial industry projects from proceeding and helps to sharpen the focus for long-term research. Long-term research involves a more complex development process resulting in improvements that can help lower offshore life-cycle system costs.

Short-Term RD&D Options

Conducting research that will lead to more rapid deployment of offshore turbines should be an upfront priority for industry. This research should address obstacles to today's projects, and could include the following tasks:

- **Define offshore resource exclusion zones:** A geographically based exclusion study using geographic information system (GIS) land use overlays would more accurately account for all existing and future marine uses and sensitive areas. This type of exclusion study could be part of a regional programmatic environmental impact statement and is necessary for a full assessment of the offshore resource (Dhanju, Whitaker, and Kempton 2006). Currently, the developer bears the burden of siting during a pre-permitting phase with very little official guidance. This activity should be a jointly funded industry project conducted on a regional basis.
- **Develop certification methods and standards:** MMS has been authorized to define the structural safety standards for offshore wind turbines on the OCS. Technical research, analysis, and testing are needed to build confidence that safety will be adequate and to prevent overcautiousness that will increase costs unnecessarily. Development of these standards will require a complete evaluation and harmonization of the existing offshore wind standards and the American Petroleum Institute (API) offshore oil and gas standards. MMS is currently determining the most relevant standards.
- **Develop design codes, tools, and methods:** The design tools that the wind industry uses today have been developed and validated for

land-based utility-scale turbines, and the maturity and reliability of the tools have led to significantly higher confidence in today's wind turbines. Offshore design tools are relatively immature by comparison. The development of accurate offshore computer codes to predict the dynamic forces and motions acting on turbines deployed at sea is essential for moving into deeper water. One major challenge is predicting loads and the resulting dynamic responses of the wind turbine support structure when it is subjected to combined wave and wind loading. These offshore design tools must be validated to ensure that they can deal with the combined dominance of simultaneous wind and wave load spectra, which is a unique problem for offshore wind installations. Floating system analysis must be able to account for additional turbine motions as well as the dynamic characterization of mooring lines.

- **Site turbines and configure arrays:** The configuration and spacing of wind turbines within an array have a marked effect on power production from the aggregate wind plant, as well as for each individual turbine. Uncertainties in power production represent a large economic risk factor for offshore development. Offshore wind plants can lose more than 10% of their energy to array losses, but improvements in array layout and array optimization models could deliver substantial recovery (Seawind 2003). Atmospheric boundary layer interaction with the turbine wakes can affect both energy capture and plant-generated turbulence. Accurate characterization of the atmospheric boundary layer behavior and more accurate wake models will be essential for designing turbines that can withstand offshore wind plant turbulence. Wind plant design tools that are able to characterize turbulence generated by wind plants under a wide range of conditions are likely necessary.
- **Develop hybrid wind-speed databases:** Wind, sea-surface temperatures, and other weather data are housed in numerous satellite databases available from the National Oceanic and Atmospheric Administration (NOAA), NASA, the National Weather Service (NWS), and other government agencies. These data can be combined to supplement the characterization of coastal and offshore wind regimes (Hasager et al. 2005). The limitations and availability of existing offshore data must be understood. Application of these data to improve the accuracy of offshore wind maps will also be important.

Long-Term R&D Options

Long-term research generally requires hardware development and capital investment, and it must take a complex development path that begins early so that mature technology will be ready when it is needed. Most long-term research areas relate to lowering offshore life-cycle system costs. These areas are subdivided into infrastructure and turbine-specific needs. Infrastructure to support offshore wind development represents a major cost element. Because this is a relatively new technology path, there are major opportunities for reducing the cost impacts in this area. Although land-based wind turbine designs can generally be used for offshore deployment, the offshore environment will impose special requirements on turbines. These requirements must be taken into account to optimize offshore deployment. Areas where industry should focus efforts include:

- **Minimize work at sea:** There are many opportunities to lower project costs by reallocating the balance between work done on land and at sea. In addition, the portion of labor devoted to project O&M, land-based installation and assembly, and remote inspections and diagnostics can be rebalanced with respect to upfront capital enhancements, such as higher quality assurance, more qualification testing, and reliable designs. This rebalancing might enable a significant life-cycle cost reduction by shifting the way wind projects are designed, planned, and managed.
- **Enhance manufacturing, installation and deployment strategies:** New manufacturing processes and improvements in existing processes that reduce labor and material usage and improve part quality have high potential for reducing costs in offshore installations. Offshore wind turbines and components could be constructed and assembled in or near seaport facilities that allow easy access from the production area to the installation site, eliminating the necessity of shipping large components over inland roadways. Fabrication facilities must be strategically located for mass-production, land-based assembly, and for rapid deployment with minimal dependence on large vessels. Offshore system designs that can be floated out and installed without large cranes can reduce costs significantly. New strategies should be integrated into the turbine design process at an early stage (Lindvig 2005; Poulsen and Skjærbæk 2005).
- **Incorporate offshore service and accessibility features:** To manage O&M, predict weather windows, minimize downtime, and reduce the equipment needed for up-tower repairs, operators should be equipped with remote, intelligent, turbine condition monitoring and self-diagnostic systems. These systems can alert operators to the need for operational changes or to schedule maintenance at the most opportune times. A warning about an incipient failure can alert the operators to replace or repair a component before it does significant damage to the system or leaves the machine inoperable for an extended period of time. More accurate weather forecasting will also become a major contributor in optimizing service for lower cost.
- **Develop low-cost foundations, anchors, and moorings:** Current shallow-water foundations have already reached a practical depth limit of 30 m, and anchor systems beyond that are derived from conservative and expensive oil and gas design practices. Cost-saving opportunities arise for wind power plants in deeper water with both fixed-bottom and floating turbine foundations, as well as for existing shallow-water designs in which value-engineering cost reductions can be achieved. Fixed-bottom systems comprising rigid lightweight substructures, automated mass-production fabrication facilities, and integrated mooring and piling deployment systems that minimize dependence on large sea vessels are possible low-cost options. Floating platforms will require a new generation of mooring designs that can be mass produced and easily installed.
- **Use resource modeling and remote profiling systems:** Offshore winds are much more difficult to characterize than winds over land. Analytical models are essential to managing risk during the initial

siting of offshore projects, but are not very useful by themselves for micrositing (Jimenez et al. 2005). Alternative methods are needed to measure wind speed and wind shear profiles up to elevations where wind turbines operate. This will require new equipment such as sonic detection and ranging (SODAR), light detection and ranging (LIDAR), and coastal RADAR-based systems that must be adapted to measure offshore wind from more stable buoy systems or from fixed bases. Some systems are currently under development but have not yet been proven (Antoniou et al. 2006). The results of an RD&D measurement program on commercial offshore projects could generate enough confidence in these systems to eliminate the requirement for a meteorological tower.

- **Increase offshore turbine reliability:** The current offshore service record is mixed, and as such, is a large contributor to high risk. A new balance between initial capital investment and long-term operating costs must be established for offshore systems, which will have a significant impact on COE. Offshore turbine designs must place a higher premium on reliability and anticipation of on-site repairs than their land-based counterparts. Emphasis should be placed on avoiding large maintenance events that require expensive and specialized equipment. This can be done by identifying the root causes of component failures, understanding the frequency and cost of each event, and appropriately implementing design improvements (Stiesdal and Madsen 2005). Design tools, quality control, testing, and inspection will need heightened emphasis. Blade designers must consider strategies to offset the impacts of marine moisture, corrosion, and extreme weather. In higher latitudes, designers must also account for ice flows and ice accretion on the blades. Research that improves land-based wind turbine reliability now will have a direct impact on the reliability of future offshore machines.
- **Assess the potential of ultra-large offshore turbines:** Land-based turbines may have reached a size plateau because of transportation and erection limits. Further size growth in wind turbines will largely be pushed by requirements unique to offshore turbine development. According to a report on the EU-funded UpWind project, "Within a few years, wind turbines will have a rotor diameter of more than 150 m and a typical size of 8 MW–10 MW" (Risø National Laboratory 2005). The UpWind project plans to develop design tools to optimize large wind turbine components, including rotor blades, gearboxes, and other systems that must perform in large offshore wind plants. New size-enabling technologies will be required to push wind turbines beyond the scaling limits that constrain the current fleet. These technologies include lightweight composite materials and composite manufacturing, lightweight drivetrains, modular pole direct-drive generators, hybrid space frame towers, and large gearbox and bearing designs that are tolerant of slower speeds and larger scales. All of the weight-reducing features of the taller land-based tower systems will have an even greater value for very large offshore machines (Risø National Laboratory 2005).

2

RD&D Summary

The advancement of offshore technology will require the development of infrastructure and technologies that are substantially different from those employed in land-based installations. In addition, these advances would need to be tailored to U.S. offshore requirements, which differ from those in the European North Sea environment. Government leadership could accelerate baseline research and technology development to demonstrate feasibility, mitigate risk, and reduce regulatory and environmental barriers. Private U.S. energy companies need to take the technical and financial steps to initiate near-term development of offshore wind power technologies and bring them to sufficient maturity for large-scale deployment. Musial (2007) and Bywaters and colleagues (2005) present more detailed analyses of actions for offshore development.

2.6 Distributed Wind Technology

Distributed wind technology (DWT) applications refer to turbine installations on the customer side of the utility meter. These machines range in size from less than 1 kW to multimegawatt, utility-scale machines used to offset electricity consumption at the retail rate. Because the WinDS deployment analysis does not currently segregate DWT from utility deployment, DWT applications are part of the land-based deployment estimates in the 20% wind energy scenario.

Historically, DWT has been synonymous with small machines. The DWT market in the 1990s focused on battery charging for off-grid homes, remote telecommunications sites, and international village power applications. In 2000, the industry found a growing domestic market for behind-the-meter wind power, including small machines for residential and small farm applications and multimegawatt-scale machines for larger agricultural, commercial, industrial, and public facility applications. Although utility-scale DWT requirements are not distinguishable from those for other large-scale turbines, small machines have unique operating requirements that warrant further discussion.

2.6.1 Small Turbine Technology

Until recently, three-bladed upwind designs using tail vanes for passive yaw control dominated small wind turbine technology rated at less than 10 kW. Furling, or turning the machine sideways to the wind with a mechanical linkage, was almost universally used for rotor overspeed control. The drivetrains were direct-drive, permanent-magnet alternators with variable-speed operation. Many of these installations were isolated from the grid. Today, there is an emerging technology trend toward grid-connected applications and nonfurling designs. U.S. manufacturers are world leaders in small wind systems rated at 100 kW or less, in terms of both market and technology.

Turbine technology begins the transition from small to large systems between 20 kW and 100 kW. Bergey Windpower (Norman, Oklahoma) offers a 50-kW turbine that uses technology commonly found in smaller machines, including furling; pultruded blades; a direct-drive, permanent-magnet alternator; and a tail vane for yaw control. Distributed Energy Systems has a 100-kW turbine that uses a direct-drive, variable-speed synchronous generator. Although most wind turbines in the 100-kW range have features common to utility-scale turbines, including gearboxes, mechanical brakes, induction generators, and upwind rotors with active yaw control, Attachment G

Final Report

Biomass Energy Potential in South Carolina: A Conspectus of Relevant Information

Prepared for

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and

U.S. Department of Energy/Southern States Energy Board
Southeast Biomass State and Regional Partnership

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NOTICE

This project is supported by the Southeastern Biomass State and Regional Partnership (SEBSRP) and administered by the Southern States Energy Board (SSEB) for the United States Department of Energy.

Note: References to SERBEP in this document refer to the U.S. Department of Energy (DOE)/Southern States Energy Board (SSEB) Southeastern Regional Biomass Energy Program, which preceded the DOE/SSEB Southeast Biomass State and Regional Partnership (SEBSRP).

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Foreword

The South Carolina Energy Office (SCEO) is a unit of the State Budget and Control Board. Established in law by the South Carolina Energy Conservation and Efficiency Act of 1992, the Energy Office has the mission of increasing energy efficiency and diversity, enhancing environmental quality and saving energy dollars for South Carolina.

Through its various programs and initiatives, the SCEO improves energy efficiency and deploys renewable energy projects. Its efficiency measures and programs are saving taxpayers over $70 million in the public sector alone. Workshops, financial aid programs, technical assistance activities and numerous publications and information activities assist and inform industrial, commercial, public sector and individual consumers in saving energy dollars and minimizing energy-related pollution.

Biomass Energy Potential in South Carolina: A Conspectus of Relevant Information is one of several activities in which the SCEO is partnering with the US Department of Energy, the Southern States Energy Board, and a host of others to identify and pursue opportunities to improve South Carolina's economy, environment and energy security through greater use of biomass energy.

Other biomass energy activities of the SCEO and its partners include formation and staffing of the South Carolina Biomass Council, implementation of a South Carolina Biomass Market Development Project, computation of macro-level metrics pertaining to potential economic and environmental benefits of biomass energy potential in the state, and studies on the feasibility of developing energy from poultry manure and litter, from waste water sewage facilities, and from used cooking oil and waste animal fats.

This conspectus is a general survey and digest of information relevant to biomass energy in South Carolina. Because it is Web-based and constantly updated as new information is gathered, it is a dynamic document. The most current version of the report is maintained on the SCEO website at www.energy.sc.gov. The online report provides links that allow the reader to access document summaries, and, in most cases, full-length documents referred to in the report.

Key SCEO staff responsible for preparation of this conspectus include John F. Clark, Michael Hughes, Elizabeth Renedo and Erika Hartwig.

We invite and encourage readers to correct errors, provide additional information and submit any other input that will assist in increasing the scope and accuracy of this document and its value toward the goal of increasing biomass energy production and use in South Carolina. Please send all comments to mhughes@energy.sc.gov. Additional contact information is provided at www.energy.sc.gov.

Biomass Energy Potential in South Carolina: A Conspectus of Relevant Information

Introduction

The creation of energy from organic renewable materials in the form of gas, liquid or solid holds tremendous beneficial potential for South Carolina. Biomass energy can be created from a variety of processes including, but not limited to: direct combustion of biomass to produce process steam and/or electricity; collection of natural biomass decomposition products such as methane; and conversion of biomass materials to create transportation fuels such as ethanol and biodiesel.

The South Carolina Energy Office (SCEO) and other public and private organizations have encouraged production of biomass energy in the state for over 25 years. A significant number of studies and reports have been produced, both in South Carolina and in other states with similar biomass resources. Nevertheless, measurable progress in South Carolina in the use of biomass energy resources has been slight.

Greater use of biomass energy resources in South Carolina is important for several reasons:

1. Economic Development: South Carolina produces no fossil fuels and thus imports the vast majority of its primary energy resources from other states and nations. Greater use of fuels derived from within the state will result in greater income multipliers from energy expenditures and thus boost economic expansion within the state, especially for the rural sector greatly in need of economic stimulus.

2. Energy Security: The transportation sector relies almost entirely on petroleum, over 60 percent of which is imported from foreign sources. An overwhelming majority of foreign petroleum reserves are in the Middle East and other countries that are problematic for US energy dependence, such as Nigeria, Venezuela and Russia. International supply, pipeline disruptions and price volatility put the country and the state at a high level of infrastructure vulnerability.

3. Environmental Enhancement: Almost two-thirds of all energy in the state is derived from fossil fuels (coal, oil and natural gas). Combustion of fossil fuels for energy releases harmful air emissions, in addition to creating problems associated with leaks and waste disposal. Fossil fuels contaminate air, water and land, create health problems, and have negative impacts on fish and wildlife. They cause crop and forest damage, and inflict enormous economic costs associated with environmental impacts. Nuclear power, providing almost a third of the state's primary energy needs, has safety problems associated with nuclear waste disposal. Biomass energy resources generally have far less adverse environmental impacts, and, in some cases, conversion of biomass into useful

energy mitigates other environmental problems, such as collecting and using harmful methane gases from landfills, animal manure, municipal sewage, and utilizing wood wastes, as well as construction and demolition debris, that would otherwise be buried in landfills.

Biomass Energy Potential in South Carolina: A Conspectus of Relevant Information summarizes studies conducted on various actual and potential feedstock resources in South Carolina and the Southeast, as well as relevant non-regional studies and other pertinent information. The report describes the existing information base, as well as information gaps, about the potential for three broad categories of biomass energy feedstocks: (1) resources for direct combustion of biomass to produce process steam and/or electricity; (2) resources for methane production; and (3) resources for production of ethanol or biodiesel transportation fuel. Ultimately, this report and other efforts will enhance biomass energy production and consumption in South Carolina.

The SCEO intends for *Biomass Energy Potential in South Carolina: A Conspectus of Relevant Information* to be a dynamic, on-going document. As additional existing and new information is identified and compiled, it will be incorporated into the report, which will serve as a primary information resource for future biomass energy production and use in South Carolina. The most current version of the report is maintained on the SCEO website at www.energy.sc.gov. The online report provides links that allow the reader to access document summaries, and, in most cases, full-length documents referred to in the report.

Conclusion

Landfill gas and combustion of waste wood by the forest products industry are the greatest biomass energy success stories thus far in South Carolina, and both products offer tremendous potential for future growth. Landfill gas opportunities have been well identified, and expansion of use of this resource is ongoing. With regard to woody biomass, the best untapped areas of potential are in use of this resource by non-forest products consumers who can switch from coal and natural gas.

Other clear opportunities are in the production of ethanol and biodiesel from corn and soybeans. Studies are now underway to determine the economic impact of biomass energy development in South Carolina and will be released in the near future.

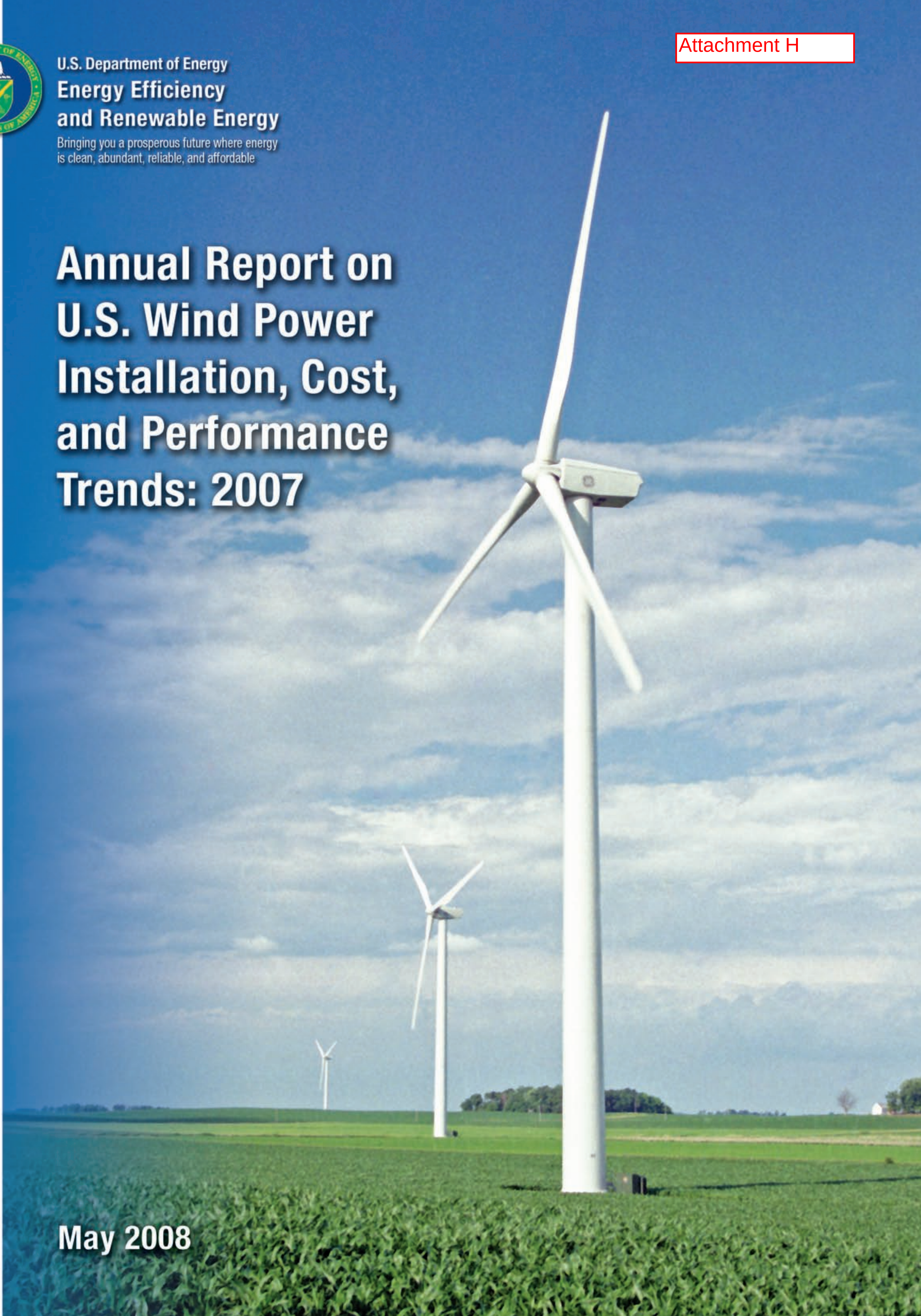
In response to the growing need for biomass energy, the South Carolina Energy Office (SCEO) has joined with a number of parties to create the South Carolina Biomass Council, which held its first meeting on April 21, 2006. The South Carolina Biomass Council is teaming with stakeholders around the state – farmers, legislators, governmental officials, the business and economic development community, environmental organizations, and the general public - to identify opportunities, obstacles and strategies to overcome barriers and increase biomass awareness, consumption and use.

Clearly, some additional analysis is needed to assess the environmental and economic viability of many forms of biomass energy production, and technology improvements are also needed before certain forms of biomass energy are feasible. However, many forms of biomass energy are already commercially available. The state only utilizes a small percent of its biomass energy capabilities and much more could be done right now. The major obstacles to overcome are not a lack of studies or need for the development of new technologies. The most significant present-day obstacle is a lack of understanding by policymakers, energy users and potential energy producers of the viability and magnitude of the opportunity for South Carolina if it makes a stellar effort to overcome institutional barriers and make full use of its indigenous biomass energy potential. Hopefully, this *Conspectus*, the work of the South Carolina Biomass Council, and implementation of other elements of the South Carolina Biomass Market Development Project by the SCEO and its partners are giant steps toward optimizing the state's biomass energy future.

Attachment H

U.S. Department of Energy
Energy Efficiency
and Renewable Energy
Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007



May 2008

Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007

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Contents

Introduction

The U.S. wind industry experienced unprecedented growth in 2007, surpassing even optimistic projections from years past. This 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 industry and its progress has never been greater. This report—the second of an ongoing annual series—attempts to meet this need by providing a detailed overview of developments and trends in the U.S. wind power market, with a particular focus on 2007.

As with the previous edition*, this report begins with an overview of key wind power development and installation-related trends, including trends in capacity growth, in turbine make and model, and among wind power developers, project owners, and power purchasers. It then reviews the price of wind power in the United States, and how those prices compare to the cost of fossil-fueled generation, as represented by wholesale power prices. Next, the report describes trends in installed wind project costs, wind turbine transaction prices, project performance, and operations and maintenance expenses. Finally, the report examines other factors impacting the domestic wind power market, including grid integration costs, transmission issues, and policy drivers. The report concludes with a brief preview of possible developments in 2008.

This version of the Annual Report updates data presented in the previous edition, while highlighting key trends and important new developments from 2007. New to this edition is a section on the contribution of wind power to new capacity additions in the electric sector, data on the amount of wind in utility systems, a summary of trends in wind project size, a discussion of the quantity of wind power capacity in various interconnection queues in the United States, and a section that underscores domestic wind turbine manufacturing investments.

A note on scope: this report concentrates on larger-scale wind applications, defined here as individual turbines or projects that exceed 50 kW in size. The U.S. wind power sector is multifaceted, however, and also includes smaller, customer-sited wind applications used to power the needs of residences, farms, and businesses. Data on these applications are not the focus of this report, though a brief discussion on *Distributed Wind Power* is provided on page 4.

Much of the data included in this report were compiled by Berkeley Lab, and come from a variety of sources, including the American Wind Energy Association (AWEA), the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). The Appendix provides a summary of the many data sources used in the report. Data on 2007 wind capacity additions in the United States are based on preliminary information provided by AWEA; some minor adjustments to those data are expected. In other cases, the data shown here represent only a sample of actual wind projects installed in the United States; furthermore, the data vary in quality. As such, emphasis should be placed on overall trends, rather than on individual data points. Finally, each section of this document focuses on historical market information, with an emphasis on 2007; the report does not seek to forecast future trends.

Acronym List

AWEA	American Wind Energy Association
BPA	Bonneville Power Administration
COD	commercial operation date
CREZ	competitive renewable energy zone
DOE	U.S. Department of Energy
EIA	Energy Information Administration
ERCOT	Electric Reliability Council of Texas
FERC	Federal Energy Regulatory Commission
IOU	investor-owned utility
IPP	independent power producer
ISO	independent system operator
LBNL	Lawrence Berkeley National Laboratory
MISO	Midwest Independent System Operator
NREL	National Renewable Energy Laboratory
POU	publicly owned utility
PPA	power purchase agreement
PTC	production tax credit
PUC	public utility commission
REC	renewable energy certificate
RPS	renewables portfolio standard
RTO	regional transmission organization
SPP	Southwest Power Pool
TVA	Tennessee Valley Authority
WAPA	Western Area Power Administration

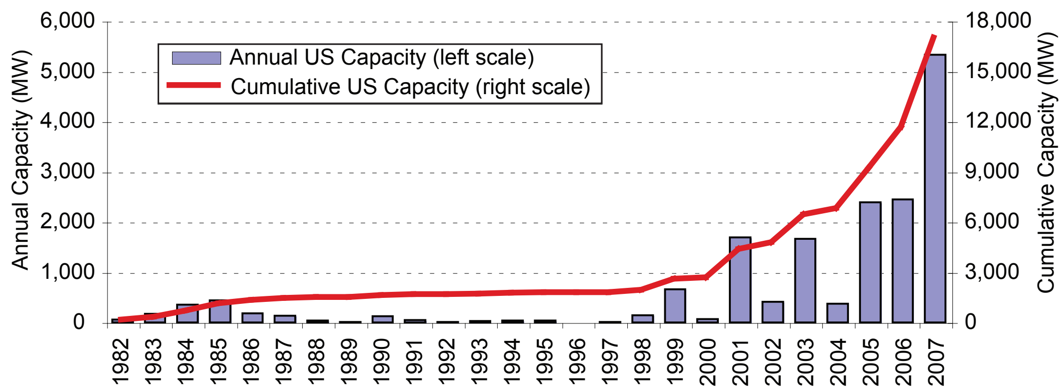
* Wiser, R.; Bolinger, M. (2007). *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2006*. 24 pp.; NREL Report No. TP-500-41435; DOE/GO-102007-2433, www.nrel.gov/docs/fy07osti/41435.pdf.

U.S. Wind Power Capacity Surged by 46% in 2007, with 5,329 MW Added and $9 Billion Invested

The U.S. wind power market surged in 2007, shattering previous records, with 5,329 MW of new capacity added, bringing the cumulative total to 16,904 MW (Figure 1). This growth translates into roughly $9 billion (real 2007 dollars) invested in wind project installations in 2007, for a cumulative total of nearly $28 billion since the 1980s.[1]

Wind installations in 2007 were not only the largest on record in the United States, but were more than twice the previous U.S. record, set in 2006. No country, in any single year, has added the volume of wind capacity that was added to the United States electrical grid in 2007. Federal tax incentives, state renewables portfolio standards (RPS), concern about global climate change, and continued uncertainty about the future costs and liabilities of natural gas and coal facilities helped spur this intensified growth.

The yearly boom-and-bust cycle that characterized the U.S. wind market from 1999 through 2004—caused by periodic, short-term extensions of the federal production tax credit (PTC)—has now been replaced by three consecutive years of sizable growth. With the PTC currently (as of early-May 2008) set to expire at the end of the year, 2008 is expected to be another year of sizable capacity additions. Unless the PTC is extended before mid-to-late 2008, however, a return to the boom-and-bust cycle can be expected in 2009.



Source: AWEA.

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

Distributed Wind Power

Wind turbines installed on the distribution side of the electric grid can provide power directly to homes, farms, schools, businesses, and industrial facilities. Distributed wind turbines can also provide power to off-grid sites. Distributed wind turbines generally range in size from a few hundred watts up to 100 kW or more, and growth in this sector has been driven—at least in part—by a variety of state incentive programs.

The table below summarizes sales of distributed wind turbines from 300 W to 100 kW in size into the U.S. market in 2007. As shown, nearly 10 MW of distributed wind turbines were sold in the U.S., with a slight majority (in capacity terms) used in grid-connected applications; 89% of this new capacity came from turbines manufactured by U.S. companies, including (but not limited to) Southwest Windpower, Bergey Windpower, Wind Turbine Industries, Entegrity Wind Systems, and Distributed Energy Systems. These installation figures represent a 14% growth in annual sales—in capacity terms—relative to 2006, yielding a cumulative installed capacity of distributed wind in the United States in this turbine size range of roughly 55-60 MW.

Application	Annual Sales in 2007		
	Number of Turbines	Capacity Additions (MW)	Sales Revenue (million $)
Off-grid	7,800	4.0	14
On-grid	1,292	5.7	28
TOTAL	**9,092**	**9.7**	**42**

Source: AWEA.

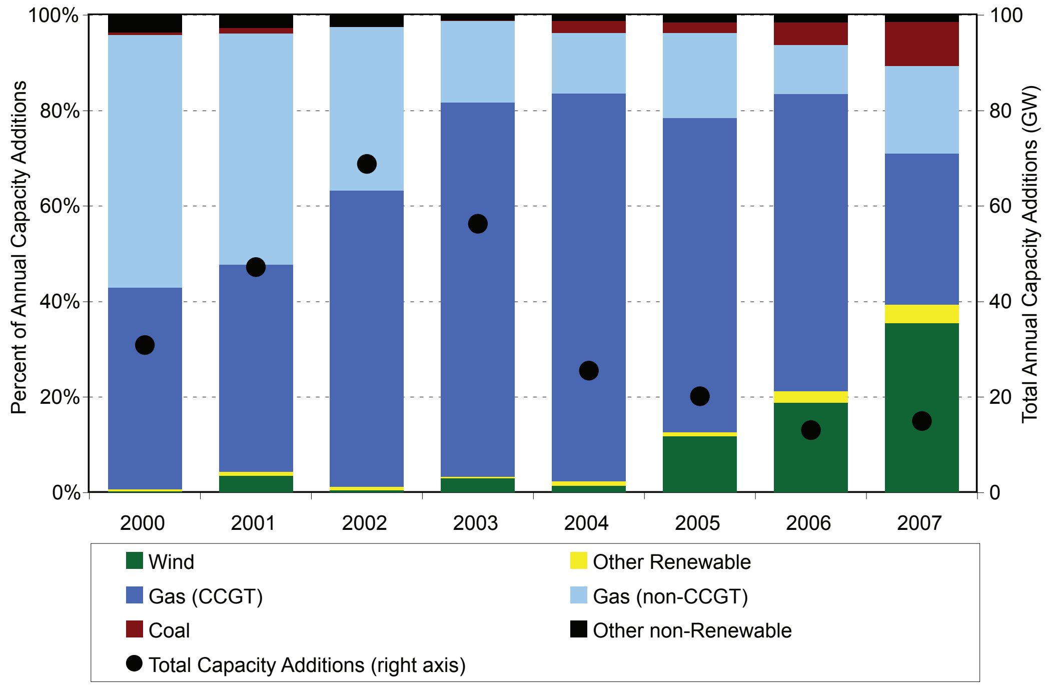
Wind Power Contributed 35% of All New U.S. Electric Generating Capacity in 2007

Wind power now represents one of the largest new sources of electric capacity additions in the United States. 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 (see Figure 2).

The EIA projects that total U.S. electricity supply will need to increase at an average pace of 47 TWh per year from 2008 to 2030 in order to meet demand growth. On an energy basis, the annual

[1] These investment figures are based on an extrapolation of the average project-level capital costs reported later in this report. Annual O&M, R&D, and manufacturing expenditures, which are not included here, would add to these figures.

amount of electricity generated by the new wind capacity added in 2007 (~16 TWh) represents roughly 35% of this average annual projected growth in supply.[2] By extension, if wind capacity additions continued through 2030 at the same pace as set in 2007 (5,329 MW per year), then 35% of the nation's projected additional electricity generation needs from 2008 through 2030 would be met with wind electricity. Although future growth trends are hard to predict, it is clear that a significant portion of the country's new generation needs are already being met by wind power.



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

Figure 2. Relative Contribution of Generation Types to Annual Capacity Additions

The United States Continued to Lead the World in Annual Capacity Growth

On a worldwide basis, roughly 20,000 MW of wind capacity was added in 2007, the highest volume achieved in a single year, and up from about 15,000 MW in 2006, bringing the cumulative total to approximately 94,000 MW. For the third straight year, the United States led the world in wind capacity additions (Table 1), capturing roughly 27% of the worldwide market, up from 16% in 2006 (Figure 3). China, Spain, Germany, and India rounded out the top five countries in 2007 for annual wind capacity additions (Table 1).[3]

In terms of cumulative installed wind capacity, the United States ended the year with 18% of worldwide capacity, in second place behind Germany. So far this decade (i.e., over the past eight years), 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.

Several countries are beginning to achieve relatively high levels of wind power penetration in their electricity grids. Figure 4 presents data on end-of-2007 (and end-of-2006) installed wind capacity, translated into projected annual electricity supply based on assumed country-specific capacity factors, and divided by projected 2008 (and 2007) electricity consumption. Using this rough approximation for the contribution of wind to electricity consumption, and focusing only on the 20 countries with the greatest cumulative installed wind capacity, 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% from last year), 8% of Ireland's (up by 0.4% from last year), and 7% of Germany's (up by 0.4% from last year). In the United States, on the other hand, the cumulative wind capacity installed at the end of 2007 would, in an average year, be able to supply roughly 1.2% of the nation's electricity consumption (up by 0.4% from last year)[4]—the same as wind's estimated 1.2% contribution to electricity consumption on a worldwide basis.

Table 1. International Rankings of Wind Power Capacity

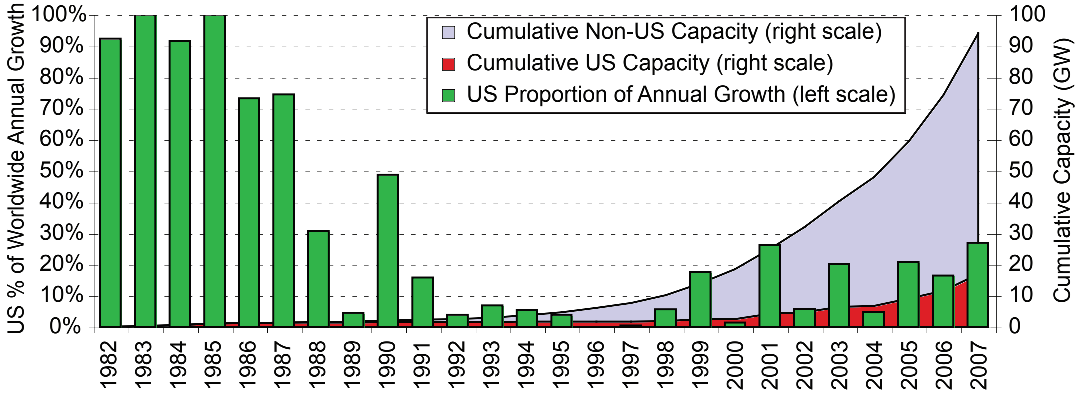
Incremental Capacity (2007, MW)		Cumulative Capacity (end of 2007, MW)	
U.S.	**5,329**	Germany	22,277
China	3,287	**U.S.**	**16,904**
Spain	3,100	Spain	14,714
Germany	1,667	India	7,845
India	1,617	China	5,875
France	888	Denmark	3,088
Italy	603	Italy	2,721
Portugal	434	France	2,471
U.K.	427	U.K.	2,394
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.

2 Given the relatively low capacity factor of wind, one might initially expect that wind's percentage contribution on an *energy* basis would be lower than on a *capacity* basis. This is not necessarily the case, in part because even though combined-cycle gas plants can be operated as baseload facilities with high capacity factors, those facilities are often run as intermediate plants with capacity factors that are not dissimilar from that of wind. Combustion turbine facilities run at even lower capacity factors.

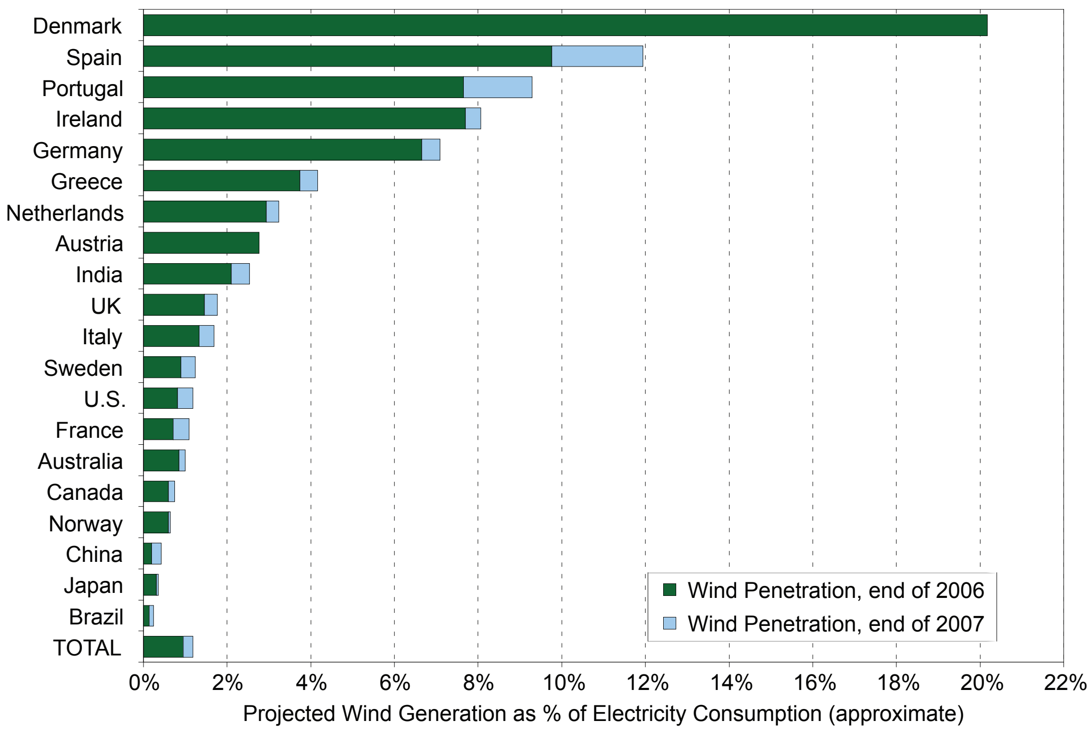
3 Yearly and cumulative installed wind capacity in the United States are from AWEA, while global wind capacity comes from BTM Consult (but updated with the most recent AWEA data for the United States) and, for earlier years, from the Earth Policy Institute. Modest disagreement exists among these data sources and others, e.g., *Windpower Monthly* and the Global Wind Energy Council.

4 In terms of actual 2007 deliveries, wind represented 0.77% of net electricity generation in the United States, and roughly 0.72% of national electricity consumption. These figures are below the 1.2% figure provided above because 1.2% is a projection based on end-of-year 2007 wind capacity.



Source: Earth Policy Institute, BTM Consult, AWEA.

Figure 3. The United States' Contribution to Global Wind Capacity



Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere.

Figure 4. Approximate Wind Power Penetration in the Twenty Countries with the Greatest Installed Wind Capacity

Texas Easily Exceeded Other States in Annual Capacity Growth

New large-scale[5] wind turbines were installed in 18 states in 2007. Texas dominated in terms of new capacity, with 1,708 MW installed in 2007 alone. As shown in Table 2 and Figure 5, other leading states in terms of new capacity include Colorado, Illinois, Oregon, Minnesota, Washington, and Iowa. Ten states added more than 100 MW each.

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. Following Texas are California, Minnesota, Iowa, Washington, and Colorado. Sixteen states had more than 100 MW of wind capacity as of the end of 2007, with nine topping 500 MW. Although all wind projects in the United States to date have been sited on land, offshore development activities continued in 2007, though not without some tribulations (see *Offshore Wind Development Activities*, page 9).

Some states are beginning to realize relatively high levels of wind penetration. Table 2 lists the top-20 states based on an estimate of wind generation from end-of-2007 wind capacity,

[5] "Large-scale" turbines are defined consistently with the rest of this report—over 50 kW.

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.

divided by total in-state generation in 2007.[6] By this (somewhat-contrived) metric, two Midwestern states lead the list in terms of estimated wind power as a percentage of total in-state generation. Specifically, wind capacity installed as of the end of 2007 is estimated, in an average year, to generate approximately 7.5% of all in-state electricity generation in both Minnesota and Iowa. Four additional states—Colorado, South Dakota, Oregon, and New Mexico—surpass the 4% mark by this metric, while thirteen states exceed 2%.

Some utilities are achieving even higher levels of wind penetration into their individual electric systems. Table 3 lists the top-20 utilities in terms of aggregate wind capacity on their systems at the end of 2007, based on data provided by AWEA. Included here are wind projects either owned by or under long-term contract with these utilities for use by their own customers; short-term renewable electricity and renewable energy certificate contracts are excluded. The table also lists the top-20 utilities based on an estimate of the percentage of retail sales that wind generation represents, using end-of-2007 wind capacity and wind capacity factors that are consistent with the state or region in which these utilities operate, and EIA-provided aggregate retail electricity sales for each utility in 2006.[7] As shown, three of the listed utility systems are estimated to have achieved in excess of 10% wind penetration based on this metric, while 15 utilities are estimated to have exceeded 5%.

6 To estimate these figures, end-of-2007 wind capacity is translated into estimated annual wind electricity production based on state-specific capacity factors that derive from the project performance data reported later in this report. The resulting state-specific wind production estimates are then divided by the latest data on total in-state electricity generation available from the EIA (i.e., 2007). The resulting wind penetration estimates shown in Table 2 differ from what AWEA provided in its Annual Rankings Report. The most significant source of these differences is that AWEA estimates wind generation based on end-of-2006 wind capacity, while this report uses end-of-2007 capacity. In addition, Berkeley Lab uses state-specific wind capacity factor assumptions that differ from those applied by AWEA.

7 A variety of caveats deserve note with respect to these calculations. First, the utility-specific capacity data that AWEA released in its *Annual Ranking Report* are assumed accurate, and are used without independent verification. Second, only utilities with 50 MW or more of wind capacity are included in the calculation of wind as a proportion of retail sales. Third, projected wind generation based on each utility's installed wind capacity at the end of 2007 is divided by the aggregate national retail sales of that utility in 2006 (which is the latest full year of utility-specific retail sales data provided by EIA). Fourth, in the case of generation and transmission (G&T) cooperatives and power authorities that provide power to other cooperatives and municipal utilities (but do not directly serve retail load themselves), 2006 retail sales from the electric utilities served by those G&T cooperatives and power authorities are used. In some cases, these individual utilities may be buying additional wind power directly from other projects, or may be served by other G&T cooperatives or power authorities that supply wind. In these cases, the penetration percentages shown here may be understated (or at least somewhat misleading). As an example, the "MSR Public Power Agency" (MSR) is a joint powers agency created to procure power for municipal utilities in the California cities of Modesto, Santa Clara, and Redding. The 200 MW of wind capacity associated with MSR in the first column of Table 3 (and the corresponding 8.4% penetration rate shown in the second column) represents MSR's power purchase agreement with the Big Horn wind project in Washington state. However, two of the three municipal utilities participating in MSR purchase additional wind power from California wind projects. The result is that if one were to look at these three municipal utilities individually rather than as a group through MSR, their penetration rates would be considerably higher than the 8.4% shown in Table 3, and all three utilities would be at the top of the rankings: Redding would be roughly 24.2%, Santa Clara 12.3%, and Modesto 11.8%. Finally, some of the entities shown in Table 3 are wholesale power marketing companies that are affiliated with electric utilities. In these cases, estimated wind generation is divided by the retail sales of the power marketing company and any affiliated electric utilities.

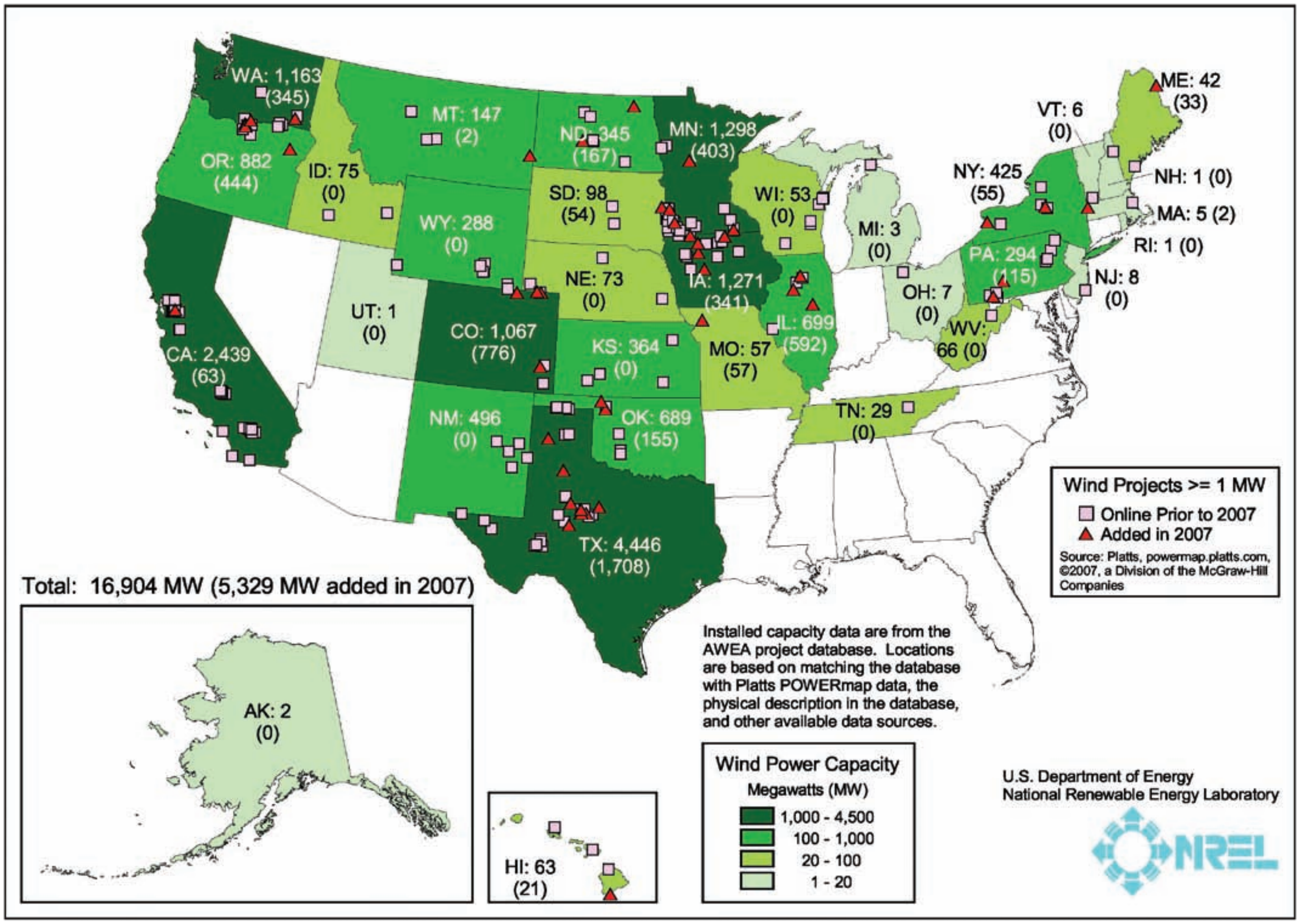


Figure 5. Location of Wind Power Development in the United States

Table 3. Top 20 Utility Wind Power Rankings

Total Wind Capacity (end of 2007, MW)		Estimated Percentage of Retail Sales (for utilities with > 50 MW of wind)	
Xcel Energy	2,635	Minnkota Power Cooperative	11.2%
MidAmerican Energy	1,201	Empire District Electric Company	10.2%
Southern California Edison	1,026	Last Mile Electric Cooperative	10.0%
Pacific Gas & Electric	878	Xcel Energy	9.3%
Luminant	704	MSR Public Power Agency	8.4%
American Electric Power	543	Public Service New Mexico	7.5%
CPS Energy	501	Oklahoma Municipal Power Authority	7.2%
Puget Sound Energy	428	CPS Energy	7.1%
Alliant Energy	378	Northwestern Energy	7.0%
Exelon Energy	342	Austin Energy	6.6%
Austin Energy	274	Otter Tail Power	6.4%
Portland General Electric	225	Great River Energy	6.3%
Great River Energy	218	Nebraska Public Power District	6.0%
Last Mile Electric Cooperative	205	Puget Sound Energy	5.2%
Public Service New Mexico	204	Seattle City Light	5.0%
MSR Public Power Agency	200	MidAmerican Energy	4.7%
Reliant Energy	199	Alliant Energy	4.2%
Seattle City Light	175	Western Farmers' Electric Cooperative	3.8%
Oklahoma Gas & Electric	170	Luminant Energy	3.6%
Empire District Electric Company	150	Minnesota Power	3.5%

Source: AWEA, EIA, Berkeley Lab estimates.

Offshore Wind Development Activities

In Europe, two offshore wind projects, totaling 200 MW, were installed in 2007, bringing total worldwide offshore wind capacity to 1,077 MW. In contrast, all wind projects built in the United States to date have been sited on land. Despite the slow pace of offshore activity, there is some interest in offshore wind in several parts of the United States due to the proximity of offshore wind resources to large population centers, advances in technology, and potentially superior capacity factors. The table on the right provides a listing, by state, of "active" offshore project proposals in the United States as of the end of 2007. Note that these projects are in various stages of development, and a number are either very early-stage proposals or reflect projects that are already in jeopardy of cancellation; clearly, considerable subjectivity is required in creating this list of "active" proposals.

State	Proposed Offshore Wind Capacity
Massachusetts	783 MW
Delaware	450 MW
New Jersey	350 MW
New York	160 MW
Texas	150 MW
Ohio	20 MW
Georgia	10 MW
TOTAL	**1,923 MW**

Source: NREL.

Several events in 2007 demonstrate that progress continues with offshore wind in the United States. Specifically, New Jersey issued a solicitation to provide financial incentives for an offshore wind project up to 350 MW in size, Ohio commissioned a study to investigate the feasibility of a 20-MW wind project in Lake Erie, the Texas General Land Office awarded the first four competitively bid leases for offshore wind power in the nation's history, and the municipal utility serving the town of Hull, Massachusetts filed for (and in February 2008, received) initial state approval for four offshore turbines. More recently, Rhode Island has also issued an RFP for offshore wind. Also in 2007, the Draft Environmental Impact Statement for the highly publicized Cape Wind project in Massachusetts reached conclusions favorable to the project, and the U.S. Minerals Management Service made progress in executing its offshore wind regulatory responsibilities.

Notwithstanding these developments, regulatory delays, turbine supply shortages, high and uncertain project costs, and public acceptance concerns have hampered progress in the offshore wind sector. In 2007 alone, for example, concerns about the high costs of offshore wind resulted in the cancellation of a 500-MW Texas project and the likely cancellation of a 150-MW New York facility, and put a 450-MW Delaware project in jeopardy (the latter two projects are included in the table on the right, as they remain at least somewhat "active").

Data from Interconnection Queues Demonstrate that an Enormous Amount of Wind Capacity Is Under Development

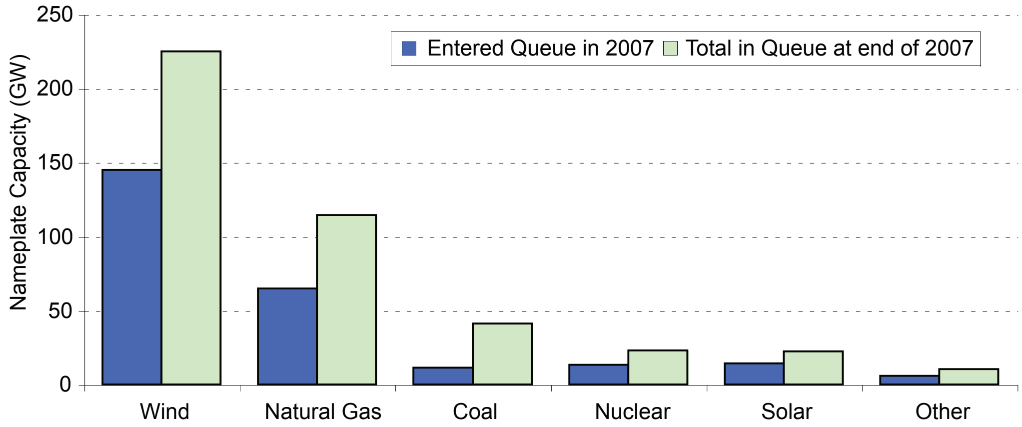
One visible testament to the surging interest in wind is the amount of wind power capacity currently working its way through the major interconnection queues across the country. Figure 6 provides this information, for wind and other resources, aggregated across eleven wind-relevant independent system operators (ISOs), regional transmission organizations (RTOs), and utilities.[8] These data should be interpreted with caution: though placing a project in the interconnection queue is a necessary step in project development, being in the queue does not guarantee that a project will actually be built. In fact, there is a growing recognition that many of the projects currently in interconnection queues are very early in the development process, and that a large number of these projects are unlikely to achieve commercial operations any time soon, if at all.[9]

Even with this important caveat, the amount of wind capacity in the nation's interconnection queues is astounding, and provides some indication of the number and capacity of projects that are in the planning phase. At the end of 2007, there were 225 GW of wind power capacity within the eleven interconnection queues reviewed for this report—more than 13 times the installed wind capacity in the United States at the end of 2007. 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). Moreover, wind's prominent position is a relatively recent phenomenon: 64% of the total wind capacity in these eleven queues at the end of 2007 first entered the queue in 2007 (for the non-wind projects, in aggregate, the comparable figure is 52%).

Much of this wind capacity is planned for the Midwest, Texas, and PJM regions: wind in the interconnection queues of MISO (66 GW), ERCOT (41 GW), and PJM (35 GW) account for nearly two-thirds of the aggregate 225 GW of wind in all eleven queues. At the other end of the spectrum, the Northeast exhibits the least amount of wind capacity in the pipeline, with the New York ISO (7 GW) and ISO-New England (2 GW) together accounting for about 4% of the aggregate 225 GW. The remaining six queues include SPP (21 GW), California ISO (19 GW), WAPA (10 GW), BPA (10 GW), PacifiCorp (9 GW), and Xcel's Colorado service area (4 GW).

8 The queues surveyed include PJM Interconnection, Midwest Independent System Operator (MISO), New York ISO, ISO-New England, California ISO, Electricity Reliability Council of Texas (ERCOT), Southwest Power Pool (SPP), Western Area Power Administration (WAPA), Bonneville Power Administration (BPA), PacifiCorp, and Xcel Energy (Colorado). To provide a sense of sample size and coverage, roughly 60% of the total installed generating capacity (both wind and non-wind) in the United States is located within these ISOs, RTOs, and utility service territories. Figure 6 only includes projects that were active in the queue at the end of 2007 but that had not yet been built; suspended projects are not included.

9 FERC held a technical conference in November 2007 focusing on the burgeoning interconnection queues and potential reforms.



Source: Exeter Associates review of interconnection queues.

Figure 6. Nameplate Resource Capacity in Eleven Major Interconnection Queues

GE Wind Remained the Dominant Turbine Manufacturer, but a Growing Number of Other Manufacturers Are Capturing Market Share

GE Wind remained the dominant manufacturer of wind turbines supplying the U.S. market in 2007, with 44% of domestic turbine installations (down from 47% in 2006 and 60% in 2005).[10] Vestas (18%) and Siemens (16%) vied for second place in 2007, with Gamesa (11%), Mitsubishi (7%), and Suzlon (4%) playing significant, but lesser, roles (Figure 7).

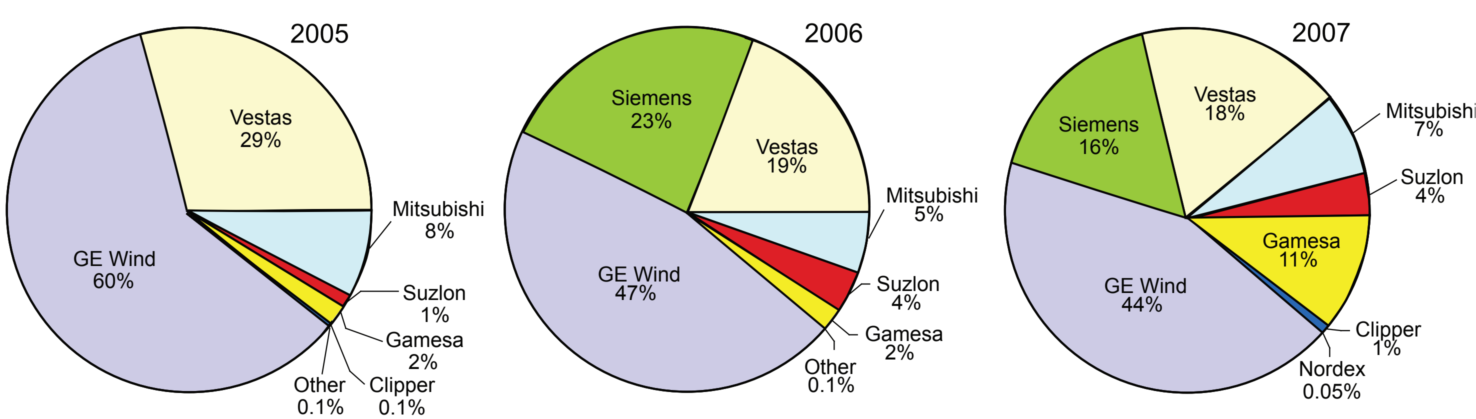
Noteworthy developments in 2007 include the growth in Gamesa's market share, from just 2% in 2005 and 2006 to 11% in 2007, and Siemens' loss of market share after a banner year in 2006. Also significant is that newcomer Clipper installed 48 MW in New York, Illinois, and Iowa in 2007, marking the start of serial production of that firm's 2.5-MW "Liberty" turbine. Nordex also re-entered the U.S. market in 2007, after a several-year hiatus, with 2.5 MW installed in Minnesota. Interestingly, though not reflected in the data shown here, U.S. developer GreenHunter announced in late 2007 an order for 108 1.5-MW Chinese-made turbines from Mingyang Wind Power Technology, for delivery in 2008.

Table 4. Annual Turbine Installations, by Manufacturer

Manufacturer	Turbine Installations (MW)		
	2005	2006	2007
GE Wind	1,433	1,146	2,342
Vestas	700	463	948
Siemens	0	573	863
Gamesa	50	50	574
Mitsubishi	190	128	356
Suzlon	25	92	197
Clipper	2.5	0	47.5
Nordex	0	0	2.5
Other	2	2	0
TOTAL	**2,402**	**2,454**	**5,329**

Source: AWEA project database.

Market share, delineated in percentage terms, can be misleading in rapidly growing markets. As shown in Table 4, every manufacturer active in the U.S. market saw installations of their turbines grow between 2006 and 2007, in many cases dramatically. The most significant growth was experienced by GE (1,196 MW), Gamesa (524 MW), and Vestas (485 MW).



Source: AWEA project database.

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

10 Market share reported here is in MW terms, and is based on project installations—not turbine shipments or orders—in the year in question.

Soaring Demand for Wind Spurs Expansion of U.S. Wind Turbine Manufacturing

The manufacturing of wind turbines and components in the United States remains somewhat limited, in part because of the continued uncertain availability of the federal PTC. As domestic demand for wind turbines continues to surge, however, a growing number of foreign turbine and component manufacturers have begun to localize operations in the United States, and manufacturing by U.S.-based companies is starting to expand.

Figure 8 presents a (non-exhaustive) list of domestic wind turbine and component manufacturing facilities announced or opened in 2007, and identifies the location of those facilities as well as the location of manufacturing facilities that opened prior to 2007. Included in the figure are not only turbine assembly and component manufacturing facilities, but also facilities that meet the needs of other segments of the wind industry's supply chain, such as wind project construction companies, anemometer suppliers, and crane and rigging providers.

Among the list of facilities opened or announced in 2007 are three owned by major international turbine manufacturers: Vestas (blades in Windsor, Colorado), Acciona (turbine assembly in West Branch, Iowa), and Siemens (blades in Fort Madison, Iowa).[11] Vestas is also known to be exploring sites for a U.S. R&D center. These plants are in addition to facilities opened by several other international turbine manufacturers in previous years, including: Gamesa (blades, towers, and nacelle assembly in Ebensburg and Fairless Hills, Pennsylvania), Suzlon (blades and nose cones in Pipestone, Minnesota), and Mitsubishi (gearboxes in Lake Mary, Florida).

Among U.S.-based wind turbine manufacturers, GE remains dominant, and has maintained a significant domestic turbine manufacturing presence, in addition to its international facilities that serve both the U.S. and global markets. GE's wind turbine manufacturing facilities in the United States include Tehachapi, California (turbine manufacturing); Pensacola, Florida (blade technology development, component assembly); Erie, Pennsylvania and Salem, Virginia (components); and Greenville, South Carolina (turbine assembly).

Signaling the emergence of new players in the U.S. wind turbine industry, three other U.S.-based turbine manufacturers continued to scale-up their activities in 2007.

- **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 Cedar Rapids, 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 Round Rock, 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 Berkeley, California, and in early 2008 announced the location of a planned manufacturing facility in Pocatello, Idaho.

Figure 8 also shows a considerable number of new component manufacturing facilities announced or opened in 2007, from both

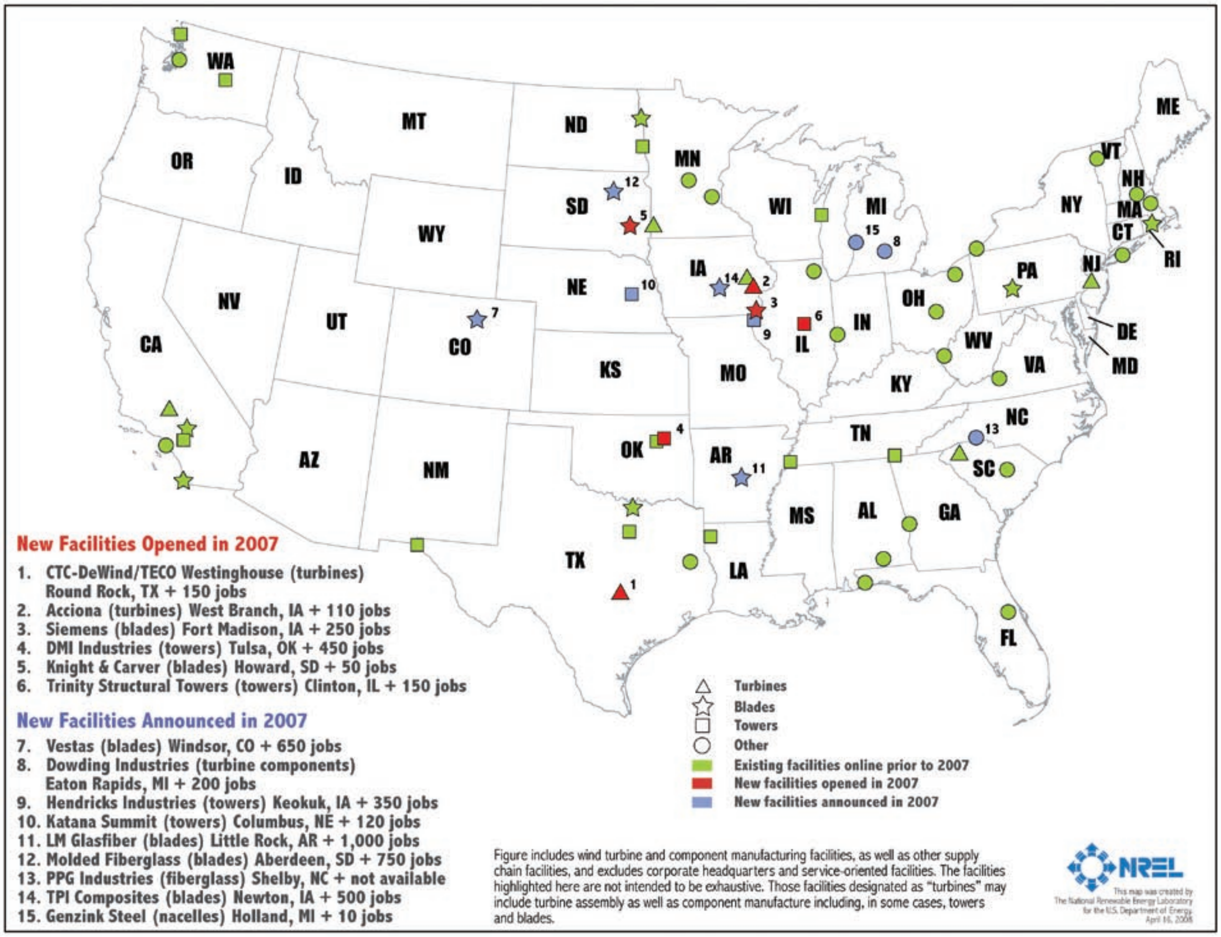


Figure 8. Location of Existing and New Wind Manufacturing Facilities

[11] In addition, in 2008, Fuhrlander announced its decision to build a turbine assembly plant in Butte, Montana, with an expected 150 jobs.

foreign and domestic firms. All told, the new turbine and component manufacturing facilities opened or announced in 2007 and listed in Figure 8 will, if fully implemented as planned, create more than 4,700 jobs.

Notwithstanding the generally positive outlook for the turbine manufacturing sector, however, impediments faced by manufacturers due to rapid scale-up are apparent. Clipper Windpower, for example, has had to reinforce some blades, and has experienced problems with some of its drivetrains, slowing shipments in 2007. Blade quality and tower manufacturing problems also surfaced at Gamesa's Pennsylvania manufacturing facilities in 2007 and early 2008; Suzlon has also recently faced blade problems. Turbine manufacturing by CTC/DeWind, meanwhile, has faced some delay, at least relative to that company's initial expectations.

Average Turbine Size Continued to Grow, Albeit at a Slower Pace

The average size of wind turbines installed in the United States in 2007 increased to roughly 1.65 MW (Figure 9), from 1.60 MW in 2006. Since 1998-99, average turbine size has increased by 130%.[12]

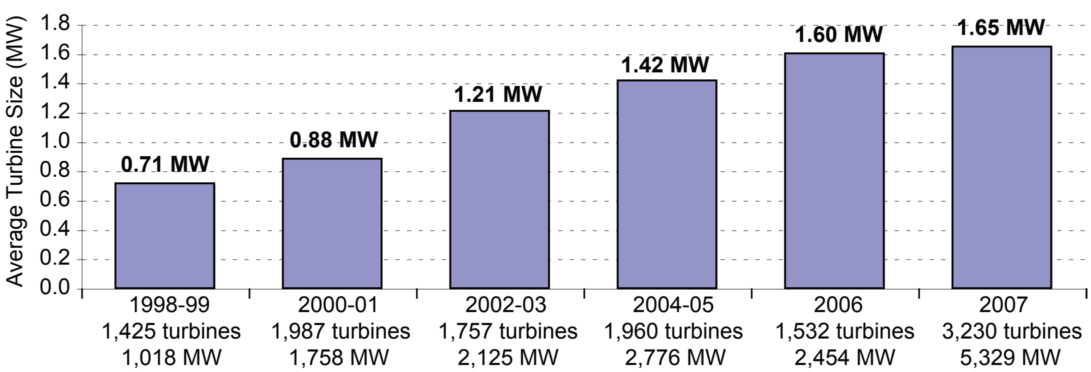
Table 5 shows how the distribution of turbine size has shifted over time; 40% of all turbines installed in 2007 had a nameplate capacity in excess of 1.5 MW, compared to 34% in 2006, 24% in 2004-2005, and 13% in 2002-2003. GE's 1.5-MW wind turbine remained by far the nation's most-popular turbine in 2007, with more than 1,500 units installed.

The Average Size of Wind Projects Expanded Significantly

As the U.S. wind industry has matured and installations have increased, so too has the average size of installed wind projects. Projects installed 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.[13]

This marked increase in average project size may reflect a number of interrelated trends highlighted elsewhere in this report: growing demand for wind driven by economics and policy; the upward march in turbine size; the large turbine orders that have become standard practice; consolidation among wind project developers to support these orders; and increasing turbine and project costs, which may require taking full advantage of any and all economies of scale. Whatever the specific cause, larger project sizes reflect an increasingly mature energy source that is beginning to penetrate into the domestic electricity market in a significant way.

Taking this trend towards larger project size to a new level, several gigawatt-scale projects were announced in 2007. In Texas, Shell WindEnergy and Luminant are jointly planning a 3,000-MW wind project, while oilman T. Boone Pickens announced plans for a project of up to 4,000 MW. While these projects should be considered speculative at this early stage, a 1,500-MW wind project being developed by Allco and Oak Creek Energy Systems in Tehachapi, California, has already secured a power purchase agreement with Southern California Edison.



Source: AWEA project database.

Figure 9. Average Turbine Size Installed During Period

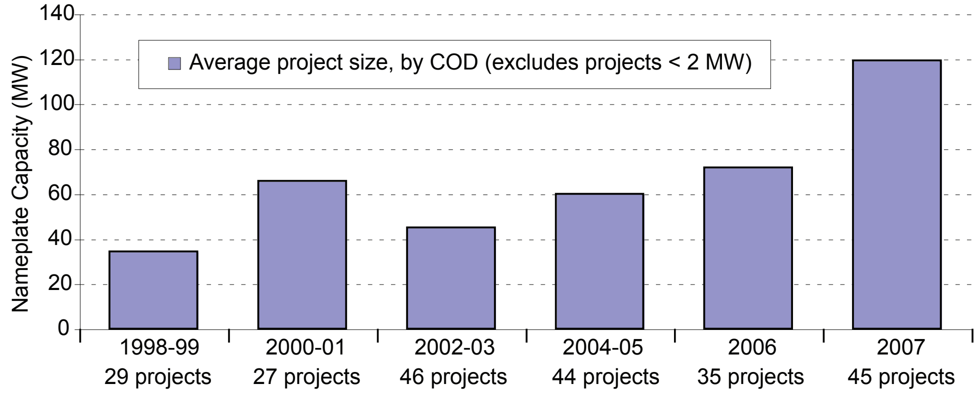
Table 5. Size Distribution of Number of Turbines Over Time

Turbine Size Range	1998-99	2000-01	2002-03	2004-05	2006	2007
	1,018 MW	1,758 MW	2,125 MW	2,776 MW	2,454 MW	5,329 MW
	1,425 turbines	1,987 turbines	1,757 turbines	1,960 turbines	1,532 turbines	3,230 turbines
0.05-0.5 MW	1.3%	0.4%	0.5%	1.8%	0.7%	0.0%
0.51-1.0 MW	98.5%	73.9%	43.4%	18.5%	10.7%	11.0%
1.01-1.5 MW	0.0%	25.4%	43.5%	56.0%	54.2%	48.6%
1.51-2.0 MW	0.3%	0.4%	12.5%	23.6%	17.6%	24.1%
2.01-2.5 MW	0.0%	0.0%	0.0%	0.1%	16.3%	15.0%
2.51-3.0 MW	0.0%	0.0%	0.1%	0.0%	0.5%	1.3%

Source: AWEA project database.

12 Except for 2006 and 2007, Figure 9 (as well as a number of the other figures and tables included in this report) combines data into two-year periods in order to avoid distortions related to small sample size in the PTC lapse years of 2000, 2002, and 2004. Though not a PTC lapse year, 1998 sample size is also small, and is therefore combined with 1999.

13 Projects less than 2 MW in size are excluded from Figure 10 so that a large number of single-turbine "projects" (that, in practice, may have been developed as part of a larger, aggregated project) do not end up skewing the average. For projects defined in phases, each phase is considered to be a separate project. Projects that are partially constructed in two different years are counted as coming online in the year in which a clear majority of the capacity was completed. If roughly equal amounts of capacity are built in each year, then the full project is counted as coming online in the later year.



Source: Berkeley Lab analysis of AWEA project database.

Figure 10. Average Project Size, by Commercial Operation Date (COD)

Developer Consolidation Continued at a Torrid Pace

Consolidation on the development end of the wind business continued the strong trend that began in 2005, and has been motivated, in part, by the increased globalization of the wind sector and the need for capital to manage wind turbine supply constraints. Table 6 provides a listing of major acquisition and investment activity among U.S. wind developers in the 2002 through 2007 timeframe.[14]

As shown, at least 11 significant transactions involving roughly 37,000 MW of in-development wind projects (also called the development "pipeline") were announced in 2007, consistent with 2006 acquisition and investment activity of 12 transactions with a total 34,000 MW in the pipeline. In 2005, eight transactions totaling nearly 12,000 MW were announced, while only four transactions totaling less than 4,000 MW were completed from 2002 through 2004.

A number of large companies have entered the U.S. wind development business in recent years, some through acquisitions, and others through their own development activity or through joint development agreements with others. Particularly striking in recent years has been the entrance of large European energy companies into the U.S. market. The two largest 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.

Table 6. Acquisition and Investment Activity Among Wind Developers*

Investor	Transaction Type	Developer	Announced
EDF (SIIF Energies)	Acquisition	enXco	May-02
Gamesa	Investment	Navitas	Oct-02
AES	Investment	US Wind Force	Sep-04
PPM (Scottish Power)	Acquisition	Atlantic Renewable Energy Corp.	Dec-04
AES	Acquisition	SeaWest	Jan-05
Goldman Sachs	Acquisition	Zilkha (Horizon)	Mar-05
JP Morgan Partners	Investment	Noble Power	Mar-05
Arclight Capital	Investment	CPV Wind	Jul-05
Diamond Castle	Acquisition	Catamount	Oct-05
Pacific Hydro	Investment	Western Wind Energy	Oct-05
EIF U.S. Power Fund II	Investment	Tierra Energy, LLC	Dec-05
Airtricity	Acquisition	Renewable Generation Inc.	Dec-05
Babcock & Brown	Acquisition	G3 Energy LLC	Jan-06
Iberdrola	Acquisition	Community Energy Inc.	Apr-06
Shaw/Madison Dearborn	Investment	UPC Wind	May-06
NRG	Acquisition	Padoma	Jun-06
CPV Wind	Acquisition	Disgen	Jul-06
BP	Investment	Clipper	Jul-06
BP	Acquisition	Greenlight	Aug-06
Babcock & Brown	Acquisition	Superior	Aug-06
Enel	Investment	TradeWind	Sep-06
Iberdrola	Acquisition	Midwest Renewable Energy Corp.	Oct-06
Iberdrola	Acquisition	PPM (Scottish Power)	Dec-06
BP	Acquisition	Orion Energy	Dec-06
Naturener	Acquisition	Great Plains Wind & Energy, LLC	Feb-07
HSH Nordbank	Investment	Ridgeline Energy	Feb-07
Energias de Portugal	Acquisition	Horizon	Mar-07
Iberdrola	Acquisition	CPV Wind	Apr-07
Duke Energy	Acquisition	Tierra Energy, LLC	May-07
Acciona	Acquisition	EcoEnergy, LLC	Jun-07
Babcock & Brown	Acquisition	Bluewater Wind	Sep-07
Good Energies	Investment	EverPower	Sep-07
E.ON AG	Acquisition	Airtricity North America	Oct-07
Wind Energy America	Acquisition	Boreal	Oct-07
Marubeni	Investment	Oak Creek Energy Systems	Dec-07

* Select list of announced transactions; excludes joint development activity.
Source: Berkeley Lab.

14 Only transactions that are known to involve 500 MW or more of in-development wind projects are included.

Comfort With and Use of Innovative Financing Structures Increased

A variety of innovative financing structures have been developed by the U.S. wind industry in recent years to allow projects to fully access federal tax incentives. The two most common structures at the present time are corporate balance-sheet finance (e.g., historically used by FPL Energy) and the "institutional investor flip" structure involving institutional "tax equity" investors.[15] With the record-shattering amount of new wind capacity installed in 2007 and the growing presence of foreign developers and owners with little appetite for U.S. tax incentives,[16] the need to attract institutional tax equity to the U.S. wind sector has never been greater. The past year has brought both good and bad news on this front.

The wind industry received welcome news in October 2007, when the IRS issued "safe harbor" guidelines (i.e., Revenue Procedure 2007-65) for wind projects utilizing special-allocation partnership flip structures. Although various permutations of these types of structures have been used for a number of years to monetize the tax benefits provided to wind projects, tax equity investors have had to absorb the risk that these deals would be challenged by the IRS. Revenue Procedure 2007-65 effectively removed this structural tax risk for projects that adhere to the prescribed investment and allocation limits, and has, through numerical example, legitimized the institutional investor flip structure.[17]

Comfort with this structure has grown to the point where even FPL Energy—which has financed the largest fleet of wind projects in the United States primarily on its balance sheet—conducted its first ever project refinancing using third-party tax equity in late 2007. While this event sparked rumors that the U.S. wind giant was running out of tax credit appetite, FPL's own explanation is more benign: the institutional investor flip structure allows FPL to focus on its core strengths—developing and operating wind projects—while capitalizing on the relatively lower cost of institutional tax equity (pre-flip) and retaining long-term upside potential (post-flip).

The year 2007 also saw the closing of a first-of-its-kind tax equity structure suitable for municipalities and cooperatives interested in long-term wind project ownership. The 205-MW White Creek Wind project was developed by four publicly owned, tax-exempt utilities in the Pacific Northwest, in cooperation with several institutional tax investors. By serving as power purchasers and pre-paying (up-front) for the minimum projected electricity output of the project over its initial 20 years of project operations, these four publicly owned utilities effectively enabled the project to take advantage of low-cost tax-exempt debt (used to finance the pre-payments) as well as the traditional tax benefits afforded to wind projects (available to the institutional tax investors). A post-flip buyout option allows for long-term ownership by the publicly owned utilities.

Although institutional tax investors were plentiful in 2007, with more than a dozen active in the market,[18] the growing dependence on such third-party investors has left the U.S. wind sector vulnerable to the broader credit crisis that began in earnest towards the end of 2007. As a result of the large losses incurred by the banking industry, institutional tax investors have less taxable income to shelter. This shortage is already being felt in the affordable housing sector—one of the wind sector's main competitors for tax equity—where the yields on affordable housing credits have been driven sharply higher by lack of demand.

It remains to be seen whether lackluster tax investor demand will spill over into the wind sector, but at the very least it seems unlikely that the cost of tax equity provided to wind projects will continue to fall in 2008. This is particularly notable because the sizable decline in the cost of tax equity over the past four or five years has partially offset (by roughly 45%, according to Berkeley Lab analysis) the impact of rising turbine and installed project costs on wind power prices. To the extent that the cost of tax equity has bottomed out or begins to rise, any further project cost increases will be felt more immediately and severely in wind power prices.

Finally, project-level debt staged a comeback of sorts in 2007, with a number of projects announcing the use of term (as opposed to just construction) debt, even alongside institutional tax equity (this combination of term debt and tax equity has heretofore been quite rare), and in some cases, in quasi-merchant wind projects. One such deal involved three projects in New York State (scheduled for completion in 2008), aggregated into a single debt facility by the project sponsor. Other deals have featured increasingly aggressive terms, with debt providers willing to extend maturities 5 years or more into a project's "merchant tail" (i.e., the period beyond which the project's power sales have been contracted), and at least one deal featuring a 20-year loan term (including a 5-year merchant tail).

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15 For more information on these and other structures, see *Wind Project Financing Structures: A Review & Comparative Analysis*, downloadable from http://eetd.lbl.gov/ea/ems/reports/63434.pdf.

16 In a telling move, Spanish wind giant Iberdrola announced in June 2007 that it intended to buy Energy East—an investor-owned utility holding company in the Northeastern United States—in part to generate U.S. income tax liability that would better enable it to use the production tax credits and depreciation deductions generated by its U.S. wind project investments.

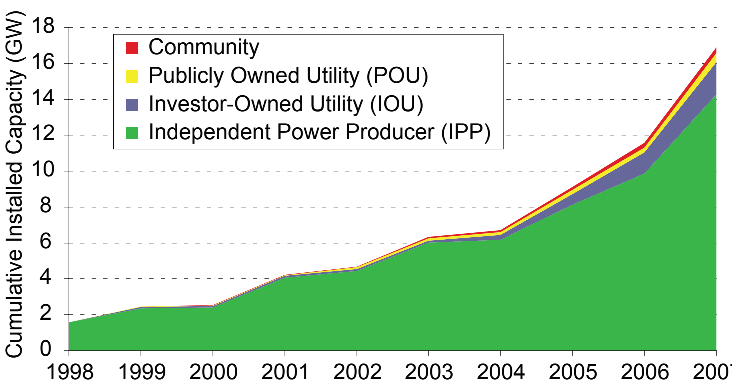
17 In contrast to its favorable implications for the institutional investor flip structure, Revenue Procedure 2007-65 is less-favorable to the pay-as-you-go (PAYGO) structure, under which the tax investor injects equity into the project over time, but only as PTCs are generated. Specifically, the Revenue Procedure limits the amount of PTC-contingent equity to 25% of the total anticipated tax equity (prior to the Revenue Procedure, the general assumption was that up to 50% of the tax equity could be PTC-contingent).

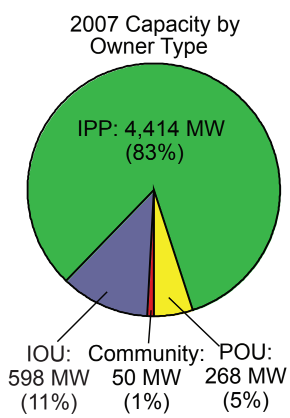
18 Institutional tax investors active in the wind market include GE Financial Services, JP Morgan Capital, Morgan Stanley, Lehman Brothers, Fortis Capital, Wachovia, Wells Fargo, Union Bank of California, Prudential Capital, Northwestern Mutual, New York Life, Babcock & Brown, Meridian Clean Fuels, and AEGON USA Realty Advisors.

IPP Project Ownership Remained Dominant, but Utility Interest in Ownership Continued, While Community Wind Faltered

Private independent power producers (IPPs) continued to dominate the wind industry in 2007, owning 83% of all new capacity (Figure 11). 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.[19] 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 16,904 MW of installed wind capacity at the end of 2007, IPPs owned 84% (14,280 MW), with utilities contributing 14% (1,790 MW for IOUs and 526 MW for POUs), and community ownership just 2% (308 MW). The community wind sector, in particular, has found it difficult to make much headway in the last couple of years, in part due to the difficulty of securing smaller turbine orders amidst the current turbine shortage. That said, state policies specifically targeting community wind and USDA Section 9006 grants may help boost the community wind numbers in future years.





Source: Berkeley Lab estimates based on AWEA project database.

Figure 11. Cumulative and 2007 Wind Capacity Categorized by Owner Type

Though Long-Term Contracted Sales to Utilities Remained the Most Common Off-Take Arrangement, Merchant Plants and Sales to Power Marketers Are Becoming More Prevalent

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 contracts (see Figure 12). Publicly owned utilities have also taken an active role, purchasing the output of 17% of new 2007 capacity and 15% of cumulative capacity. For both IOUs and POUs, power purchase agreement (PPA) terms for projects built in 2007 range from 15 to 25 years, with 20 years being the most common.

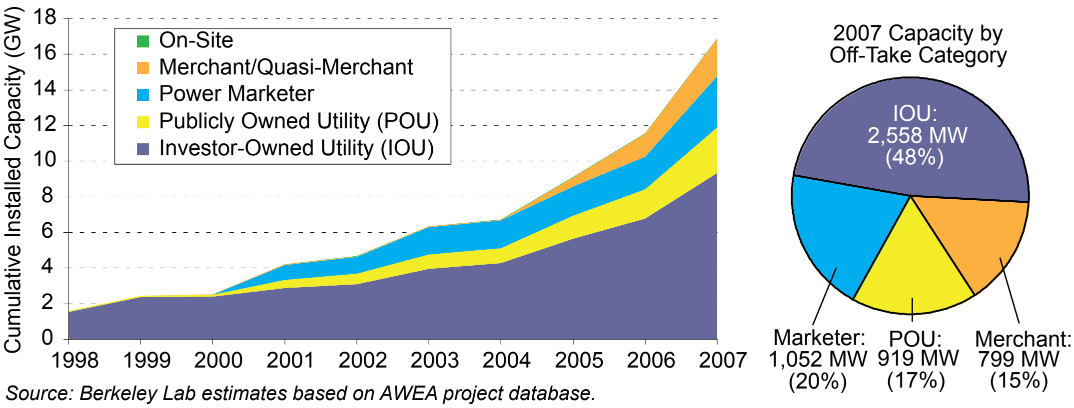
The role of power marketers—defined here as corporate intermediaries that purchase power under contract and then re-sell that power to others, sometimes taking some merchant risk[20]– in the wind power market has increased dramatically since 2000, when such entities first entered the wind sector. In 2007, power marketers purchased the output of 20% of new wind power capacity and 17% of cumulative capacity. Among projects built in 2007, PPAs with power marketers range from 5 to 23 years in length, somewhat shorter than the range of utility PPAs.

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 rather than through PPAs[21]). 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

[19] Compared to the recent past, the growth in publicly owned utility ownership in 2007 is striking. This growth is, arguably, inflated by the categorization of the 205-MW White Creek Wind project as a POU-owned project. Although the four POUs involved with the White Creek project do not technically own any part of the project unless and until they exercise their purchase option (after the project's tenth year), by pre-paying for a substantial portion of the project's power, these utilities have nevertheless contributed roughly half of the capital required to build the project. This, plus the fact that the financing structure is specifically designed to result in long-term POU ownership (through the buyout option), favors the categorization of this project as POU-owned.

[20] Power marketers are defined here to include not only traditional marketers such as PPM Energy, but also the wholesale power marketing affiliates of large investor-owned utilities (e.g., PPL Energy Plus or FirstEnergy Solutions), which may buy wind power on behalf of their load-serving affiliates.

[21] Hedge providers active in the market in 2007 include Fortis, Credit Suisse, Barclay's, J. Aron & Company, and Coral Energy Holding (a division of Shell). These hedges are often structured as a "fixed-for-floating" power price swap—a purely financial arrangement whereby the wind project swaps the "floating" revenue stream that it earns from spot power sales for a "fixed" revenue stream based on an agreed-upon strike price. For at least one project in Texas (where natural gas is virtually always the marginal supply unit), the hedge has been structured in the natural gas market rather than the power market, in order to take advantage of the greater liquidity and longer terms available in the forward gas market.



Source: Berkeley Lab estimates based on AWEA project database.

Figure 12. Cumulative and 2007 Wind Capacity Categorized by Power Off-Take Arrangement

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).

Another interesting development in 2007 was the initiation of cross-border sales of wind electricity into the United States, despite the fact that those facilities are not eligible for U.S. tax incentives. A portion of the West Cape wind project, located in Price Edward Island (New Brunswick), began exporting power and renewable energy certificates (RECs) to New England in mid-2007. Later that year, Hydro-Quebec received permission to sell into New England from two of its wind facilities. Finally, San Diego Gas & Electric announced a 20-year contract with the proposed 250-MW La Rumorosa wind project in Baja, Mexico.

Upward Pressure on Wind Power Prices Continued in 2007

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, and therefore wind power prices, in 2007.

Berkeley Lab maintains a database of wind power sales prices, which currently contains price data for 128 projects installed between 1998 and the end of 2007. These wind projects total 8,303 MW, or 55% of the wind capacity brought on line in the United States over the 1998-2007 period. The prices in this database reflect the price of electricity as sold by the project owner, and might typically be considered busbar energy prices.[22] The prices are suppressed by the receipt of any available state and federal incentives (e.g., the PTC), as well as by the value that might be received through the separate sale of renewable energy certificates (see *REC Markets Remain Fragmented and Prices Volatile*, page 18).[23] The prices reported here would therefore be higher if wind projects did not have access to these state and federal incentives and, as a result, these prices do not represent wind energy generation costs.

Based on this database, the capacity-weighted average power sales price from the sample of post-1997 wind projects remains low by historical standards. Figure 13 shows the cumulative capacity-weighted average wind power price (plus or minus one standard deviation around that price) in each calendar year from 1999 through 2007. Based on the limited sample of seven projects built in 1998 or 1999 and totaling 450 MW, the weighted-average price of wind in 1999 was nearly $63/MWh (expressed in 2007 dollars). By 2007, in contrast, the cumulative sample of projects built from 1998 through 2007 had grown to 128 projects totaling 8,303 MW, with an average price of just under $40/MWh (with the one standard deviation range extending from $24/MWh to $55/MWh).[24] Although Figure 13 does show a modest increase in the weighted-average wind power price in 2006 and 2007, reflecting rising prices from new projects, the cumulative nature of the graphic mutes the degree of increase.

To better illustrate changes in the price of power from newly built wind projects, Figure 14 shows average wind power sales prices in 2007, grouped by each project's initial commercial operation date (COD).[25] Although the limited project sample and the considerable variability in price across projects installed in a given time period complicate analysis of national price trends (with averages subject to regional and other factors), the general trend exhibited by the capacity-weighted-average prices (i.e., the blue columns) nevertheless suggests that, following a general decline since 1998, prices bottomed out for projects built in 2002 and 2003, and have since risen significantly.[26] Given the year-on-year increase in project-level installed costs from 2006 to 2007 (see a later section of this report), however, it comes as some surprise that prices from projects installed in 2007 were, on average, somewhat lower than from projects installed in 2006.

22 These prices will typically include interconnection costs and, in some cases, transmission expansion costs that are needed to ensure delivery of the energy to the purchaser.

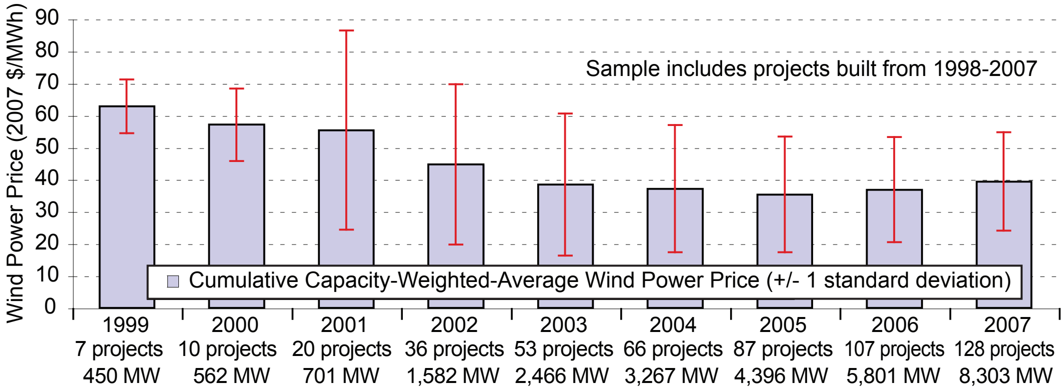
23 For most of the wind power sales prices reported here, the wind generator is selling electricity and RECs in a bundled fashion, and the price reported here therefore reflects the delivery of that bundled product. For at least 10 of the 128 projects in the sample, however, the wind project appears to receive additional revenue (beyond the power price reported) from the separate sale of RECs. The prices provided in this report do not include this separate REC revenue stream, and therefore understate total sales revenue for these projects. Because a minority of projects (10 out of 128) fall in this category, however, this factor is unlikely to significantly bias the overall results presented in this report.

24 All wind power pricing data presented in this report exclude the few projects located in Hawaii. Such projects are considered outliers in that they are significantly more expensive to build than projects in the continental United States, and receive a power sales price that is significantly higher than normal, in part because it is linked to the price of oil. For example, the three major wind projects located in Hawaii (totaling 62 MW) earned revenue in 2007 that ranged from $112/MWh to $177/MWh on average, which is considerably higher than the price received by most wind projects built on the mainland.

25 Prices from two individual projects built during the 2000-2001 period are not shown in Figure 14 (due to the scale of the y-axis), but are included in the capacity-weighted average for that period. The omitted prices are roughly $91/MWh and $150/MWh.

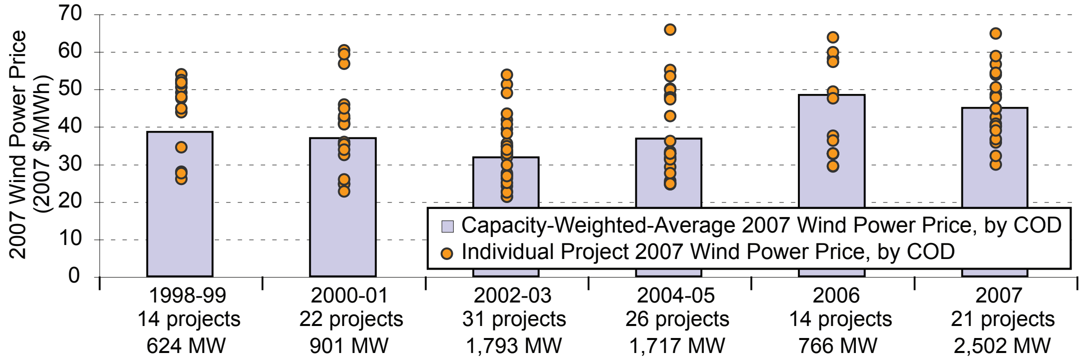
Specifically, the capacity-weighted average 2007 sales price for projects in the sample built in 2007 was roughly $45/MWh (with a range of $30 to $65/MWh).[27] Although this price is (somewhat surprisingly) slightly less than the average of $48/MWh for the sample of projects built in 2006, it is still higher than the average price of $37/MWh for the sample of projects built in 2004 and 2005, as well as the $32/MWh for the sample of projects built in 2002 and 2003. Moreover, because ongoing turbine price increases are not fully reflected in 2007 wind project prices—many of these projects had locked in turbine prices and/or negotiated power purchase agreements as much as 18 to 24 months earlier—prices from projects being built in 2008 and beyond may be higher still.

The underlying variability in the price sample is caused in part by regional factors, which may affect not only project capacity factor (depending on the strength of the wind resource in a given region), but also development and installation costs (depending on a region's physical geography, population density, or even regulatory processes).[28] Figure 15 shows individual project and average 2007 wind power prices by region for just those wind projects installed in 2006 and 2007 (a period of time in which pricing was reasonably consistent), with regions as defined in Figure 16. Although sample size is extremely problematic in numerous regions,[29] Texas and the Heartland region appear to be among the lowest cost on average, while the East, California, and New England are among the higher cost areas.



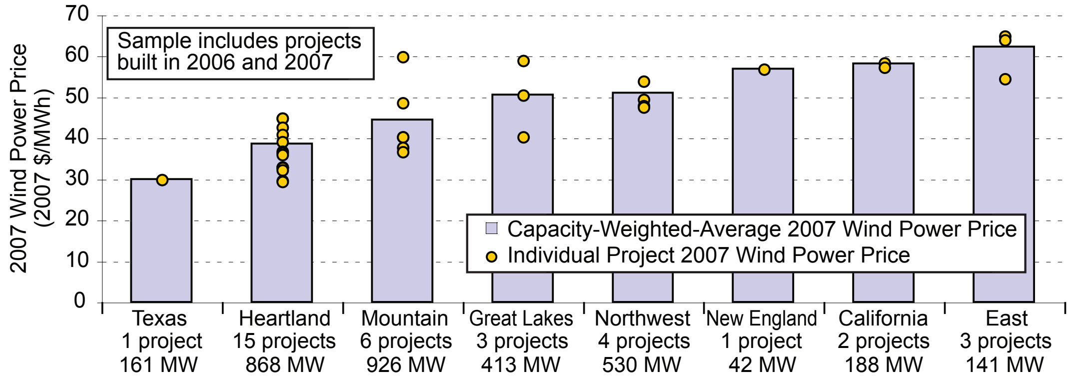
Source: Berkeley Lab database.

Figure 13. Cumulative Capacity-Weighted-Average Wind Power Prices Over Time



Source: Berkeley Lab database.

Figure 14. 2007 Wind Power Prices by Commercial Operation Date (COD)



Source: Berkeley Lab database.

Figure 15. 2007 Wind Power Prices by Region: 2006-2007 Projects Only

26 Although it may seem counterintuitive, the weighted-average price in 1999 for projects built in 1998 and 1999 (shown in Figure 13 to be about $63/MWh) is significantly higher than the weighted-average price in 2007 for projects built in 1998 and 1999 (shown in Figure 14 to be $39/MWh) for three reasons: (1) the sample size is larger in Figure 14, due to the fact that 2007 prices are presented, rather than 1999 prices as in Figure 13 (i.e., we were unable to obtain early-year pricing for some of the projects built in 1998-1999); (2) two of the larger projects built in 1998 and 1999 (for which both 1999 and 2007 prices are available, meaning that these projects are represented within both figures) have nominal PPA prices that actually *decline*, rather than remaining flat or escalating, over time; and (3) inflating all prices to constant 2007 dollar terms impacts older (i.e., 1999) prices more than it does more recent (i.e., 2007) prices.

27 If the federal PTC was not available, wind power prices for 2007 projects would range from approximately $50/MWh to $85/MWh, with an average of roughly $65/MWh.

28 It is also possible that regions with higher wholesale power prices will, in general, yield higher wind contract prices due to arbitrage opportunities on the wholesale market.

29 It may be surprising to some that relatively little pricing data are available for Texas, despite the enormous growth in wind capacity in that state. The reason is simple: because ERCOT is not electrically connected to the remainder of the U.S. grid, generators located within ERCOT are not required to file pricing information with FERC. The pricing information for Texas provided in this report comes primarily from projects located in the Texas panhandle, which is covered by the Southwest Power Pool rather than ERCOT.

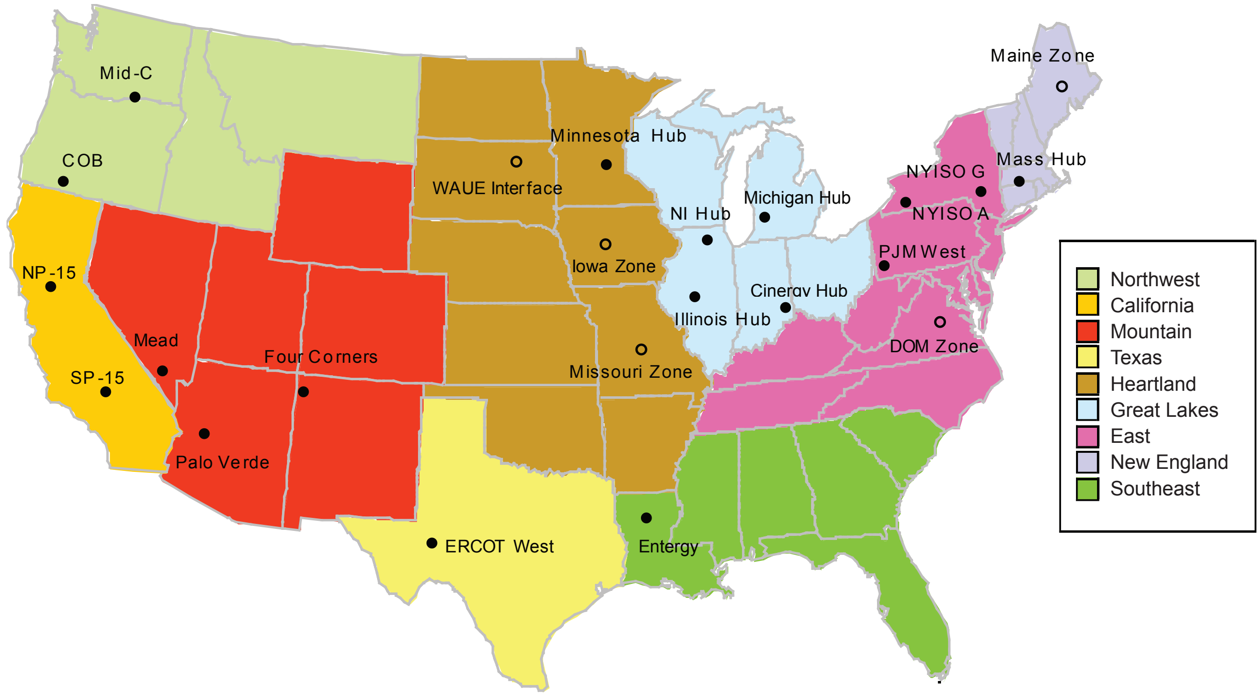


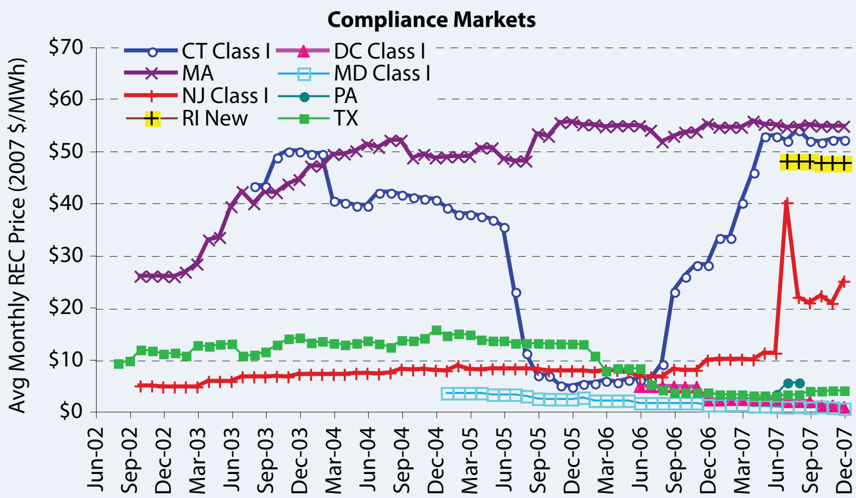
Figure 16. Map of Regions and Wholesale Price Hubs Used in Analysis

REC Markets Remain Fragmented and Prices Volatile

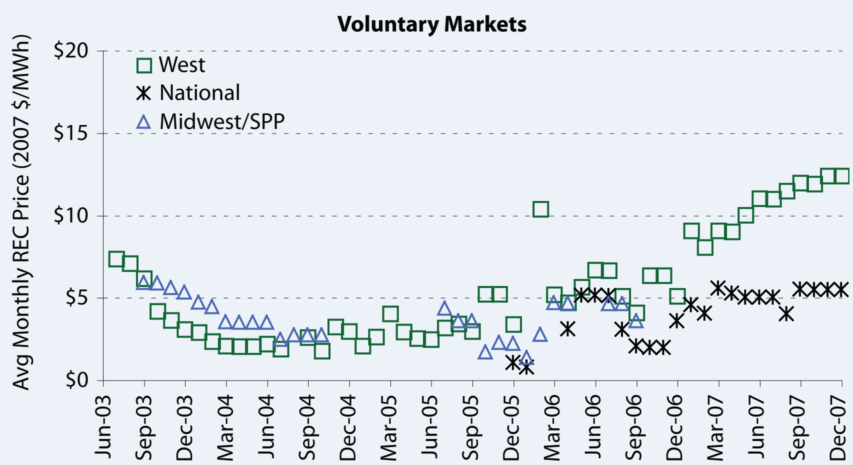
Most of the wind power transactions identified in Figures 13 through 15 reflect the bundled sale of both electricity and RECs, but for at least 10 of these projects, RECs may be sold separately to earn additional revenue. REC markets are highly fragmented in the United States, but consist of two distinct segments: compliance markets in which RECs are purchased to meet state RPS obligations, and green power markets in which RECs are purchased on a voluntary basis.

The year 2007 saw the completion of two new regional electronic REC tracking systems: the Western Renewable Energy Generation Information System (WREGIS) and the Midwest Renewable Energy Tracking System (MRETS). As such, electronic REC tracking systems are now widespread, with operational systems in New England, the PJM Interconnection, Texas, the Western Electricity Coordinating Council, and the upper Midwest, and another system under development in New York.

The figures to the right present indicative monthly data on spot-market REC prices in both compliance and voluntary markets; data for compliance markets focus on the "Class I" or "Main Tier" of the RPS policies. Clearly, spot REC prices have varied substantially, both among states and over time within individual states. Key trends in 2007 compliance markets include continued high prices to serve the Massachusetts RPS, dramatically increasing prices under the Connecticut RPS, high initial prices to serve the Rhode Island RPS, and a large spike in the price for Class I certificates under the New Jersey RPS. Prices remained relatively low in Texas, Maryland, Pennsylvania, and Washington D.C. due to a surplus of eligible renewable energy supply relative to RPS-driven demand in those markets. Despite low REC prices in Texas, the combination of high wholesale power prices and the possibility of additional REC revenue increased merchant wind activity in that state in 2007. RECs offered in voluntary markets ranged from less than $5/MWh to more than $10/MWh in 2007, with strong upward movement in Western REC prices.



Source: Evolution Markets.



Source: Evolution Markets.

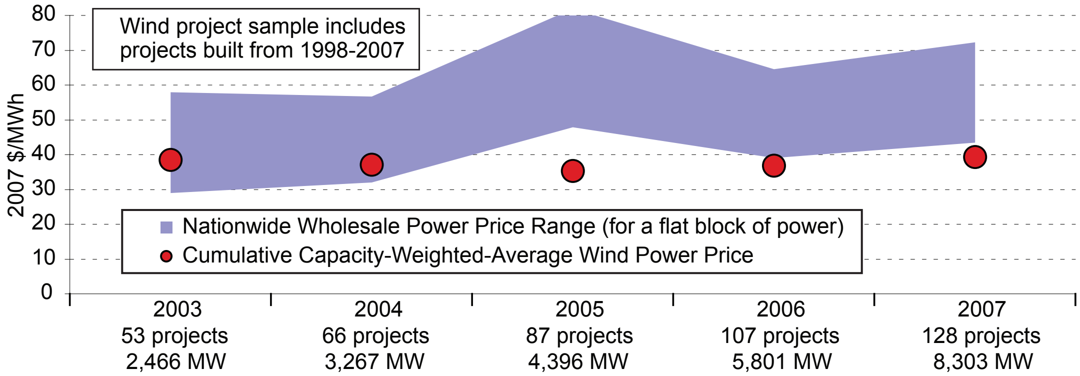
Wind Remained Competitive in Wholesale Power Markets

A simple comparison of the wind prices presented in the previous section to recent wholesale power prices throughout the United States demonstrates that wind power prices have been competitive with wholesale power market prices over the past few years. Figure 17 shows the range (minimum and maximum) of average annual wholesale power prices for a flat block of power[30] going back to 2003 at twenty-three different pricing nodes located throughout the country (refer to Figure 16 for the names and approximate locations of the twenty-three pricing nodes represented by the blue-shaded area[31]). The red dots show the cumulative capacity-weighted-average price received by wind projects in each year among those projects in the sample with commercial operation dates of 1998 through 2007 (consistent with the data first presented in Figure 13). At least on a cumulative basis within the sample of projects reported here, average wind power prices have consistently been at or below the low end of the wholesale power price range.

Though Figure 17 shows that—on average—wind projects installed from 1998 through 2007 have, since 2003 at least, been priced at or below the low end of the wholesale power price range on a nationwide basis, there are clearly regional differences in wholesale power prices and in the average price of wind power. These variations are reflected in Figure 18, which focuses on 2007 wind and wholesale power prices in the same regions as shown earlier, based on the entire sample of wind projects installed from 1998 through 2007.[32] Although there is quite a bit of variability within some regions, in most regions the average wind power price was below the range of average wholesale prices in 2007.

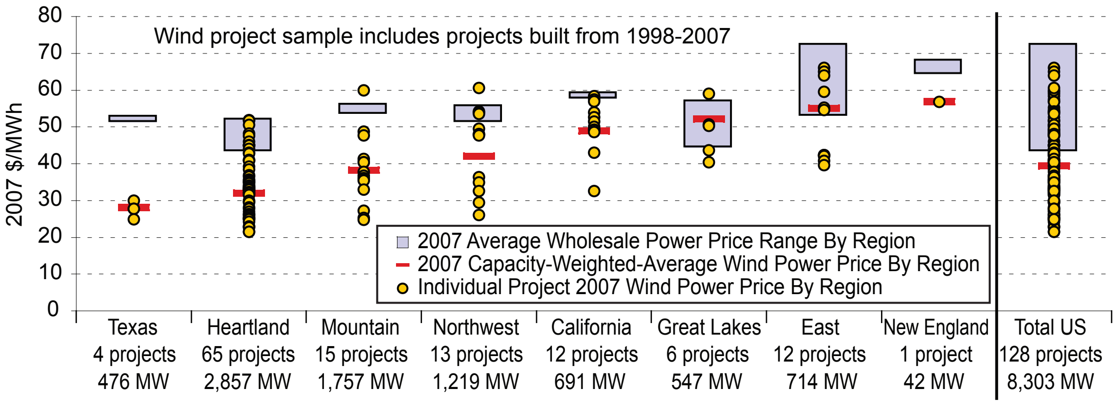
To try to control for the fact that wind power prices have risen in recent years, Figure 19 focuses just on those projects in the sample that were built in 2006 and 2007 (as opposed to 1998 through 2007). At this level of granularity, sample size is clearly an issue in most regions. Nevertheless, while there is greater convergence between wind and wholesale prices in this instance, power prices from wind projects built in 2006 and 2007 still appear, for the most part, to be either within or below the range of 2007 wholesale power prices. Rising wholesale power prices since earlier in the decade have, to a degree, mitigated the impact of rising wind power prices on wind's competitive position.

Notwithstanding the comparisons made in Figures 17-19, it should be recognized that neither the wind nor wholesale power prices presented in this section reflect the full social costs of power generation and delivery. Specifically, the wind power prices are suppressed by virtue of federal and, in some cases, state tax and financial incentives (a few



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

Figure 17. Average Cumulative Wind and Wholesale Power Prices Over Time



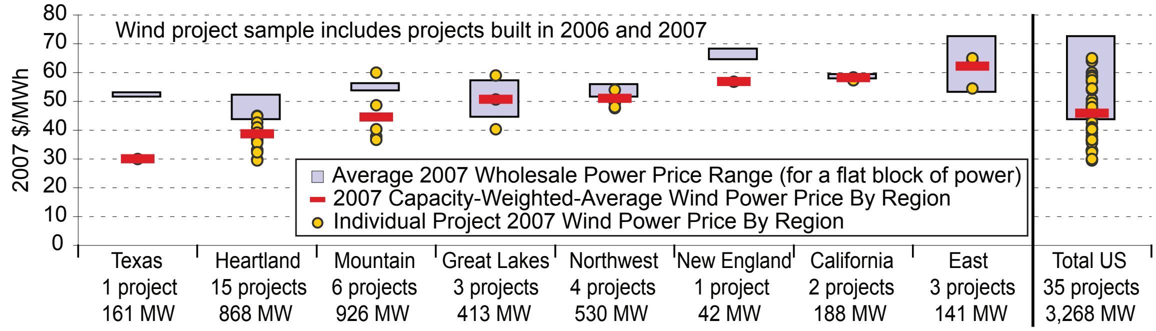
Source: Berkeley Lab database, Ventyx.

Figure 18. Wind and Wholesale Power Prices by Region: 1998-2007 Projects

30 Though wind projects do not provide a perfectly flat block of power, as a common point of comparison, a flat block is not an unreasonable starting point. In other words, the time-variability of wind generation is often such that its wholesale market value is not too dissimilar from that of a flat block of (non-firm) power.

31 The five pricing nodes represented in Figure 16 by an open rather than closed bullet do not have complete pricing history back through 2003.

32 Although their prices are factored into the capacity-weighted-average wind power price (depicted by the red dash), two individual projects are not shown in Figure 18, due to scale limitations: one in the Great Lakes region, at roughly $91/MWh; and one in the East, at roughly $150/MWh.



Source: Berkeley Lab database, Ventyx.

Figure 19. Wind and Wholesale Power Prices by Region: 2006-2007 Projects Only

projects also receive additional revenue from unbundled REC sales). Furthermore, these prices do not fully reflect integration, resource adequacy, or transmission costs. At the same time, wholesale power prices do not fully reflect transmission costs, may not fully reflect capital and fixed operating costs, and are suppressed by virtue of any financial incentives provided to fossil-fueled generation and by not fully accounting for the environmental and social costs of that generation. In addition, wind power prices—once established—are typically fixed and known, whereas wholesale power prices are short-term and therefore subject to change over time. Finally, the location of the wholesale pricing nodes and the assumption of a flat block of power are not perfectly consistent with the location and output profile of the sample of wind projects.

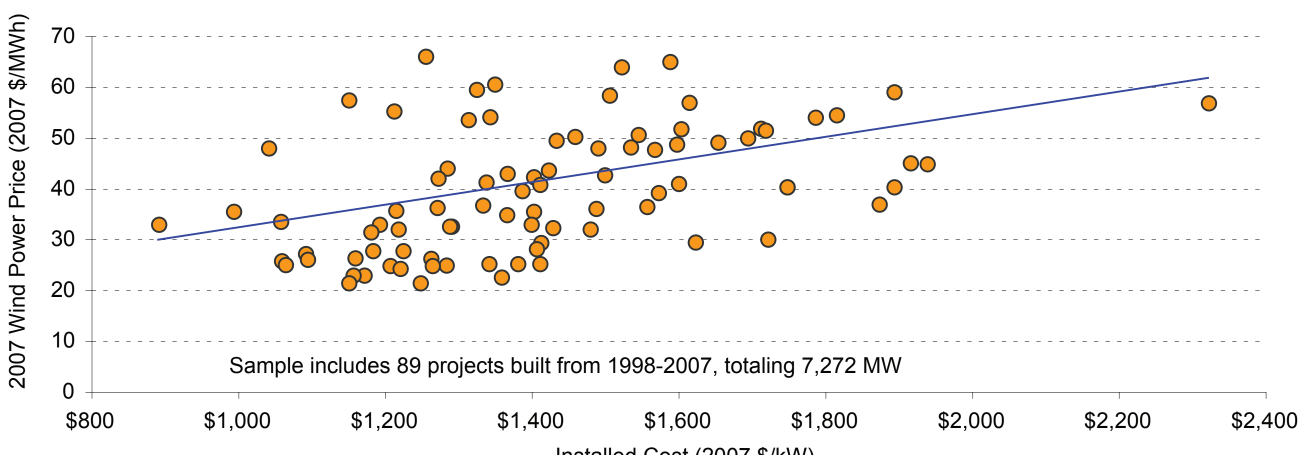
In short, comparing wind and wholesale power prices in this manner is spurious, if one's goal is to fully account for the costs and benefits of wind relative to its competition. Another way to think of Figures 17-19, however, is as loosely representing the decision facing wholesale power purchasers—i.e., whether to contract long-term for wind power or buy a flat block of (non-firm) spot power on the wholesale market. In this sense, the costs represented in Figures 17-19 are reasonably comparable in that they represent (to some degree, at least) what the power purchaser would actually pay.

Project Performance and Capital Costs Drive Wind Power Prices

Wind power sales prices are affected by a number of factors, two of the most important of which are installed project costs and project performance.[33] Figures 20 and 21 illustrate the importance of these two variables.

Figure 20 shows the relationship between project-level installed costs and power sales prices in 2007 for a sample of more than 7,200 MW of wind projects installed in the United States from 1998 through 2007.[34] Though the scatter is considerable, in general, projects with higher installed costs also have higher wind power prices. Figure 21 illustrates the relationship between project-level capacity factors in 2007 and power sales prices in that same year for a sample of more than 5,700 MW of wind projects installed from 1998 through 2006. The inverse relationship shows that projects with higher capacity factors generally have lower wind power prices, though considerable scatter is again apparent.

The next few sections of this report explore trends in installed costs and project performance in more detail, as both factors can have significant effects on wind power prices.

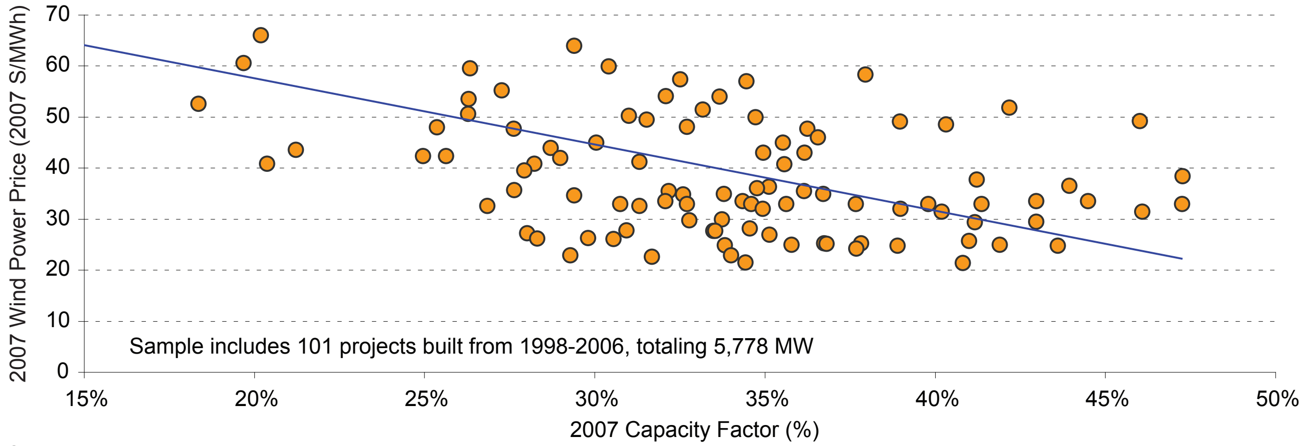


Source: Berkeley Lab database.

Figure 20. 2007 Wind Power Price as a Function of Installed Project Costs

33 Operations and maintenance (O&M) costs are another important variable that affects wind power prices. A later section of this report covers trends in project-level O&M costs.

34 In both Figures 20 and 21, two project outliers (the same two described earlier) are obscured by the compressed scales, yet still influence the trend lines.



Source: Berkeley Lab database.

Figure 21. 2007 Wind Power Price as a Function of 2007 Capacity Factor

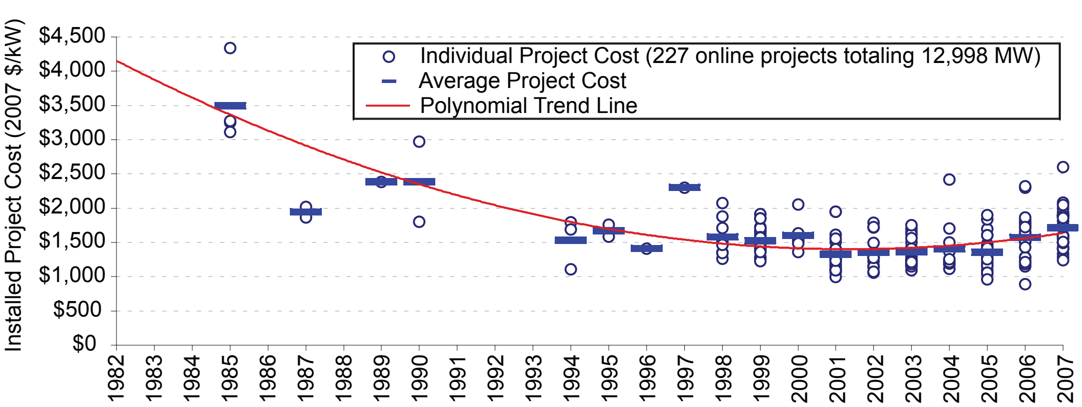
Installed Project Costs Continued to Rise in 2007, After a Long Period of Decline

Berkeley Lab has compiled a sizable database of the installed costs of wind projects in the United States, including data on 36 projects completed in 2007 totaling 4,079 MW, or 77% of the wind power capacity installed in that year. In aggregate, the dataset includes 227 completed wind projects in the continental United States totaling 12,998 MW, and equaling roughly 77% of all wind capacity installed in the United States at the end of 2007. The dataset also includes cost projections for a sample of proposed projects. In general, reported project costs reflect turbine purchase and installation, balance of plant, and any substation and/or interconnection expenses. Data sources are diverse, however, and are not all of equal credibility, so emphasis should be placed on overall trends in the data, rather than on individual project-level estimates.

As shown in Figure 22, wind project installed costs declined dramatically from the beginnings of the industry in California in the 1980s to the early 2000s, falling by roughly $2,700/kW over this period.[35] More recently, however, costs have increased. Among the sample of projects built in 2007, reported installed costs ranged from $1,240/kW to $2,600/kW, with an average cost of $1,710/kW. 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. Project costs are clearly on the rise.

Moreover, there is reason to believe that recent increases in turbine costs did not fully work their way into installed project costs in 2007, and therefore that even higher installed costs are likely in the near future. The average cost estimate for 2,950 MW of proposed projects in the dataset (not shown in Figure 22, but most of which are expected to be built in 2008), for example, is $1,920/kW, or $210/kW higher than for projects completed in 2007.

Project costs may be influenced by a number of factors, including project size. Focusing only on those projects completed in 2006 and 2007 (to try to remove the confounding effect of rising costs over the past few years), Figure 23 tries to identify the existence of project-level economies of scale. There is clearly a wider spread in project-level costs among smaller wind projects than among larger projects, but Figure 23 does not show strong evidence of economies of scale.[36] Given the wide spread in the data, it is clear that other factors must play a major role in determining installed project costs.



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

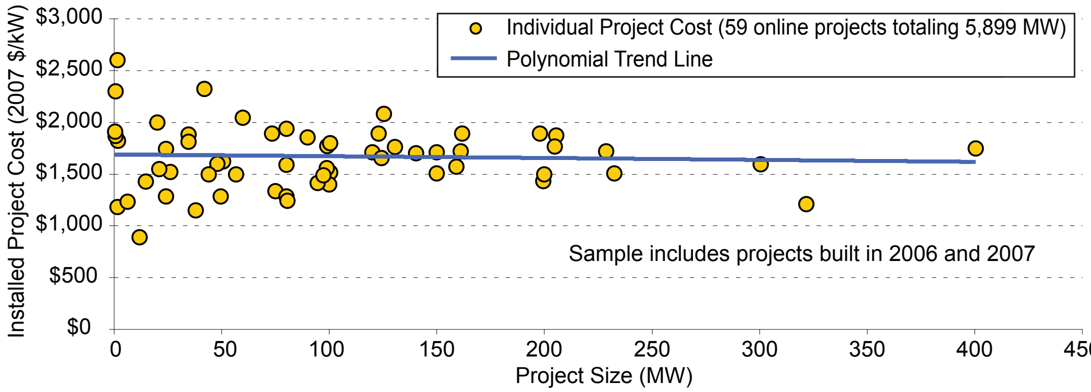
Figure 22. Installed Wind Project Costs Over Time

[35] Limited sample size early on – particularly in the 1980s – makes it difficult to pin down this number with a high degree of confidence.

[36] This may simply be an artifact of the limited quantity and quality of available data, and the influence of other confounding factors. Alternatively, it may be that economies of scale are evident in turbine transactions (larger turbine orders yielding lower prices), but those economies do not necessarily correspond with project size because a large turbine order could be used for either one large project or allocated among multiple smaller projects.

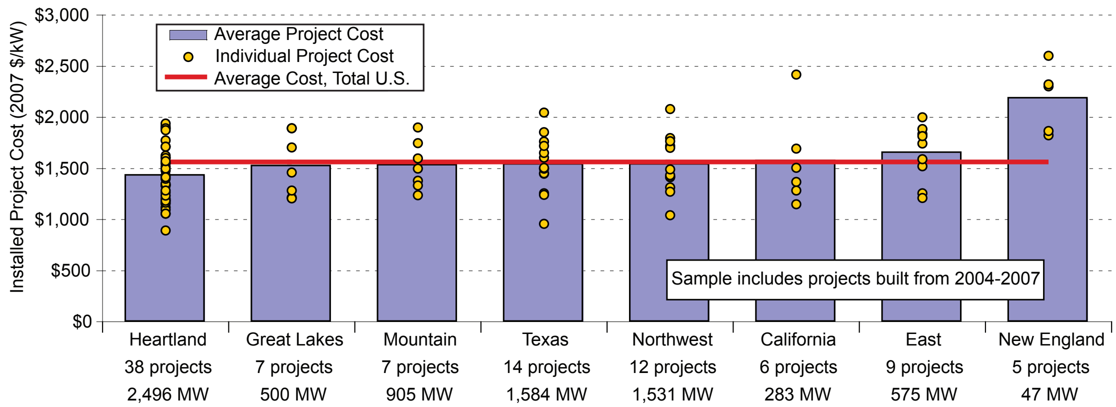
Differences in installed costs exist regionally due to variations in development costs, transportation costs, siting and permitting requirements and timeframes, and balance-of-plant and construction expenditures. Considering projects in the sample installed in 2004 through 2007, Figure 24 shows that average costs equaled $1,540/kW nationwide over this period, but varied somewhat by region. New England was the highest cost region, while the Heartland was the lowest.[37]

Finally, it is important to recognize that wind is not alone in seeing upward pressure on project costs—other types of power plants have seen similar increases in capital costs in recent years. In September 2007, for example, the Edison Foundation published a report showing increases in the installed cost of both natural gas and coal power plants that rival that seen in the wind industry.[38]



Source: Berkeley Lab database.

Figure 23. Installed Wind Project Costs as a Function of Project Size: 2006-2007 Projects



Source: Berkeley Lab database.

Figure 24. Installed Wind Project Costs by Region: 2004-2007 Projects

Project Cost Increases Are a Function of Turbine Prices, and Turbine Prices Have Increased Dramatically

Increases in wind power prices and overall installed project costs mirror increases in the cost of wind turbines. Berkeley Lab has gathered data on 49 U.S. wind turbine transactions totaling 16,600 MW, including 16 transactions summing to 7,600 MW in 2007 alone. Figure 25 depicts these reported wind turbine transaction prices.

Sources of transaction price data vary, but most derive from press releases and press reports. Wind turbine transactions differ in the services offered (e.g., whether towers and installation are provided, the length of the service agreement, etc.) and on the timing of future turbine delivery, driving some of the observed intra-year variability in transaction prices. Nonetheless, most of the transactions included in the Berkeley Lab dataset likely include turbines, towers, erection, and limited warranty and service agreements; unfortunately, because of data limitations, the precise content of many of the individual transactions is not known.

Since hitting a nadir of roughly $700/kW in the 2000-2002 period, turbine prices appear to have increased by approximately $600/kW (85%), on average. Between 2006 and 2007, capacity-weighted-average turbine prices increased by roughly $115/kW (10%), from $1,125/kW to $1,240/kW. Recent increases in turbine prices have likely been caused by several factors, including the declining value of the U.S. dollar relative to the Euro, increased materials and energy input prices (e.g., steel and oil), a general move by manufacturers to improve their profitability, shortages in certain turbine components, an up-scaling of turbine size (and hub height), and improved sophistication of turbine design (e.g., improved grid interactions). The shortage of turbines has also led to a secondary market in turbines, through which prices may be even higher than those shown in Figure 25.

Though by no means definitive, Figure 25 also suggests that larger turbine orders (> 300 MW) may have generally yielded somewhat lower pricing than smaller orders (< 100 MW) at any given point in time. This is reflected in the fact that most of the larger turbine orders shown in Figure 25 are located below the polynomial trend line, while the majority of the smaller orders are located above that line.

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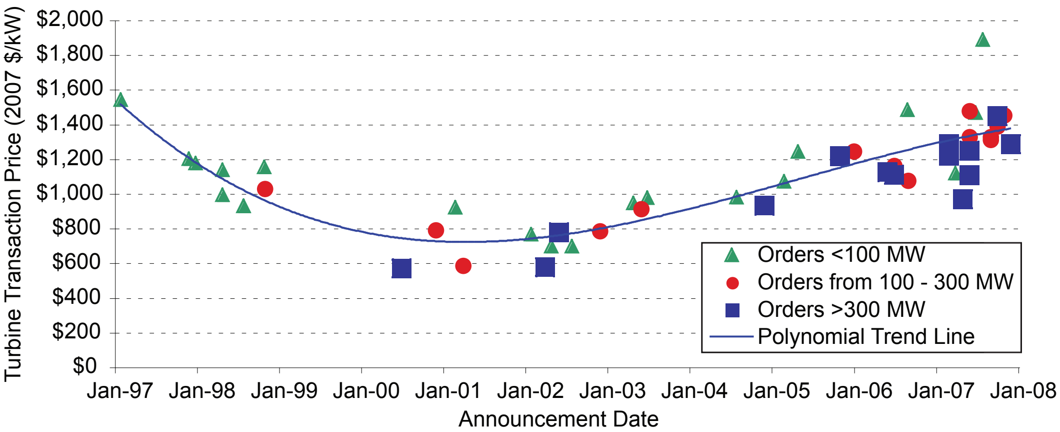
[37] Graphical presentation of the data in this way should be viewed with some caution, as numerous factors influence project costs (e.g., whether projects are repowered vs. "greenfield" development, etc.). As a result, actual cost differences among some regions may be more (or less) significant than they appear in Figure 24.

[38] See: www.edisonfoundation.net/Rising_Utility_Construction_Costs.pdf



Source: Berkeley Lab database.

Figure 25. Reported U.S. Wind Turbine Transaction Prices Over Time

This trend of increasing turbine prices suggests that virtually the entire recent rise in installed project costs reported earlier has come from turbine price increases (recognizing that these prices reflect the cost of turbines, towers, and erection). In fact, because project-level installed costs have increased, on average, by roughly $370/kW during the last several years, while turbine prices appear to have increased by $600/kW over the same time span, further increases in project costs should be expected in the near future as the increases in turbine prices flow through to project costs.

Wind Project Performance Has Improved Over Time

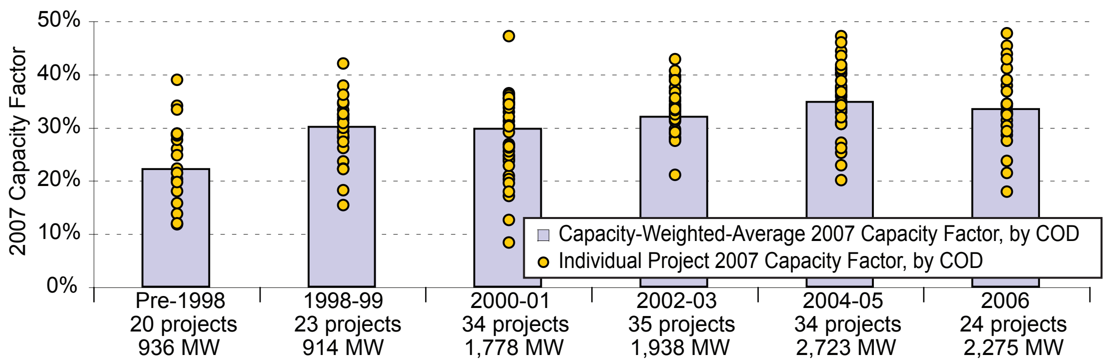
Though recent turbine and installed project cost increases have driven wind power prices higher, improvements in wind project performance have mitigated these impacts to some degree. In particular, capacity factors have increased for projects installed in recent years, driven by a combination of higher hub heights, improved siting, and technological advancements.

Figures 26 and 27, as well as Table 7, present excerpts from a Berkeley Lab compilation of wind project capacity-factor data. The sample consists of 170 projects built between 1983 and 2006, and totaling 10,564 MW (91% of nationwide installed wind capacity at the end of 2006).[39] Though capacity factors are not an ideal metric of project performance due to variations in the design and rating of wind turbines, absent rotor diameter data for each project, this report is unable to present the arguably more-relevant metric of electricity generation per square meter of swept rotor area. Both figures and the table summarize project-level capacity factors in the year 2007, thereby limiting the effects of inter-annual fluctuations in the nationwide wind resource.[40]

Figure 26 shows individual project as well as capacity-weighted average 2007 capacity factors broken out by each project's commercial operation date. The capacity-weighted-average 2007 capacity factors in the Berkeley Lab sample increased from 22% for wind projects installed before 1998 to roughly 30%-32% for projects installed from 1998-2003, and to roughly 33%-35% for projects installed in 2004-2006. [41]

In the best wind resource areas, capacity factors in excess of 40% are increasingly common. Of the 112 projects in the sample installed prior to 2004, for example, only 4 (3.6%) had capacity factors in excess of 40% in 2007 (in capacity terms, 56 MW, or 1%, exceeded 40%). Of the 58 projects installed from 2004 through 2006, on the other hand, 15 (25.9%) achieved capacity factors in excess of 40% in 2007 (in capacity terms, 836 MW, or 16.7%, exceeded 40%).

These increases in capacity factors over time suggest that improved turbine designs, higher hub heights, and/or improved siting are outweighing the otherwise-presumed trend towards



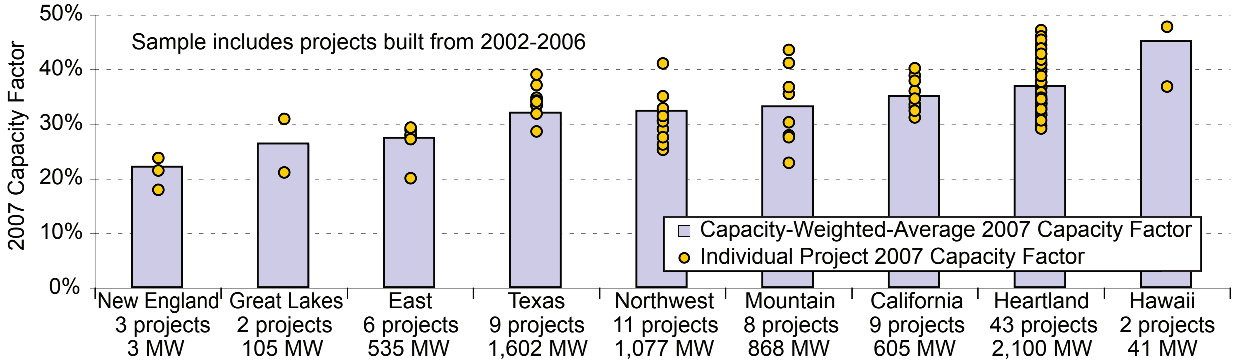
Source: Berkeley Lab database.

Figure 26. 2007 Project Capacity Factors by Commercial Operation Date

39 Though some performance data for wind projects installed in 2007 are available, those data do not span an entire year of operations. As such, for the purpose of this section, the focus is on project-level 2007 capacity factors for projects with commercial online dates in 2006 and earlier.

40 Focusing just on 2007 means that the *absolute* capacity factors shown in Figure 26 may not be representative if 2007 was not a representative year in terms of the strength of the wind resource. Note also that by including only 2007 capacity factors, variations in the quality of the wind resource year in 2007 across regions could skew the regional results presented in Figure 27 and Table 7.

41 The capacity-weighted-average 2007 capacity factor for projects installed in 2006 (33.4%) is down slightly from that for projects installed in 2004-2005 (34.8%), in large part due to the impact of a single large project. Specifically, a very large 2006 project in Texas achieved a capacity factor of just 28.7% in 2007; if this single project were excluded from the sample, the capacity-weighted-average 2007 capacity factor from projects built in 2006 would rise to 35.7% (up from 34.8% for projects built in 2004-2005). The impact of this single project is also evident in Figure 27 (where the capacity-weighted-average for Texas is at the low end of the individual project range) and Table 7 (where the steady upward march of average capacity factors in Texas is abruptly reversed in 2006).



Source: Berkeley Lab database.

Figure 27. 2007 Project Capacity Factors by Region: 2002-2006 Projects Only

Table 7. Capacity-Weighted-Average 2007 Capacity Factors by Region and COD

Capacity Factor	Heartland	Texas	California	Northwest	Mountain	East	Great Lakes	Hawaii	New England
Pre-1998	28.9%	11.9%	22.3%	—	—	—	—	—	19.8%
1998-99	30.2%	28.2%	29.8%	32.1%	34.4%	—	23.4%	—	—
2000-01	33.4%	29.6%	34.5%	28.7%	29.3%	22.5%	23.5%	—	27.0%
2002-03	34.4%	33.5%	32.6%	30.5%	30.3%	28.5%	21.2%	—	—
2004-05	36.8%	34.5%	37.5%	34.0%	38.9%	26.7%	31.0%	—	—
2006	40.8%	30.4%	36.9%	31.3%	34.7%	29.4%	—	45.0%	22.1%

Sample	#	MW	#	MW	#	MW	#	MW	#	MW	#	MW	#	MW	#	MW	#	MW
Pre-1998	1	26	1	34	17	870	—	—	—	—	—	—	—	—	—	—	1	6
1998-99	8	470	3	139	5	190	1	25	3	68	—	—	3	22	—	—	—	—
2000-01	10	229	7	911	1	67	3	388	4	123	6	78	2	32	—	—	1	1
2002-03	20	628	2	198	4	287	2	105	3	510	3	161	1	50	—	—	—	—
2004-05	16	1,086	4	461	3	130	5	434	3	208	2	349	1	54	—	—	—	—
2006	7	386	3	944	2	188	4	538	2	150	1	26	—	—	2	41	3	3
Total	**62**	**2,825**	**20**	**2,686**	**32**	**1,732**	**15**	**1,440**	**15**	**1,059**	**12**	**613**	**7**	**158**	**2**	**41**	**5**	**10**

lower-value wind resource sites as the best locations are developed. Further analysis would be needed to determine the relative importance of the variables influencing performance improvements.

Although the overall trend is towards higher capacity factors, the project-level spread shown in Figure 26 is enormous, with capacity factors ranging from 18% to 48% among projects built in the same year, 2006. Some of this spread is attributable to regional variations in wind resource quality. Figure 27 shows the regional variation in 2007 capacity factors, based on a sub-sample of wind projects built from 2002 through 2006. For this sample of projects, capacity factors are the highest in Hawaii (though just two projects) and the Heartland (above 35% on average), and lowest in New England, the Great Lakes, and the East (below 30% on average). Given the small sample size in some regions, however, as well as the possibility that certain regions may have experienced a particularly good or bad wind resource year in 2007, care should be taken in extrapolating these results.

Though limited sample size is again a problem for many regions, Table 7 illustrates trends in 2007 capacity factors for projects with different commercial operation dates, by region. In the Heartland region, with the largest sample of projects in terms of installed capacity, the average capacity factor of projects installed in 2006 (40.8%) is approximately 35% greater than that of the 1998-1999 vintage projects in the sample (30.2%).

Operations and Maintenance Costs Are Affected by the Age and Size of the Project, Among Other Factors

Operations and maintenance (O&M) costs are a significant component of the overall cost of wind projects, but can vary widely among projects. Market data on actual project-level O&M costs for wind plants are scarce. Even where these data are available, care must be taken in extrapolating historical O&M costs given the dramatic changes in wind turbine technology that have occurred over the last two decades, not least of which has been the up-scaling of turbine size (see Figure 9, earlier).

Berkeley Lab has compiled O&M cost data for 95 installed wind plants in the United States, totaling 4,319 MW of capacity, with commercial operation dates of 1982 through 2006. These data cover facilities owned by both independent power producers and utilities, though data since 2004 is exclusively from utility-owned plants. A full-time series of O&M cost data, by year, is available for only a small number of projects; in all other cases, O&M cost data are available for just a subset of years of project operations. Although the data sources do not all clearly define what items are included in O&M costs, in most cases the reported values appear to include the costs of wages and materials associated with operating and maintaining the facility, as well as rent (i.e., land lease payments). Other ongoing expenses, including taxes, property insurance, and workers' compensation insurance, are generally not included. Given the scarcity and varying quality of the data, caution should be taken when interpreting the results shown below. Note also that the available data are presented in $/MWh terms, as if O&M represents a variable cost. In fact, O&M costs are in part variable and in part fixed. [42]

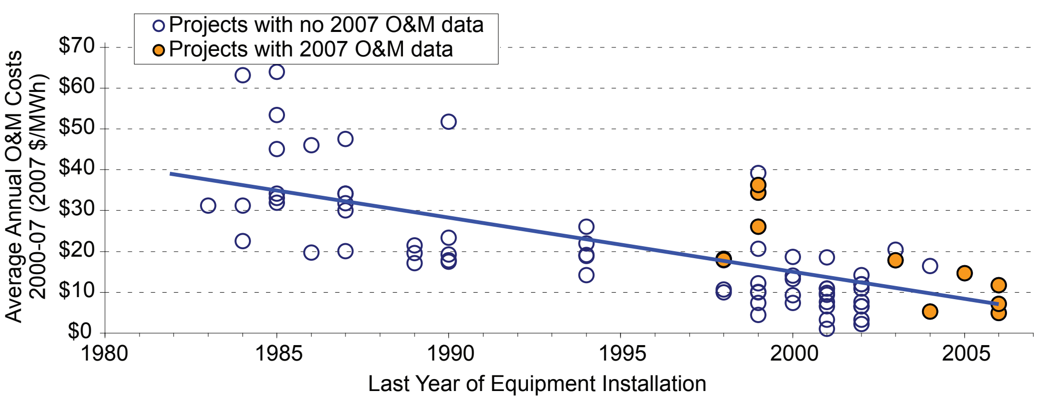
Figure 28 shows project-level O&M costs by year of project installation (i.e., the last year that original equipment was installed, or the last year of project repowering). Here, O&M costs represent an average of annual project-level data available for the years 2000 through 2007. For example, for projects that reached commercial operations in 2006, only year 2007 data are available, and that is what is shown in the figure.[43] Many other projects only have data for a subset of years during the 2000-2007 period, either because they were installed after 2000 or because a full-time series is not available, so each data point in the chart may represent a different averaging period over the 2000-07 timeframe. The chart also identifies which of the data points contain the most-updated data, from 2007.

The data exhibit considerable spread, demonstrating that O&M costs are far from uniform across projects. However, Figure 28 suggests that projects installed more recently have, on average, incurred much lower O&M costs. Specifically, capacity-weighted-average 2000-2007 O&M costs for projects in the sample constructed in the 1980s equal $30/MWh, dropping to $20/MWh for projects installed in the 1990s, and to $9/MWh for projects installed in the 2000s. This drop in O&M costs may be due to a combination of at least two factors: (1) O&M costs generally increase as turbines age, component failures become more common, and as manufacturer warranties expire[44]; and (2) projects installed more recently, with larger turbines and more sophisticated designs, may experience lower overall O&M costs on a per-MWh basis.

To help tease out the possible influence of these two factors, Figure 29 shows annual O&M costs over time, based on the number of years since the last year of equipment installation. Annual data for projects of similar vintages are averaged together, and data for projects under 5 MW in size are excluded (to help control for the confounding influence of economies of scale). Note that, for each group, the number of projects used to compute the average annual values shown in the figure is limited, and varies substantially (from 3 to 21 data points per project-year for projects installed in 1998 through 2000; 10 data points per project-year for projects installed in 2001 through 2003; and from 3 to 6 data points for projects installed in 2004 through 2006). With this limitation in mind, the figure appears to show that projects installed in 2001 and later have had lower O&M costs than those installed from 1998 through 2000, at least during the initial two years of operation. In addition, the data for projects installed from 1998 through 2000 show a quite modest upward trend in project-level O&M costs after the third year of project operation, though the sample size after year four is quite limited.

Another variable that may impact O&M costs is project size. Figure 30 presents average O&M costs for 2000 through 2007 (as in Figure 28) relative to project size. Though substantial spread in the data exists and the sample is too small for definite conclusions, project size does appear to have some impact on average O&M costs, with higher costs typically experienced by smaller projects. More data would be needed to confirm this inference.

Though interesting, the trends noted above are not necessarily useful predictors of long-term O&M costs for the latest turbine models. The U.S. DOE, in collaboration with the wind industry, is currently funding additional efforts to better understand the drivers for O&M costs and component failures, and to develop models to project future O&M costs and failure events.



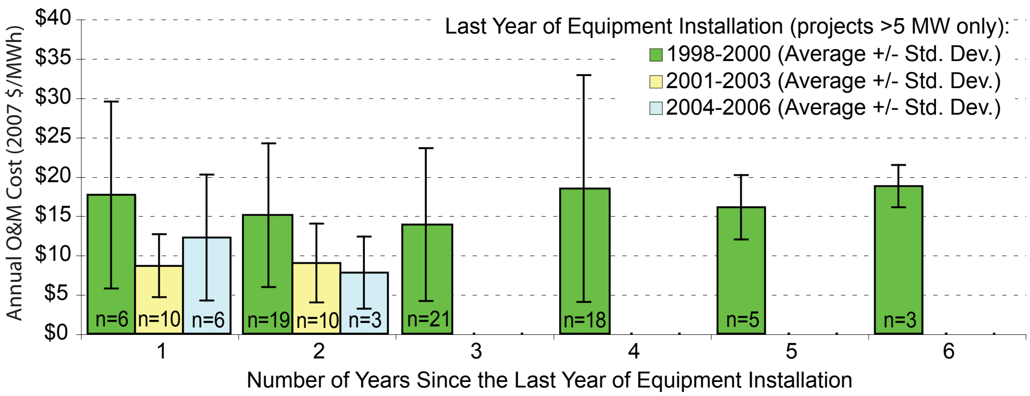
Source: Berkeley Lab database; five data points suppressed to protect confidentiality.

Figure 28. Average O&M Costs for Available Data Years from 2000-2007, by Last Year of Equipment Installation

[42] Although not presented here, expressing O&M costs in units of $/kW-yr was found to yield qualitatively similar results.

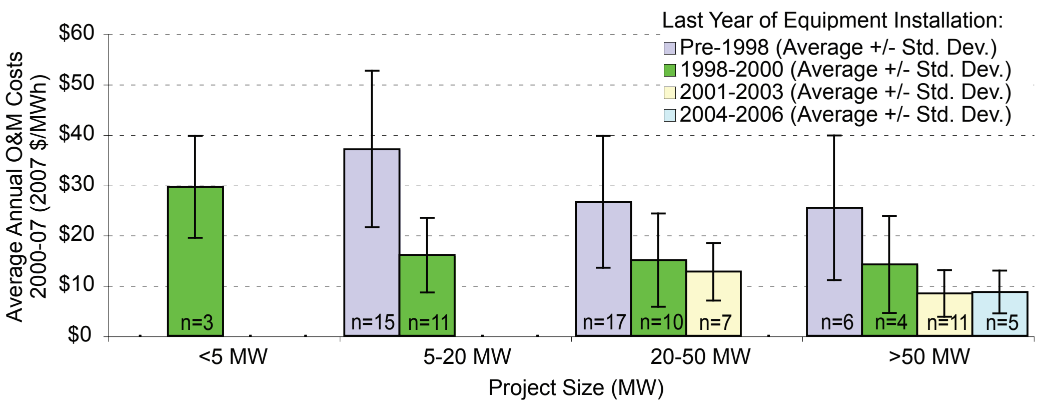
[43] Projects installed in 2007 are not shown because only data from the first full year of project operations (and afterwards) are used, which in the case of projects installed in 2007 would be year 2008 (for which data are not yet available).

[44] Many of the projects installed more recently may still be within their turbine manufacturer warranty period, in which case the O&M costs reported here may or may not include the costs of the turbine warranty, depending on whether the warranty is paid up-front as part of the turbine purchase, or is paid over time.



Source: Berkeley Lab database; averages shown only for groups of three or more projects.

Figure 29. Annual Average O&M Costs, by Project Age and Last Year of Equipment Installation



Source: Berkeley Lab database; averages shown only for groups of three or more projects.

Figure 30. Average O&M Costs for Available Data Years from 2000-2007, by Project Size

New Studies Continued to Find that Integrating Wind into Power Systems Is Manageable, but Not Costless

During the past several years, there has been a considerable amount of analysis on the potential impacts of wind energy on power systems, typically responding to concerns about whether the electrical grid can accommodate significant new wind additions, and at what cost. The sophistication of these studies has increased in recent years, resulting in a better accounting of wind's impacts and costs. Key trends among some of the more recent studies include evaluating even higher levels of wind penetration, evaluating the integration of wind within larger electricity market areas, and identifying approaches to mitigate integration concerns.

Table 8 provides a selective listing of results from major wind integration studies completed from 2003 through 2007.[45] Because methods vary and a consistent set of operational impacts has not been included in each study, results from the different analyses are not entirely comparable. Nonetheless, key conclusions that continue to emerge from the growing body of integration literature include: (1) wind integration costs are well below $10/MWh—and typically below $5/MWh—for wind capacity penetrations[46] of as much as 30% of the peak load of the system in which the wind power is delivered[47]; (2) regulation impacts are often found to be relatively small, whereas the impacts of wind on load-following and unit commitment are typically found to be more significant; (3) larger balancing areas, such as those found in RTOs and ISOs, make it possible to integrate wind more easily and at lower cost than is the case in small balancing areas[48]; and (4) the use of wind power forecasts can significantly reduce integration challenges and costs.

Additional wind integration research is planned for 2008. Perhaps of greatest import is that the National Renewable Energy Laboratory is in the process of examining higher levels of wind penetration in larger electrical footprints. The Western Wind and Solar Integration Study (WWSIS), in collaboration with GE and WestConnect, is analyzing wind penetration levels of up to 30% on an energy basis in the WestConnect footprint, which includes parts of Wyoming, Colorado, New Mexico, Arizona, and Nevada. The Eastern Wind Integration Study, to be conducted in collaboration

45 Some of the studies included in the table also address capacity valuation for resource adequacy purposes; those results are not presented here. Two major integration studies for California were also completed in 2007: one conducted by the California ISO and another by the California Energy Commission's Intermittency Analysis Project. Neither of these studies sought to comprehensively calculate integration costs, however, so neither is listed in the table.

46 Wind penetration on a capacity basis (defined as nameplate wind capacity serving a region divided by that region's peak electricity demand) is frequently used in integration studies. For a given amount of wind capacity, penetration on a capacity basis is typically higher than the comparable wind penetration in energy terms.

47 The relatively low cost estimate in the 2006 Minnesota study, despite an aggressive level of wind penetration, is partly a result of relying on the overall Midwest Independent System Operator (MISO) market to accommodate certain elements of integrating wind into system operations. The low costs found in the 2006 California study arise because of the large electrical market in which wind power is integrated, as well as the relatively low penetration level analyzed. Conversely, the higher integration costs found by Avista and Idaho Power are, in part, caused by the relatively smaller markets in which the wind is being absorbed and, in part, by those utilities' operating practices (specifically, that sub-hourly markets are not used, as is common in ISOs and RTOs). Note also that the rigor with which the various studies have been conducted has varied, as has the degree of peer review.

48 Even outside of ISOs and RTOs, there is increasing interest in collaborative system control actions among balancing areas to address market operations inefficiencies, including helping to mitigate the impact of wind variability on systems operation and cost. In the West, for example, the Area Control Error (ACE) Diversity Interchange project has sought to pilot the pooling of individual ACEs to take advantage of control error diversity.

Table 8. Key Results from Major Wind Integration Studies Completed 2003-2007

Date	Study	Wind Capacity Penetration	Cost ($/MWh)				
			Regulation	Load Following	Unit Commitment	Gas Supply	TOTAL
2003	Xcel-UWIG	3.5%	0	0.41	1.44	na	1.85
2003	We Energies	29%	1.02	0.15	1.75	na	2.92
2004	Xcel-MNDOC	15%	0.23	na	4.37	na	4.60
2005	PacifiCorp	20%	0	1.60	3.00	na	4.60
2006	CA RPS (multi-year)*	4%	0.45	trace	trace	na	0.45
2006	Xcel-PSCo	15%	0.20	na	3.32	1.45	4.97
2006	MN-MISO**	31%	na	na	na	na	4.41
2007	Puget Sound Energy	10%	na	na	na	na	5.50
2007	Arizona Public Service	15%	0.37	2.65	1.06	na	4.08
2007	Avista Utilities***	30%	1.43	4.40	3.00	na	8.84
2007	Idaho Power	20%	na	na	na	na	7.92

** regulation costs represent 3-year average*
*** highest over 3-year evaluation period*
**** unit commitment includes cost of wind forecast error*

Source: Berkeley Lab based, in part, on data from NREL.

with the Joint Coordinated System Plan (whose participants include MISO, SPP, TVA, and PJM), will examine a similar wind penetration in the combined footprint of these RTOs and ISOs.[49] Finally, in 2008, ERCOT will issue a study by GE on the potential impact of wind development on ERCOT's ancillary service requirements.

Solutions to Transmission Barriers Began to Emerge, but Constraints Remain

After a prolonged period of relatively little transmission investment, expenditures on new transmission are on the rise. The Edison Electric Institute, for example, projects that its member companies will invest $37 billion in transmission from 2007-2010, a 55% increase from the 2003-2006 period.

Nonetheless, lack of transmission availability remains a primary barrier to wind development. New transmission facilities are particularly important for wind power because wind projects are constrained to areas with adequate wind speeds, which are often located at a distance from load centers. In addition, there is a mismatch between the short lead time needed to develop a wind project and the lengthier time often needed to develop new transmission lines. Moreover, the relatively low capacity factor of wind can lead to underutilization of new transmission lines that are intended to only serve this resource. The allocation of costs for new transmission investment is also of critical importance for wind development, as are issues of transmission rate "pancaking" when power is wheeled across multiple utility systems, charges imposed for inaccurate scheduling of wind generation, and interconnection queuing procedures.

A number of federal, state, and regional developments occurred in 2007 that may help ease the transmission barrier for wind over time. At the federal level, the U.S. DOE issued its *National Electric Transmission Congestion Report*, which designates two constrained corridors: the Southwest Area National Interest Electric Transmission Corridor and the Mid-Atlantic Area National Interest Electric Transmission Corridor. Under the Energy Policy Act of 2005, FERC can approve proposed new transmission facilities in these corridors if states fail to do so within one year, among other conditions. The U.S. DOE's designations have proven controversial, however, and multiple efforts to reverse these designations have occurred or are underway.

Also at the federal level, in February 2007, FERC issued Order 890, which includes several provisions of importance to wind. First, the order adopts a cost-based energy imbalance policy that replaces the penalty-based energy imbalance charges that applied under FERC Order 888 and that were much more punitive for wind. Second, the order requires transmission providers to participate in an open transmission planning process at the local and regional level. Third, if transmission capacity is unavailable to service a firm point-to-point transmission application, then the transmission provider is required to examine redispatch and conditional firm service as alternative transmission service options. More recently, FERC has begun to investigate ways to ease barriers imposed by current interconnection queuing procedures; more activity on this topic is expected in 2008.

States and grid operators are also increasingly taking more proactive steps to encourage transmission investment, often

[49] Note that the two NREL studies are not expected to be complete until 2009.

within the context of growing renewable energy demands. Several examples of these initiatives are presented below:

- **Texas**: In October 2007, the Texas public utilities commission (PUC) issued an interim order designating five competitive renewable energy zones (CREZ), defined as areas of high-quality renewable resources to which transmission could be built in advance of installed generation. These CREZs could stimulate as much as 22,806 MW of new wind power capacity, and ERCOT has subsequently completed a transmission study for these areas.
- **Colorado**: Legislation enacted in January 2007 requires utilities to submit biennial reports designating energy resource zones (ERZs) and to submit applications for certificates of public convenience and necessity (CPCN) for these areas. In October 2007, Xcel Energy identified four potential ERZ areas, created in large measure to support renewable energy development, and the Colorado PUC recently approved Xcel's application for a 345-kV line in northeastern Colorado.[50]
- **California**: In late 2007, the California ISO received FERC approval for a new transmission interconnection category for location-constrained resources, such as renewable energy facilities. Once a resource area has been identified, transmission would be built in advance of generation being developed, and costs would be initially recovered through the California ISO transmission charge. California also started the Renewable Energy Transmission Initiative to help define renewable energy zones in and around the state, and to prepare transmission plans for those zones.

Progress was also made in 2007 on a number of specific transmission projects that are designed to, in part, support wind power. In March 2007, for example, the California PUC approved the first three of ultimately 11 segments of Southern California Edison's Tehachapi transmission project. Fully developed, the project will transmit up to 4,500 MW of wind power. In Minnesota, meanwhile, utilities that are part of the CapX 2020 statewide transmission planning group filed applications at the Minnesota PUC for four 345-kV lines that will collectively increase transmission capacity in southwestern Minnesota by 800 MW, to about 2,000 MW total. Finally, a number of states have created transmission infrastructure authorities to support new transmission investment;[51] two of these states—Colorado and New Mexico—created transmission authorities in 2007 in large measure to support renewable energy.

Policy Efforts Continued to Affect the Amount and Location of Wind Development

A variety of policy drivers have been important to the recent expansion of the wind power market in the United States. Most obviously, the continued availability of the federal PTC has sustained industry growth. First established by the Energy Policy Act of 1992, the PTC provides a 10-year credit at a level that equaled 2.0¢/kWh in 2007 (adjusted annually for inflation). The importance of the PTC to the U.S. wind industry is illustrated by the pronounced lulls in wind capacity additions in the three years—2000, 2002, and 2004—in which the PTC lapsed (see Figure 1). With the PTC currently (as of early-May 2008) scheduled to expire at the end of 2008, the U.S. wind industry may experience another quiet year in 2009 absent an imminent extension.

A number of other federal policies also support the wind industry. Wind power property, for example, may be depreciated for tax purposes over an accelerated 5-year period, with bonus depreciation allowed for certain projects completed in 2008. Because tax-exempt entities are unable to take direct advantage of tax incentives, the Energy Policy Act of 2005 created the Clean Renewable Energy Bond (CREB) program, effectively offering interest-free debt to eligible renewable projects (though not without certain additional transaction costs).[52] Finally, the USDA provides grants to certain renewable energy applications.

State policies also continue to play a substantial role in directing the location and amount of wind development. From 1999 through 2007, for example, more than 55% of the wind power capacity built in the U.S. was located in states with RPS policies; in 2007 alone, this proportion was more than 75%. Utility resource planning requirements in Western and Midwestern states have also helped spur wind additions in recent years, as has growing voluntary customer demand for "green" power, especially among commercial customers. State renewable energy funds provide support for wind projects, as do a variety of state tax incentives. Finally, concerns about the possible impacts of global climate change are fueling interest by states, regions, and the federal government to implement carbon reduction policies, a trend that is likely to increasingly underpin wind power expansion in the years ahead.

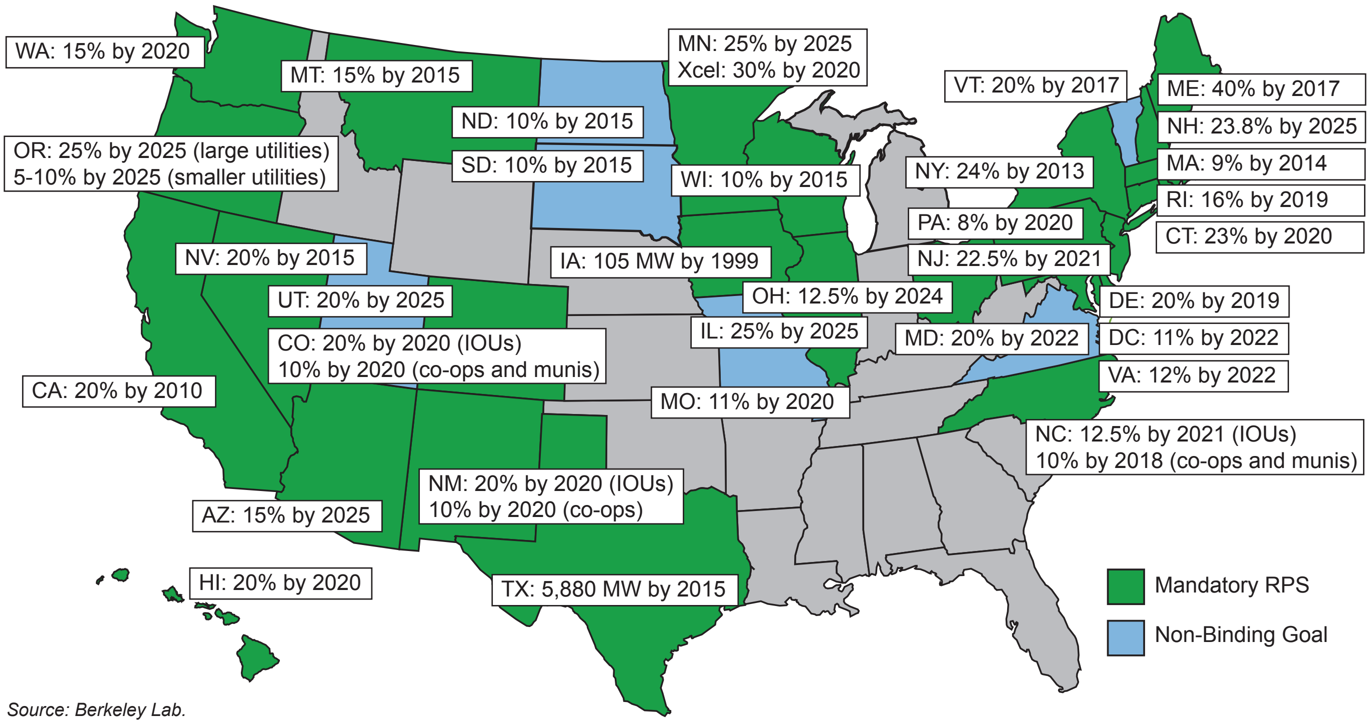
Key policy developments in 2007 included:

- In February 2008, the IRS announced the distribution of roughly $400 million in CREBs, based on applications received in 2007, including $170 million for 102 wind power projects.
- In September 2007, a total of more than $18 million in grant and loan awards were announced under the USDA's Section 9006 grant program, including $2.7 million for 7 "large wind" projects totaling 8.2 MW in capacity.
- Illinois, New Hampshire, North Carolina, and Oregon enacted mandatory RPS policies in 2007, while Ohio established an RPS in early 2008, bringing the total to 26 states and Washington D.C. (see Figure 31). A large number of additional states strengthened previously established RPS programs in 2007.
- A variety of states and regions continued to make progress in implementing carbon reduction policies, and a rising number of electric utilities considered the possible implementation of carbon regulation in their resource planning and selection processes.
- State renewable energy funds, state tax incentives, utility resource planning requirements, and green power markets all helped contribute to wind expansion in 2007.

50 In 2008, Xcel Energy reached a settlement with interveners to submit CPCN applications for new transmission facilities in all four ERZ areas by March 2009.

51 These include Colorado, Idaho, Kansas, North Dakota, New Mexico, South Dakota, and Wyoming.

52 Such entities have also been eligible to receive the Renewable Energy Production Incentive (REPI), which offers a 10-year cash payment equal in face value to the PTC, but the need for annual appropriations and insufficient funding have limited the effectiveness of the REPI.



Source: Berkeley Lab.

Figure 31. State RPS Policies and Non-Binding Renewable Energy Goals (as of May 2008)

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 5,000 MW appears to be in the offing, and past installation records may again fall. Local manufacturing of turbines and components is also anticipated to continue to grow, as announced manufacturing facilities come on line and existing facilities reach capacity and expand.

And 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.

Appendix: Sources of Data Presented in this Report

Wind Installation Trends

Data on wind power additions in the United States come from AWEA. Annual wind capital investment estimates derive from multiplying these wind capacity data by weighted-average capital cost data, provided elsewhere in the report. Data on non-wind electric capacity additions come primarily from the EIA (for years prior to 2007) and Ventyx's Energy Velocity database (for 2007), except that solar data come from the Interstate Renewable Energy Council (IREC) and Berkeley Lab. Data on the distributed wind segment come primarily from AWEA and, to a lesser extent, NREL. Information on offshore wind development activity in the United States was compiled by NREL.

Global cumulative (and 2007 annual) wind capacity data come from BTM Consult, but are revised to include the most recent AWEA data on U.S. wind capacity. Historical cumulative and annual worldwide capacity data come from BTM Consult and the Earth Policy Institute. Wind as a percentage of country-specific electricity consumption is based on end-of-2007 wind capacity data and country-specific assumed capacity factors that primarily come from BTM Consult's *World Market Update 2007*. For the United States, the performance data presented in this report are used to estimate wind production. Country-specific projected wind generation is then divided by projected electricity consumption in 2008 (and 2007), based on actual 2005 consumption and a country-specific growth rate assumed to be the same as the rate of growth from 2000 through 2005 (these data come from the EIA's *International Energy Annual*).

The wind project installation map of the United States was created by NREL, based in part on AWEA's database of wind power projects and in part on data from Platts on the location of individual wind power plants. Effort was taken to reconcile the AWEA project database and the Platts-provided project locations, though some discrepancies remain. Wind as a percentage contribution to statewide electricity generation is based on AWEA installed capacity data for the end of 2007 and the underlying wind project performance data presented in this report. Where necessary, judgment was used to estimate state-specific capacity factors. The resulting state wind generation is then divided by in-state total electricity generation in 2007, based on EIA data.

Data on wind capacity in various interconnection queues come from a review of publicly available data provided by each ISO, RTO, or utility. Only projects that were active in the queue at the end of 2007, but that had not yet been built, are included. Suspended projects are not included in these listings.

Wind Capacity Serving Electric Utilities

The listing of wind capacity serving specific electric utilities comes from AWEA's *2008 Annual Rankings Report*. To translate this capacity to projected utility-specific annual electricity generation, regionally appropriate wind capacity factors are used. The resulting utility-specific projected wind generation is then divided by the aggregate national retail sales of each utility in 2006 (based on EIA data). Only utilities with 50 MW or more of wind capacity are included in these calculations. In the case of G&T cooperatives and power authorities that provide power to other cooperatives and municipal utilities (but do not directly serve load themselves), this report uses 2006 retail sales from the electric utilities served by those G&T cooperatives and power authorities. In some cases, these individual utilities may be buying additional wind directly from other projects, or may be served by other G&T cooperatives or power authorities that supply wind. In these cases, the penetration percentages shown in the report may be understated. Finally, some of the entities shown in Table 3 are wholesale power marketing companies that are affiliated with electric utilities. In these cases, estimated wind generation is divided by the retail sales of the power marketing company and any affiliated electric utilities.

Turbine Manufacturing, Turbine Size, and Project Size

Turbine manufacturer market share, average turbine size, and average project size are derived from the AWEA wind project database. Information on wind turbine and component manufacturing come from NREL, AWEA, and Berkeley Lab, based on a review of press reports, personal communications, and other sources. The listings of manufacturing and supply chain facilities are not intended to be exhaustive. Information on wind developer consolidation and financing trends were compiled by Berkeley Lab. Wind project ownership and power purchaser trends are based on a Berkeley Lab analysis of the AWEA project database.

Wind Power Prices and Wholesale Market Prices

Wind power price data are based on multiple sources, including prices reported in FERC's Electronic Quarterly Reports (in the case of non-qualifying-facility projects), FERC Form 1, avoided cost data filed by utilities (in the case of some qualifying-facility projects), pre-offering research conducted by Standard & Poor's and other bond rating agencies, and a Berkeley Lab collection of power purchase agreements.

Wholesale power price data were compiled by Berkeley Lab from FERC's *2006 State of the Markets Report* and *2004 State of the Markets Report*, as well as from Ventyx's Energy Velocity database of wholesale power prices (which itself derives data from the IntercontinentalExchange—ICE—and the various ISOs).

REC price data were compiled by Berkeley Lab based on a review of Evolution Markets' monthly REC market tracking reports.

Installed Project and Turbine Costs

Berkeley Lab used a variety of public and some private sources of data to compile capital cost data for a large number of U.S. wind power projects. Data sources range from pre-installation corporate press releases to verified post-construction cost data. Specific sources of data include: EIA Form 412, FERC Form 1, various Securities and Exchange Commission filings, various filings with state public utilities commissions, *Windpower Monthly* magazine, AWEA's *Wind Energy Weekly*, DOE/EPRI's Turbine Verification Program, *Project Finance* magazine, various analytic case studies, and general web searches for news stories, presentations, or information from project developers. Some data points are suppressed in the figures to protect data confidentiality. Because the data sources are not equally credible, little emphasis should be placed on individual project-level data; instead, it is the trends in those underlying data that offer insight. Only wind power cost data from the contiguous lower-48 states are included.

Wind turbine transaction prices were compiled by Berkeley Lab. Sources of transaction price data vary, but most derive from press releases and press reports. In part because wind turbine transactions vary in the services offered, a good deal of intra-year variability in the cost data is apparent.

Wind Project Performance

Wind project performance data are compiled overwhelmingly from two main sources: FERC's *Electronic Quarterly Reports* and EIA Form 906. Additional data come from FERC Form 1 filings and, in several instances, other sources. Where discrepancies exist among the data sources, those discrepancies are handled based on the judgment and experience of Berkeley Lab staff.

Wind Project Operations and Maintenance Costs

Wind project operations and maintenance costs come primarily from two sources: EIA Form 412 data from 2001-2003 for private power projects and projects owned by POUs, and FERC Form 1 data for IOU-owned projects. Some data points are suppressed in the figures to protect data confidentiality.

Wind Integration, Transmission, and Policy

The wind integration, transmission, and policy sections were written by staff at Berkeley Lab, NREL, and Exeter Associates, based on publicly available information.

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www1.eere.energy.gov/windandhydro/

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