U.S. Wind Turbine Manufacturing: Federal Support for an Emerging Industry

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Summary

Increasing U.S. energy supply diversity has been the goal of many Presidents and Congresses. This commitment has been prompted by concerns about national security, the environment, and the U.S. balance of payments. More recently, investments in new energy sources have been seen as a way to expand domestic manufacturing. For all of these reasons, the federal government has a variety of policies to promote wind power.

Expanding the use of wind energy requires installation of wind turbines. These are complex machines composed of some 8,000 components, created from basic industrial materials such as steel, aluminum, concrete, and fiberglass. Major components in a wind turbine include the rotor blades, a nacelle and controls (the heart and brain of a wind turbine), a tower, and other parts such as large bearings, transformers, gearboxes, and generators. Turbine manufacturing involves an extensive supply chain. Until recently, Europe has been the hub for turbine production, supported by national renewable energy deployment policies in countries such as Denmark, Germany, and Spain. Competitive wind turbine manufacturing sectors are also located in India and Japan and are emerging in China and South Korea.

U.S. and foreign manufacturers have expanded their capacity in the United States to assemble and produce wind turbines and components. Nearly 400 U.S. manufacturing facilities produced wind turbines and components in 2010, up from as few as 30 in 2004. An estimated 20,000 U.S. workers were employed in the manufacturing of wind turbines in 2010. Because turbine blades, towers, and certain other components are large and difficult to transport, manufacturing clusters have developed in certain states, notably Colorado, Iowa, and Texas, which offer proximity to the best locations for wind energy production. The U.S. wind turbine manufacturing industry also depends on imports, with the majority coming from European countries, where the technical ability to produce large wind turbines was developed. Although turbine manufacturers' supply chains are global, recent investments are estimated to have raised the share of parts manufactured in the United States to 50%-60%, up from 25% in 2005.

The outlook for wind turbine manufacturing in the United States is partially dependent upon federal and state policies. A variety of federal laws and policies has encouraged both wind energy production and the use of U.S.-made equipment to generate that energy. Some of these policies are subject to change at the end of 2011, and others are scheduled to expire in 2012. Future decisions about these policies will affect the extent to which wind turbine manufacturing becomes an important industrial sector in the United States.

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Introduction

This report discusses the U.S. wind turbine manufacturing industry, its supply chain, employment and international trade trends, major federal policy efforts aimed at supporting the industry, and issues affecting its future. The wind industry's national trade group, the American Wind Energy Association (AWEA), reported that an estimated 20,000 Americans were employed directly and indirectly in wind turbine manufacturing in 2010, compared to 2,500 in 2004. Another 55,000 U.S. workers reportedly were employed in other parts of the wind industry in 2010, including construction and services.[1] The U.S. wind turbine market has grown in size from an estimated $2.7 billion in 2005 to $12.5 billion in 2009.[2] Following an unprecedented period of growth in the U.S. wind power market between 2005 and 2009, about half as many new wind turbines were installed in 2010 (some 3,000) as in 2009.

Aside from GE Energy and Clipper Windpower, most of the manufacturers that sell, assemble, or manufacture turbines and wind-related components in the U.S. market are headquartered outside the United States. Vestas, Gamesa, and Siemens are among the European manufacturers that have responded to government regulations that mandate the use of renewables, including wind power. Other firms manufacturing wind turbines for the U.S. wind market include Japanese and Indian companies such as Mitsubishi and Suzlon. Manufacturers from South Korea and China are also expanding production capacity and entering the U.S. market.

Federal interest in the U.S. wind turbine manufacturing industry is based on (1) increasing the role of clean energy technology in energy production; (2) encouraging advanced manufacturing and the creation of skilled manufacturing jobs; and (3) enhancing the diversity of U.S. energy sources.[3] In 2009, the Obama Administration stated that it has the goal of:

> doubling U.S. renewable energy generation capacity from wind, solar, and geothermal by 2012. This was a bold goal—to install as much renewables in the next three years as the U.S. had in the previous thirty. In addition, President Obama set the goal of doubling U.S. renewable manufacturing capacity, so that the U.S. can gain leadership in manufacturing these technologies as well.[4]

Wind energy, like many energy technologies, benefits from government incentives.[5] Without them, it does not appear likely that there would be a U.S. wind turbine industry. To a large extent,

[1] Employment data for the U.S. wind energy sector is currently only reported by the American Wind Energy Association (AWEA). Recent statistics can be found in AWEA's annual report, *U.S. Wind Industry Annual Market Report Year Ending 2010*, p. 36. The Bureau of Labor Statistics (BLS) is in the process of collecting data on "green jobs," including wind-related employment, with data publication planned for 2012 and annually thereafter. More information on the BLS Green Jobs Initiative can be found at, http://www.bls.gov/green/.

[2] The U.S. International Trade Commission's (USITC) estimate of the size of the U.S. wind turbine market was calculated by multiplying the number of megawatts (MW) supplied by each original equipment manufacturer (OEM) by the average price per MW of wind turbines for that OEM. For a discussion of this methodology see, Andrew David, *Impact of Wind Energy Installations on Domestic Manufacturing and Trade*, U.S. International Trade Commission, July 2010, p. 19, http://www.usitc.gov/publications/332/working_papers/ID-25.pdf.

[3] The U.S. Energy Information Administration (EIA) reports wind energy represented 2.3% of net electricity generation and 2.5% of national electricity consumption in the United States in 2010.

[4] White House, *The Recovery Act: Transforming the American Economy Through Innovation*, August 2010, p. 17, http://www.whitehouse.gov/sites/default/files/microsites/Recovery_Act.PDF.

[5] EIA, *Direct Federal Financial Interventions and Subsidies in Energy in Fiscal Year 2010*, July 2011, http://docs.wind-watch.org/US-subsidy-2010.pdf.

the federal government sets the framework and influences the pace of domestic wind power development.

One of the main federal policy tools to encourage wind generation is a tax credit, known as the production tax credit (PTC), which is slated to expire at the end of 2012.[6] Other policy drivers include state renewable portfolio standards, which have been adopted by more than half the states to mandate production of electricity from "clean" sources.[7] No nationwide renewable electricity standard currently exists, but the Obama Administration and some Members of Congress have endorsed the concept.[8] These policies do not directly address manufacturing, but greater wind power adoption supports the development of a U.S. wind energy manufacturing base. In addition, the federal government and some state governments have maintained programs that provide financial incentives for manufacturing of wind power equipment.

Many international wind turbine manufacturers and component suppliers have opened manufacturing facilities in the United States since 2005. In 2010, there were nearly 400 U.S.-based wind turbine manufacturing facilities—a 10-fold increase in five years—ranging from wind turbine assembly plants to factories producing various wind-related components including large bearings, castings, electrical wiring, fasteners, hydraulics, and power electronics. Given the interest in wind power around the world, manufacturers with U.S. production facilities may be able to increase exports of advanced wind-energy components. Less than $150 million in fully assembled wind turbines were exported from the United States in 2010.

The industry's future in the absence of government support, however, is open to question. While the cost of electricity from land-based wind turbines is less than the cost of power from other alternative sources, such as concentrated solar plants and geothermal installations, it is still, in general, somewhat higher than the cost of power from new gas-fired generators. This means that without government support, electricity suppliers' demand for wind turbines would be relatively limited. It is possible that, if existing policy tools are allowed to expire at the end of 2012, wind industry manufacturing will face a difficult future. On the other hand, it is imaginable that technological improvements in wind generation and higher costs for construction of fossil-fuel power plants could at some point make wind cost-competitive with coal and gas as a source of electricity, creating a bright outlook for wind turbine manufacturing.

Wind Turbine Manufacturing

Wind turbine manufacturing is at the core of the multifaceted wind power industry. Because of the use of castings, forgings, and machining, turbine manufacturing is a significant contributor to U.S. heavy manufacturing. By the end of 2010, over 35,600 wind turbines were installed in the

[6] For a detailed discussion on energy tax incentives see CRS Report R41953, *Energy Tax Incentives: Measuring Value Across Different Types of Energy Resources*, by Molly F. Sherlock.

[7] EIA, Renewable and Alternative Fuels, *Renewable Portfolio Standards and State Mandates by State*, August 2010. http://www.eia.gov/cneaf/solar.renewables/page/trends/table28.html.

[8] The Clean Energy Standard Framework announced by the White House in 2011 is discussed in CRS Report, R41720, *Clean Energy Standard: Design Elements, State Baseline Compliance and Policy Considerations*, by Phillip Brown.

United States.[9] Procurement of wind turbines accounts for an estimated 60% to 70% of overall expenses for wind energy developers.[10]

The market potential of offshore wind power is not covered in this report. No offshore projects have been installed in the United States to date, and the industry faces difficulties with permitting, financing, and infrastructure availability.[11] So far, Cape Wind, off the coast of Nantucket in Massachusetts, is the only project that has a commercial wind energy development lease from the U.S. government. Also, this report does not cover small wind turbine manufacturing, which AWEA defines as turbines with rated capacities of 100 kilowatts (kW) or less. This segment of the wind turbine market appears to be growing, with 95 manufacturers of small wind turbines based in the United States in 2009, up from 66 in 2008.[12]

Historical Overview

The use of a wind turbine to generate electricity is an American invention of the late 19th century.[13] The development of U.S. commercial wind turbine manufacturing can be traced back to the 1970s, when the U.S. government advanced the technology in response to the oil crises of 1973 and 1979 as an alternative to power generation from fossil fuels.

The first U.S. wind farms were developed in California, and the state dominated worldwide wind development in the early 1980s.[14] This created a market for wind turbine manufacturers. Enertech, U.S. Windpower (renamed Kenetech in 1988), and Zond were among the American suppliers. Other U.S. manufacturers included technology and aerospace firms such as Westinghouse and Boeing. In 1986, 60 U.S. firms produced turbines for the California market.[15] Foreign suppliers from Denmark, Germany, Japan, and the Netherlands, among other countries, also sold their wind turbines in California.[16] The California "wind rush" became the training

[9] AWEA, U.S. Wind Industry Annual Market Report 2010, p. 2.

[10] Worldwatch Institute, *Made in China, or Made by China? Chinese Wind Turbine Manufacturers Struggle to Enter Own Market*, http://www.worldwatch.org/node/3931.

[11] U.S. Department of Energy, *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States*, February 2011, http://www1.eere.energy.gov/windandhydro/pdfs/national_offshore_wind_strategy.pdf.

[12] AWEA, *2010 Small Wind Turbine Global Market Study*, Year Ending 2009, p. 18, http://www.awea.org/learnabout/smallwind/upload/2010_AWEA_Small_Wind_Turbine_Global_Market_Study.pdf.

[13] Charles F. Brush, an American inventor, constructed the first modern wind turbine in 1888, in Cleveland, OH, for the purpose of electricity generation. He used it to power his home. Thereafter, other Americans such as Palmer C. Putman built wind turbine generators, mostly for farm use, at a time when electricity distribution systems had not yet been installed. U.S. manufacturers of early wind turbine generators included Jacobs Wind and Parris-Dunn. The rural electrification project of 1936 effectively killed the wind-generated power market in the United States until the early 1970s. For more information, see Windsector, *The First Wind Turbine in the United States*, April 17, 2011. http://windsector.tumblr.com/post/4711554356/the-first-wind-turbine-in-america.

[14] Janet Swain, "The Role of Government in the Development and Diffusion of Renewable Energy Technologies: Wind Power in the United States, California, Denmark, and Germany," (Ph.D. dissertation, Fletcher School of Law and Diplomacy, 2001), pp. 200-203. This dissertation notes that by 1991 77% of the world's wind capacity was installed in California.

[15] Geoffrey Jones and Loubna Bouamane, "Historical Trajectories and Corporate Competences in Wind Energy," (Working Paper 11-112, Harvard Business School, 2011), p. 32. http://www.hbs.edu/research/pdf/11-112.pdf.

[16] Over 15,000 medium-sized wind turbines were installed in California between 1981 and 1986. See Union of Concerned Scientists, Briefing on How Wind Energy Works, http://www.ucsusa.org/clean_energy/coalvswind/brief_wind.html.

ground for several firms, including the Danish manufacturer Vestas, now the world's largest manufacturer of utility-scale wind turbines.[17]

However, a drop in oil prices, along with reductions in government tax credits, caused a near total collapse of this market in the mid-1980s.[18] In 1986, Congress eliminated the investment tax credit for wind.[19] By the end of the decade, many wind turbine manufacturers went bankrupt as the industry adjusted to a much smaller market.

For the next two decades fuel prices were low and U.S. incentives spotty. In the United States, annual installed wind power capacity slowed from 1987 to 2000. The entire U.S. wind fleet exceeded 1,000 megawatts (MW) for the first time in 1986, but then took 13 years to reach approximately 2,400 MW.[20]

In the 1990s a more sustained market for wind power and wind turbine manufacturing evolved overseas. Strong, consistent government incentives and policies, which have included a policy mix of direct government investment, tax breaks, loans, regulations and laws that cap or tax emissions, supported the development of manufacturers abroad, particularly in Europe.[21] This allowed wind turbine manufacturers to establish themselves in countries such as Denmark, Spain, and Germany, where many wind turbine manufacturers are now based.[22]

Demand for Wind Turbines and Components

Demand for wind turbines and components is driven by growth in wind power capacity. More consistent U.S. policies have resulted in a substantial increase in cumulative utility-scale wind power capacity, growing from 9,000 MW in 2005 to more than 40,000 MW in 2010.[23] The United States was second to China in cumulative and new installed wind power capacity in 2010.[24] China

[17] Large wind turbines are often called utility-scale because they generate enough power for utilities, or electric companies, to sell.

[18] Jens Vestergaard, Lotte Brandstrup, and Robert Goddard, *Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States*, Published in the Academy of International Business Conference Proceedings, p. 16-18, http://pure.au.dk/portal/files/2552/windmill_paper2.pdf.

[19] Frank Harris and Peter Navarro, *Policy Options for Promoting Wind Energy Development in California: A Report to the Governor and State Legislature*, November 1999, p. 20. http://web.gsm.uci.edu/~navarro/windfinal110899.pdf.

[20] Lester Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse*, Earth Policy Institute, Supporting Data Showing Cumulative Installed Wind Power Capacity and Annual Additions to the United States, 1980-2009, 2011, http://www.earth-policy.org/books/wote/wote_data_topic.

[21] An overview of policy instruments used by various governments to promote renewables, including wind power, can be found on the Renewable Energy Policy Network website at http://www.ren21.net/RenewablesPolicy/PolicyInstruments/tabid/5608/Default.aspx.

[22] The wind turbine industry advanced in Europe, specifically in Denmark, beginning in the early 20th century based largely on the wind turbines constructed by Poul la Cour. For background, see Jens Vestergaard, Lotte Brandstrup, and Robert Goddard, *"A Brief History of the Wind Turbine Industries in Denmark and the United States,"* (Academy of International Business, 2004), http://www.hha.dk/man/cmsdocs/publications/windmill_paper1.pdf.

[23] AWEA, *U.S. Wind Industry Annual Market Report 2010*, p. 4. Utility-scale wind turbines as defined by AWEA are large turbines with generating capacity of 100 kW and larger.

[24] China faces major challenges with grid connection of installed wind turbines, as some projects in China have to wait several months before being connected to the national grid. Thus, the United States continues to exceed China in grid connected wind power capacity. China issues two figures when it reports its wind power data. In 2010, China reported that it installed 44.7 gigawatts (GW) of onshore wind power, but only 31 GW was operational and connected to the grid. In other markets, it is common practice to count all turbines as soon as they are grid connected and producing (continued...)

and the United States accounted for over 40% of total installed worldwide wind power capacity at the end of 2010.[25] The size of the U.S. market, notwithstanding the sharp decrease in new installed capacity in 2010, has made the United States an attractive investment location for wind turbine and wind component manufacturers.[26]

Major customers for wind turbine manufacturers are large independent power producers (IPPs) and utilities such as Iberdrola Renewables, NextEra Energy Resources, Horizon-EDPR, Terra-Gen, Duke Energy, or Xcel Energy, which purchase wind turbines for commercial electricity generation.[27] Other wind turbine customers include universities and military bases, but these customers account for a very small share of the market.

Commercial utility-scale onshore wind turbines are installed at wind farms, which are clusters of wind turbines grouped together to produce large amounts of electricity. Currently, there are more than 800 wind farms in the United States.[28] The largest wind projects are located in Texas (see **Table 1**), which is by far the leading state in wind energy output with over 10,000 MW of total installed capacity by year-end 2010.[29] Other large wind-power projects are in Indiana, Oregon, and Colorado. Several large U.S. wind farms are owned and managed by overseas companies. For example, the world's largest wind farm, in Roscoe, TX, is owned and operated by Germany-based E.ON Climate and Renewables. It consists of more than 600 wind turbines purchased from three different manufacturers: Mitsubishi, General Electric (GE), and Siemens.[30]

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electricity. For more information see REN21, *Renewables 2011 Global Status Report*, Table R2, p. 71. http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf.

[25] Global Wind Energy Council (GWEC) *Global Wind 2010 Report*, August 2011, p. 11, http://www.gwec.net/fileadmin/documents/Publications/Global_Wind_2007_report/GWEC%20Global%20Wind%20Report%202010%20low%20res.pdf.

[26] The United States saw a sharp decline in new installations in 2010 measured by wind power capacity, which dropped nearly 50% to 5,100 MW in 2010 from a record 10,000 MW installed in 2009.

[27] Independent power producers are companies that produce power that they sell to electric utilities.

[28] A list of the more than 800 wind farms in the United States can be accessed at Windpower's wind turbine and wind farms database, http://www.thewindpower.net/country-datasheet-windfarms-4-usa.php.

[29] If Texas were a country, it would rank sixth in the world in total installed capacity, behind India but ahead of several European countries including Italy, France, and the United Kingdom. AWEA, *U.S. Wind Industry Annual Market Report 2010*, p. 9.

[30] E.On Climate & Renewables is based in Dusseldorf, Germany. More information about their North American projects can be founded at, http://www.eoncrna.com/contentProjects.html.

Table 1. Largest U.S. Wind Power Projects

Top 5 Projects by Installed Capacity

Project Name	State	Installed Capacity (MW)	Year Online	Owner	Turbines/Manufacturers/Turbine Size
Roscoe	Texas	781.5	2008	E.On Climate & Renewables	406 Mitsubishi 1 MW WT; 55 Siemens 2.3 MW WT; 166 GE 1.5 MW WT
Horse Hollow	Texas	735.5	2006, 2006	NextEra Energy Resources	291 GE 1.5 MW; 130 Siemens 2.3 MW
Capricorn Ridge	Texas	662.5	2007, 2008	NextEra Energy Resources	342 GE 1.5 MW; 62 Siemens 2.3 MW
Sweetwater	Texas	585.3	2003, 2005, 2007	Babcock & Brown Wind, Catamount	135 Mitsubishi 1 MW; 46 Siemens 2.3 MW WT
Buffalo Gap	Texas	523.3	2005, 2007, 2008	AES	67 Vestas 1.8 MW; 155 GE, 1.5 MW; 74 Siemens 2.3 MW

Source: American Wind Energy Association (AWEA)

Wind Turbine Suppliers

International Manufacturers Dominate Wind Turbine Manufacturing

In 2010, 10 wind turbine manufacturers accounted for more than three-quarters of the global market measured by newly installed capacity. The three largest manufacturers were:

- Vestas at 14.8% (Denmark);
- Sinovel at 11.1% (China); and,
- GE at 9.6% (U.S.).[31]

Other leading manufacturers are listed in **Appendix A**. These firms are headquartered in Europe, the United States, India, and China. GE Energy[32] and UTC/Clipper Windpower[33] are the only U.S.-headquartered utility-scale wind turbine manufacturers.

[31] Ekopolitan, "World Turbine Manufacturers' Market Shares, 2008-2010," BTM Estimates, http://www.ekopolitan.com/tech/wind-global-market-shares-2010.

[32] Zond was purchased by Enron Wind in 1997, which was the only surviving U.S.-headquartered manufacturer of utility-scale wind turbines by 2002. GE's embrace of wind began with the bankruptcy of Houston's Enron Corporation. In 2002, GE, which had long produced turbines for power generation, acquired Enron Wind's fully integrated wind power capacity including its line of wind turbine generators positioning its business unit, GE Wind Energy, to become a major player in the wind power industry.

[33] Clipper Windpower does not rank among the top 10 global wind turbine manufacturers and it has found itself squeezed in the United States, its main market, by larger competitors such as GE, Vestas, and Siemens. In December 2010, United Technologies Corporation (UTC) purchased all of the stock in Clipper. Clipper manufactures one of the (continued...)

Some manufacturers, including Gamesa, Vestas, and Suzlon, focus exclusively on wind turbines. Others are part of larger diversified companies. All pursue a global business strategy, which means selling outside their home markets. Many operate manufacturing facilities throughout the world, including the United States, Europe, and China.

Recently, several Chinese companies have begun producing wind turbines, selling mainly in the large and growing China market.[34] China, which had virtually no wind turbine manufacturing capabilities in 2005, is now home to over 270 producers,[35] some of them capable of producing complete wind turbine systems with locally made products.[36] Four of the top 10 manufacturers worldwide in 2010 were headquartered in China (see **Appendix A**), where, by some estimates, turbines can be manufactured for 30% less than in Europe, the United States, or Japan.[37] Some Chinese firms apparently are looking for overseas markets,[38] but concerns about the quality of Chinese turbines are one factor that might limit foreign sales since Chinese-made turbines are not yet seen as being as high in quality as European and American ones.[39]

South Korean companies are also making huge investments in wind turbine production. Two large South Korean shipbuilders, Hyundai Heavy Industries and Samsung Heavy Industries, have announced their intention to manufacture wind turbines. Additionally, South Korean wind turbine component manufacturers like Doosan, Hanjin, Taewoong, Hyosung, CS Wind, and Korea Tech are becoming important suppliers of towers, blades, generators, transformers, gearboxes, nacelle control systems, and cables.

U.S. Market Attracts More Foreign Wind Turbine Manufacturers

The leading manufacturers of utility-scale wind turbines in the United States are shown in **Table 2**. In 2005, six wind turbine manufacturers (GE Energy, Vestas, Gamesa, Suzlon, Mitsubishi, and Clipper) installed about 1,600 new utility-scale turbines in the United States which produced nearly 2,400 MW of new wind capacity. In 2010, 18 wind turbine manufacturers—a three-fold increase in five years—installed nearly 3,000 new turbines nationwide, generating 5,100 MW of new capacity. This was down from the 2009 peak, when some 5,700 new wind turbines were installed, adding nearly 10,000 MW of new utility-scale wind capacity.[40] AWEA data indicate that

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largest wind turbines made in the United States, the 2.5-MW Liberty turbine. For more information on UTC's acquisition see, United Technologies Complete Clipper Windpower Acquisition, December 15, 2010. http://www.utc.com/News/Archive/2010/United+Technologies+Completes+Clipper+Windpower+Acquisition.

[34] GWEC reports China's wind market doubled every year between 2006 and 2009, and it has been the largest annual market by installed capacity in the world since 2009.

[35] Joshua Meltzer, *The United States and China: The Next Five Years*, The Brookings Institution, May 19, 2011, p. 17, http://www.brookings.edu/~/media/Files/events/2011/0519_us_china/20110519_us_china_panel4.pdf.

[36] Geoffrey Jones and Loubna Bouamane, "Historical Trajectories and Corporate Competences in Wind Energy," (Working Paper 11-112, Harvard Business School, 2011), p. 55.

[37] Pilita Clark and Leslie Hook, "China Set to Challenge Global Wind Industry," *Financial Times*, August 28, 2011.

[38] John McDonald, *Wind Power Market Opportunity Profile, China*, British Columbia Trade and Investment, 2009, pp. 2-3, https://trade.britishcolumbia.ca/Export/Markets/Documents/China_WindPower.pdf.

[39] Joanna Lewis, *Can Green Sunrise Industries Lead the Drive into Recovery? The Case of the Wind Power Industry in China and India*, United Nations Industrial Development Organization, 2010, p. 7, http://www.unido.org/fileadmin/user_media/Publications/RSF_DPR/WP202009_Ebook.pdf.

[40] AWEA, *U.S. Wind Industry Annual Market Report 2010*, p. 27.

more new capacity will be installed in 2011 than in 2010.[41] To install these turbines, thousands of blades, tower sections, and bolts, among many other components, are needed, which in turn creates demand for wind-related products.[42]

Table 2. Annual Wind Turbine Installations in the United States

Top 10 Manufacturers by selected years, 2005, 2009, and 2010, Ranked by Number Installed in 2010

Original Equipment Manufacturer (OEM)/Assembler[a]	Location of Headquarters	2005 (# of Turbines)	2009 (# of Turbines)	2010 (# of Turbines)
GE Energy	United States	954	2,663	1,679
Siemens	Germany	0	505	360
Gamesa	Spain	25	300	282
Suzlon[b]	India	8	344	201
Mitsubishi	Japan	190	491	146
Vestas	Denmark	403	830	75
Acciona WP	Spain	0	136	66
Repower	Germany	0	165	34
UTC/Clipper[c]	United States	1	242	28
Daewoo CTC/DeWind[d]	South Korea	0	3	10
All Others		33	86	6
Total		**1,614**	**5,765**	**2,942**

Source: AWEA, U.S. Wind Industry Annual Market Report, 2010 and U.S. Wind Industry Annual Market Report, 2009. The number of turbines is based on data compiled by AWEA and is accurate as of August 31, 2011, but is subject to revision.

Notes:

a. A wind turbine OEM designs the full turbine, it typically assembles the nacelle, and sells the completed turbine to developers.

b. Suzlon wind turbine installations would total 235 if REpower's 34 turbines were added to Suzlon's turbines. Full control of REpower by Suzlon is expected to be approved at the next Annual General Meeting of REpower presumably to take place in September 2011.

c. Clipper was acquired by United Technologies Corporation in 2010.

d. CTC/DeWind was acquired by the South Korean company Daewoo Shipbuilding & Marine Engineering Company (DSME) in 2009 and is now a wholly-owned subsidiary.

[41] AWEA's 2nd Quarter 2011 Market Report found that total installations through the first half of 2011 reached 2,151 MW compared to 1,250 for the same period in 2010.

[42] According to AWEA, the installation of over 5,700 turbines in the United States in 2009 required industrial manufacturers to supply 17,000 blades and tower sections, approximately 3.2 million bolts, 36,000 miles of rebar, and 1.7 million cubic yards of concrete. AWEA, *Anatomy of a Wind Turbine*, http://www.awea.org/issues/supply_chain/Anatomy-of-a-Wind-Turbine.cfm.

In 2010, GE continued to lead in the number of new wind turbine installations at nearly 60% of the U.S. market. Of foreign-owned wind turbine manufacturers, European companies represent a significant share each year. In 2010, Siemens, Gamesa, and Vestas comprised over three-quarters of new wind turbine installations in the United States. While U.S. and European manufacturers install the overwhelming majority of wind turbines in the United States, the U.S. market is becoming more diverse. In 2009, for the first time, a Chinese manufacturer installed wind turbines in the United States at the Uilk wind farm project in Pipestone, MN.[43] South Korean manufacturers are new to the U.S. market and have installed about a dozen wind turbines in the United States.[44]

Wind Turbine Components, Raw Materials, Global Supply Chain, and U.S. Manufacturing Capacity

Wind Turbine Components

A wind turbine is a collection of operating systems that convert energy from wind to produce electricity. Utility-scale wind turbines are massive, complex pieces of machinery which come in many sizes and configurations.[45] Wind turbine blades range in size from 34 to 55 meters, the hub can weigh 8 to 10 tons, and towers are usually 80-100 meters tall and weigh 55 to 70 tons.[46]

[43] Goldwind, *About Goldwind History*, http://www.goldwindamerica.com/about_history.aspx.

[44] South Korea's Daewoo Shipbuilding & Marine Engineering Company (DSME) acquired DeWind in 2009. The company's objective is to become the world's third largest wind turbine market by 2020. Analysts expect South Korean manufacturers to make more strategic acquisitions in the wind sector. More information on South Korea's wind energy sector, including major players in the South Korean wind industry, can be found in a report by the Maine International Trade Center, *"Opportunities for Maine Companies in Korean New and Renewable Energy (NRE) Markets*," pp, 7-9, November 2010. http://www.mitc.com/PDFs/RenewableEnergyinKorea_Report.pdf.

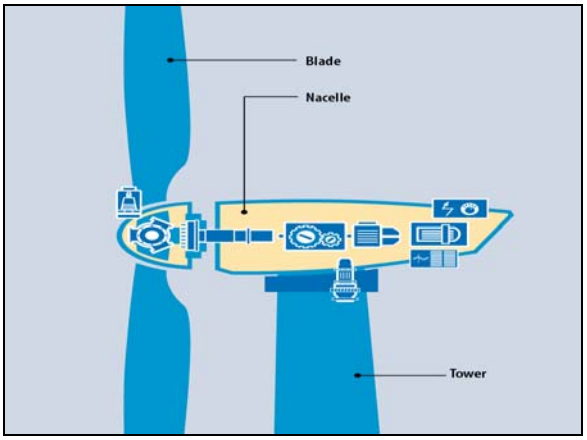
[45] For more information about commercial, utility-scale wind turbine technology see, CRS Report RL34546, *Wind Power in the United States: Technology, Economic, and Policy Issues*, by Stan Mark Kaplan.

[46] AWEA, *Anatomy of a Wind Turbine*, http://www.awea.org/issues/supply_chain/Anatomy-of-a-Wind-Turbine.cfm.

In simple terms, as shown in **Figure 1**, the major components in a wind turbine consist of:

- a rotor comprising four principal components—the blade, the blade extender, the hub, and the pitch drive system;
- a nacelle, the external shell or structure resting atop the tower containing and housing the controller, gearbox, generator, large bearings, connecting shafts, and electronic components that allow the turbine to monitor changes in wind speed and direction;

Figure 1. Wind Turbine Overview



Source: Wind Directions, *"Supply Chain: The Race to Meet Demand,"* January/February 2007

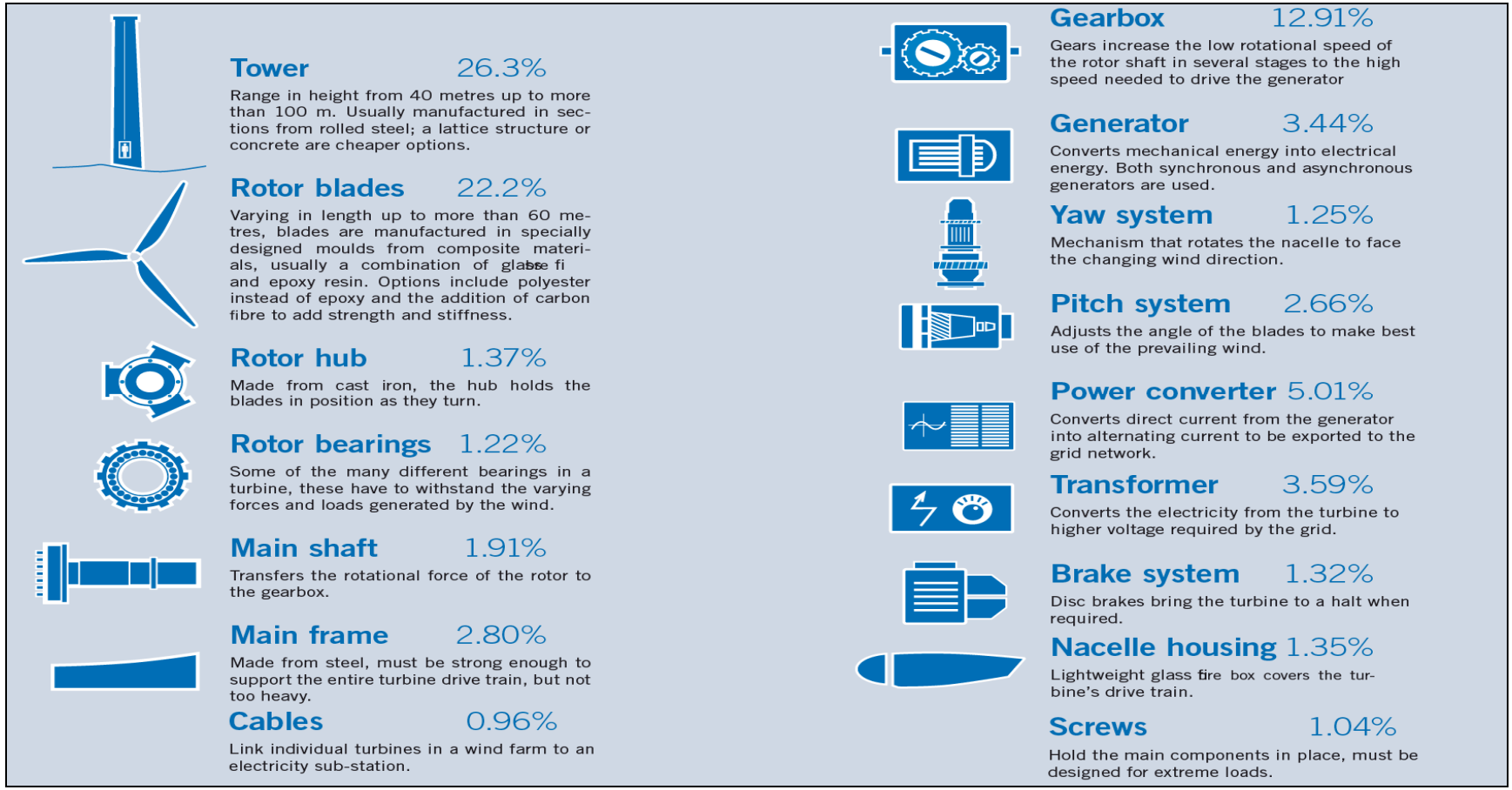
- a tower, normally made of rolled steel tube sections that are bolted together to provide the support system for the blades and nacelle; and,
- other components, including transformers, circuit breakers, fiber optic cables, and ground-mounted electrical equipment.[47]

Beyond the major components, there are many subcomponents in a wind turbine. The percentages shown in **Figure 2** indicate the costs of the components relative to the overall cost of a turbine. The tower, for example, is over 26% of the total cost of a wind turbine, rotor blades 22%, the gearbox 13%, and the other components 5% or less.

[47] A detailed description of the components in a wind turbine can be found in *Wind Turbine Development: Location of Manufacturing Activity*, by George Sterzinger and Matt Svrcek, Renewable Energy Policy Project, September 2004. http://www.repp.org/articles/static/1/binaries/WindLocator.pdf.

Figure 2. Wind Turbine Components

Contribution of main parts as a percentage of overall costs based on a REpower MM92 Turbine



Source: Wind Directions, *"Supply Chain: The Race to Meet Demand,"* January/February 2007.

Wind turbines vary greatly in size and are getting larger as technology advances. They have grown from dozens of kilowatts in the early 1980s to as large as 7 MW.[48] Most land-based wind turbines are in the 1.5 MW to 3 MW range.[49] Components also change as technology improves. Research and development (R&D) is critical to the long-term competitiveness of the wind turbine industry. Manufacturers strive to make their turbines more powerful, efficient, and reliable without significantly increasing costs. European and U.S. wind turbine manufacturers have invested heavily over the decades in developing their respective turbine technologies, leading to improvements in the efficiency of wind blades and turbines and longer turbine life. New wind turbine manufacturers, especially from China, are not yet globally competitive. According to recent research, they generally lack state-of-the-art technology, focus mainly on producing smaller turbines, and experience significant quality control problems.[50] Raw materials availability and changing commodity prices of raw materials used in wind turbines affect wind turbine manufacturers' production costs.[51] A typical wind turbine is made primarily of steel (about 90% by weight) (see **Table 3**). Aluminum and other light-weight composites are also important, particularly for blade manufacturing. Other core materials include pre-stressed concrete, copper, and fiberglass. Turbines also utilize permanent magnets, cast iron, carbon fiber, rubber, wood expoxy, ferrite, brass, ceramics, and teflon.[52]

Table 3. Raw Materials Requirements for Wind Turbines

based on a 1.5MW Wind Turbine by % of Weight, including blades and towers

	Steel	Fiberglass	Copper	Concrete	Adhesive	Aluminum	Core Materials
Weight %	89.1%	5.8%	1.6%	1.3%	1.1%	0.8%	0.4%

Source: U.S. Department of Energy, 20% Wind Energy by 2030, p. 63, July 2008

Global Wind Turbine Assembly Supply Chain

Wind turbines are manufactured by original equipment manufacturers, or OEMs, which design, assemble, and brand their products. Similar to automobile assemblers that make a car or truck, OEMs are mostly system integrators. Assemblers must bring together an estimated 8,000 precision parts and components to produce a wind turbine.[53] One supplier might roll large plates

[48] The German manufacturer Enercon has built the world's largest turbine model to date, the Enercon E-126, which can generate up to 7 MW of power.

[49] Economic and Workforce Development Program California Community Colleges, *Wind Turbine Technicians*, September 2009, p. 35, http://www.coeccc.net/Environmental_Scans/wind_scan_sw_09.pdf.

[50] Chi-Jen Yang, Eric Williams, and Jonas Monast, *Wind Power: Barriers and Policy Solutions*, Nicholas School of the Environment at Duke University, November 2008, pp. 14-15. http://nicholasinstitute.duke.edu/climate/electricity/wind-power-barriers-and-policy-solutions.

[51] Jacob Funk Kirkegaard, Thilo Hanemann, and Lutz Weischer, *It Should Be a Breeze: Harnessing the Potential of Open Trade and Investment Flows in the Wind Energy Industry*, Peterson Institute for International Economics, December 2010, p. 41, http://www.iie.com/publications/wp/wp09-14.pdf.

[52] David Wilburn, *Wind Energy in the United States and Materials Required for the Land-Based Wind Turbine Industry From 2010 through 2030*, U.S. Geological Survey, Scientific Investigations Report 2011-5036, 2011, pp. 7-8, http://pubs.usgs.gov/sir/2011/5036/sir2011-5036.pdf.

[53] Gloria Ayee, Marcy Lowe, and Gary Gereffi, et al., *Manufacturing Climate Solutions Carbon Reducing Technologies and U.S. Jobs*, Center on Globalization Governance and Competitiveness, Wind Power, September 22, 2009, p. 10, http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch11_WindPower.pdf.

of steel into the towers that support the turbine. A second company might make the turbine blades from special carbon fiber materials, and a third might manufacture the electronic computerized control systems. Each of these components might be produced domestically, might be assembled domestically from imported inputs, or might be imported as an assembled product.[54]

Tier 1 and Tier 2 Wind Turbine Component Suppliers

Many suppliers and specialty firms are part of this complex global supply chain. Tier 1 suppliers make large components such as towers, hubs, blades, or gearboxes. They include firms such as LM Wind (blades), SKF (bearings), and Winergy (gearboxes). Tier 2 suppliers produce subassemblies such as ladders, fiberglass, control systems, hydraulics, power electronics, fasteners, resin, machine parts, or motors. They include companies such as American Roller Bearings (power transmission bearings), Cardinal Fasteners (structural fasteners), and Timken (power transmission bearings).

Manufacturing Strategies

A wind turbine is a significant investment. One source reports commercial-scale turbines, which on average are 2 MW in size, cost about $3.5 million installed.[55] Researchers at the Lawrence Berkeley National Laboratory reported that wind turbine transaction price quotes can range from as low as $900/kilowatt (kW) to a high of $1,400/kW.[56]

Each wind turbine assembler uses different sourcing strategies and levels of vertical integration. Some produce almost all major components internally or through subsidiaries, while others outsource many of their critical components.[57] For instance, some manufacturers produce blades, generators, or gearboxes in-house, while others opt for outside suppliers. Hundreds of smaller companies make specialized parts such as clutches, rotor bearings, fasteners, sensors, and gears for the wind industry.[58] Illustrative examples of some of the thousands of components in a modern wind turbine are shown in **Table 4**.

Very high levels of expertise and specialization are required of wind turbine suppliers, with the level of precision similar to that of the aerospace industry. Turbine manufacturers often establish relationships with suppliers in the interest of quality, as a failure in a turbine part can be very expensive to fix. Wind turbines are expected to survive largely unattended in extreme climactic

[54] BlueGreen Alliance, *Clean Energy Economy Report 2009*, June 15, 2009, p. 3, http://www.repp.org/articles/BGA_Repp.pdf.

[55] "How Much Do Wind Turbines Cost?," *Windustry*. http://www.windustry.org/how-much-do-wind-turbines-cost.

[56] U.S. Department of Energy, *2010 Wind Technologies Market Report*, June 2011, p. 51.

[57] One analysis of vertical integration among wind OEMs indicates that companies like Suzlon and Enercon have significant in-house production and high or very high levels of vertical integration; Siemens and Vestas fall in the middle; and GE is less vertically integrated than many other manufacturers, relying on outside suppliers for blades, gearboxes, generators, castings and forgings, and towers. Josh Lutton, *Wind Turbine Manufacturer Recommendations (Round 2)*, Woodlawn Associates, April 27, 2010, p. 6, http://www.woodlawnassociates.com/uploads/Woodlawn_Associates_WT_Recs_-_R2_100427.pdf.

[58] Dan Ancona and Jim McVeigh, *Wind Turbine—Materials and Manufacturing Fact Sheet*, Prepared by the Office of Industrial Technologies, U.S. Department of Energy. August 29, 2001. http://www.perihq.com/documents/WindTurbine-MaterialsandManufacturing_FactSheet.pdf.

conditions for a design life of as much as 20 years.[59] Product quality is also of concern to wind farm operators, as a malfunctioning turbine can reduce operating revenue.[60]

Table 4. Selected Wind Turbine Components

Towers:	**Nacelle:**	**Foundation:**
• Towers	• Nacelle Cover	• Rebar
• Ladders	• Nacelle Base	• Concrete
• Lifts	• Heat exchanger	• Casings
Rotor:	• Controllers	**Other:**
• Hub	• Generator	• Transformers
• Nose Cone	• Power Electronics	• Bolts/Fasteners
• Blades	• Lubricants	• Wire
• Pitch Mechanisms	• Filtration	• Paints and Coatings
• Drives	• Insulation	• Lighting Protection
• Bakes	• Gearbox	• Steelworking/Machining
• Rotary Union	• Pump	• Communication Devices
	• Drivetrain	• Control and Condition Monitoring Equipment
	• Ceramics	• Electrical Interface and Connections
	• Shaft	• Batteries
		• Bearings
		• Brakes

Source: AWEA, *Manufacturing Supplier Handbook for the Wind Energy Industry*, 2011, p. 29. http://www.awea.org/issues/supply_chain/upload/Supplier-Handbook.pdf

[59] Michelle Avis and Preben Maegaard, *Worldwide Wind Turbine Market and Manufacturing Trends*, Xmire, January 2008, p. 21, http://www.folkecenter.net/mediafiles/folkecenter/pdf/Market_and_Manufacturer_Trends.pdf.

[60] Manufacturers like Suzlon have experienced recent failures of their turbines. Reliability and performance are critical factors affecting shareholder value, the reputation, and future growth of any wind OEM.

U.S. Wind Turbine Manufacturing Facilities

At the end of 2010, the American Wind Energy Association reported that 395 wind turbine manufacturing facilities were located in the United States, up substantially from the 30-40 wind-related manufacturing facilities nationwide in 2004.[61] Over that period, the number of tower plants increased from 6 to 22; the number of blade facilities rose from 4 to 11; and the number of nacelle assembly facilities grew from 3 to 12.[62] The others were Tier 2 manufacturing facilities, which include factories manufacturing critical components such as bearings, castings, fasteners, gearboxes, and generators.[63] Total investment in facilities to manufacture for the wind industry in the United States has exceeded $1.5 billion.[64]

U.S. Wind-Related Manufacturing Facilities, Number of Facilities by Selected Categories, 2010

Towers 22

Blades 11

Nacelle Assembly 12

Fasteners 19

Bearings 18

Castings 13

Gearboxes 1

Generators 1

These figures reflect the number of U.S. production facilities at the end of 2010. **Source**: AWEA

Greater demand for wind turbines, cost savings related to transportation, and concern about the risks associated with currency fluctuations are among the reasons wind turbine and component manufacturers have opened new production facilities in the United States since 2005.[65] Even with increased domestic production capacity, wind turbine assemblers source parts and components on a worldwide basis, reflecting the industry's global supply chain. Many wind manufacturers with production facilities in the United States also produce elsewhere, typically in Europe and Asia.

Towers and Blades

Towers and blades were among the first wind products manufactured in the United States because they are large, expensive, and difficult to transport.[66] Thus, manufacturers find it easier and less costly to fabricate near their installation point. Many tower manufacturers in the United States are American companies and include firms such as Ameron, Trinity Structural Towers, DMI Industries, and Tower Tech Systems. Foreign manufacturers, such as Gamesa and Vestas, also

[61] In some of its publications AWEA reports that there were over 400 wind-related manufacturing facilities. This larger number includes small wind production and R&D facilities.

[62] AWEA, Wind *Energy Industry Manufacturing Supplier Handbook*, p. 13, June 2010.

[63] AWEA provided these statistics to CRS via email on August 29, 2011.

[64] AWEA, *Policy and Manufacturing: Demand-Side Policies Will Fuel Growth in the Wind Manufacturing Sector*, 2011, p. 3, http://www.thenewnorth.com/resources/mwgpolicypaper.pdf.

[65] Andrew David, *Impact of Wind Energy Installations on Domestic Manufacturing and Trade*, U.S. International Trade Commission, July 2010, p. 7, http://www.usitc.gov/publications/332/working_papers/ID-25.pdf.

[66] Transporting wind turbines, which requires special trucks, railroad carriages, and cranes, is difficult because of their unusual weight, length, and shape. For example, a typical nacelle weighs between 50 and 70 tons. Blades can run from 110 feet to 145 feet. Towers can weigh 70 tons. According to some estimates, transportation costs can account for up to 20% of the installed cost of a wind turbine. Estimates from AWEA suggest that per-turbine transportation and logistics costs range from $100,000 to $150,000. For more information see, *The Logistics of Transporting Wind Turbines: Reducing Inefficiencies, Costs, and Community Impact by Streamlining the Supply Chain*, CN White Paper 2009, http://www.cn.ca/documents/WhitePapers/Transporting-Wind-Turbines-White-Paper-en.pdf.

have located tower manufacturing facilities in the United States. Similarly, suppliers of blades have increased their U.S. manufacturing capacity, with nearly three times as many facilities in 2010 as in 2005. For example, LM Wind Power, headquartered in Denmark, is the largest supplier of blades in the world; it now produces blades at two U.S. manufacturing facilities, in addition to a plant in Canada and production facilities in Europe, India, and China.[67] Other blade manufacturers with U.S. production facilities include two American companies, TPI Composites and Molded Fiberglass. Both make blades for GE.

Turbine Nacelle Assembly

European OEMs—Gamesa, Acciona, Nordex, Siemens, and Vestas—have opened nacelle assembly plants in the United States in recent years.[68] Some started investing in the United States heavily after the American Recovery and Reinvestment Act (P.L. 111-5) passed in 2009.[69] Siemens and Nordex also opened their first U.S. nacelle assembly facilities in 2009. GE has three nacelle assembly facilities in the United States, all established prior to 2005, and also operates turbine component plants in China, Vietnam, and Europe. With the exception of DeWind, which was a German-owned manufacturer acquired by South Korea's Daewoo Shipbuilding & Marine Engineering Company in 2009, Asian manufacturers lag behind in establishing a U.S. nacelle manufacturing presence. For instance, Japanese-headquartered Mitsubishi expects to open its first U.S. nacelle assembly plant in 2012, although the plant may sit idle until GE and Mitsubishi resolve a lengthy patent dispute.[70] If the Mitsubishi plant comes online, it is expected to manufacture up to 250 wind turbine nacelles, 250 wind generating sets, and 750 nacelle components each year for the U.S. market and export.[71] **Appendix B** provides an overview of the varied investment strategies pursued by wind turbine assemblers from Europe, as well as India and Japan, in the United States.

Other Wind Turbine Components

A more robust domestic manufacturing base for wind turbine components such as bearings, gearboxes, and power transmissions is also being established in the United States, albeit more slowly than for towers, blades, and nacelle assembly. Gearboxes and bearings are among the most critical components for any wind turbine manufacturer because failures in either of these parts mean the wind turbine will fail. Bearings for wind turbines are made by a few manufacturers, such as German-headquartered FAG[72] and U.S.-headquartered Timken.[73] Both have production

[67] LM Wind Power, LM Wind Power Group—Facts, http://www.lmwindpower.com/upload/lmwp_factsheet_groupuk_020511.pdf.

[68] AWEA, *U.S. Wind Industry Annual Market Report, 2010*, 2011, p. 33.

[69] The American Recovery and Reinvestment Act (ARRA) was signed into law by President Obama on February 17, 2009. The $787 billion economic stimulus package contains spending and tax cuts for the energy sector, including energy grants, loans, and tax credits.

[70] Mitsubishi Power Systems, "GE Faces Antitrust Lawsuit Over Unlawful Efforts to Monopolize U.S. Variable Speed Wind Turbine Market," press release, May 20, 2010, http://www.mpshq.com/company/pdf/GElitigation.pdf.

[71] "FTZ Subzone Requested at Arkansas Wind Turbine Facility," *World Trade Interactive*, August 26, 2011.

[72] FAG, a unit of the Schaeffler Group, is one of the world's largest manufacturers of rolling bearings. It has been producing bearings for wind turbines for over 30 years. It has a U.S. production facility in Joplin, MO See FAG, *"Expertise in Bearing Technology and Service for Wind Turbines,"* March 2010, http://www.schaeffler.com/remotemedien/media/_shared_media/library/schaeffler_2/brochure/downloads_1/pwe_de_en.pdf.

capacity in the United States and operate factories in Europe and Asia. Gearboxes are also made by a relatively small number of companies, such as Winergy (now part of Siemens), which established U.S. production capacity in Illinois in 2009.[74] Winergy also makes gearboxes in Europe, China, and India.[75] Suppliers of power transmissions to wind manufacturers, such as ABB, Beckmann Volmer, and Vest-Fiber, have announced that they intend to open U.S. plants.

Outlook

So far, there is little evidence that the financial crisis and recession of 2008 and 2009 has substantially diminished the interest by manufacturers in establishing wind-related production facilities in the United States. Arguably, some of the provisions in the American Reinvestment and Recovery Act (ARRA) have helped to sustain this sector. In 2010, 40 manufacturers, including Alstom (turbines), Schuff Steel (towers), and ZF (gearboxes) announced plans to build manufacturing facilities in the United States.[76] A Chinese OEM, A-Power, also announced plans to construct a U.S. turbine nacelle assembly facility in Nevada.[77] Over 450 wind-related manufacturing facilities are expected to locate production in the United States in coming years, assuming that economic conditions justify the investment.[78]

An Emerging U.S. Wind Manufacturing Corridor

A concentration of tower, blade, and nacelle assembly plants is found in the central part of the United States, as shown in **Figure 3**. Texas, Iowa, Colorado, Arkansas, and Kansas are positioned near sites that are favorable for wind power generation, enabling manufacturers there to minimize transportation challenges and costs.[79] In addition, wind turbine assemblers and tower and blade manufacturers have been attracted to these states by incentive packages including property tax abatements, sales tax reductions, low-interest loans, and support for worker training. Other wind-related manufacturing facilities are located in Pennsylvania, Michigan, and Ohio, where the decline of automotive and heavy industrial manufacturing has left behind a workforce with prior experience with steel, assembly lines, robotics, and other aspects of heavy manufacturing.

(...continued)

[73] Timken, headquartered in Ohio, is a global supplier of bearings with a full line for the wind industry. Timken has one U.S. production plant located in South Carolina. It also has eight plants in China. Timken, *Wind Energy Solutions*, 2009, http://www.timken.com/en-us/solutions/windenergy/Documents/10280WindEnergyBrochure.pdf.

[74] "Siemens & Winergy Open Wind Turbine Manufacturing Plant," *Renewable Energy World.com*, August 31, 2009. http://www.renewableenergyworld.com/rea/news/article/2009/08/siemens-winergy-open-turbine-manufacturing-plant.

[75] Winergy, Production Locations, http://www.winergy-group.com/cms/website.php?id=/en/about-winergy/locations.htm.

[76] AWEA, *U.S. Wind Industry Annual Market Report, 2010*, 2011, p. 31.

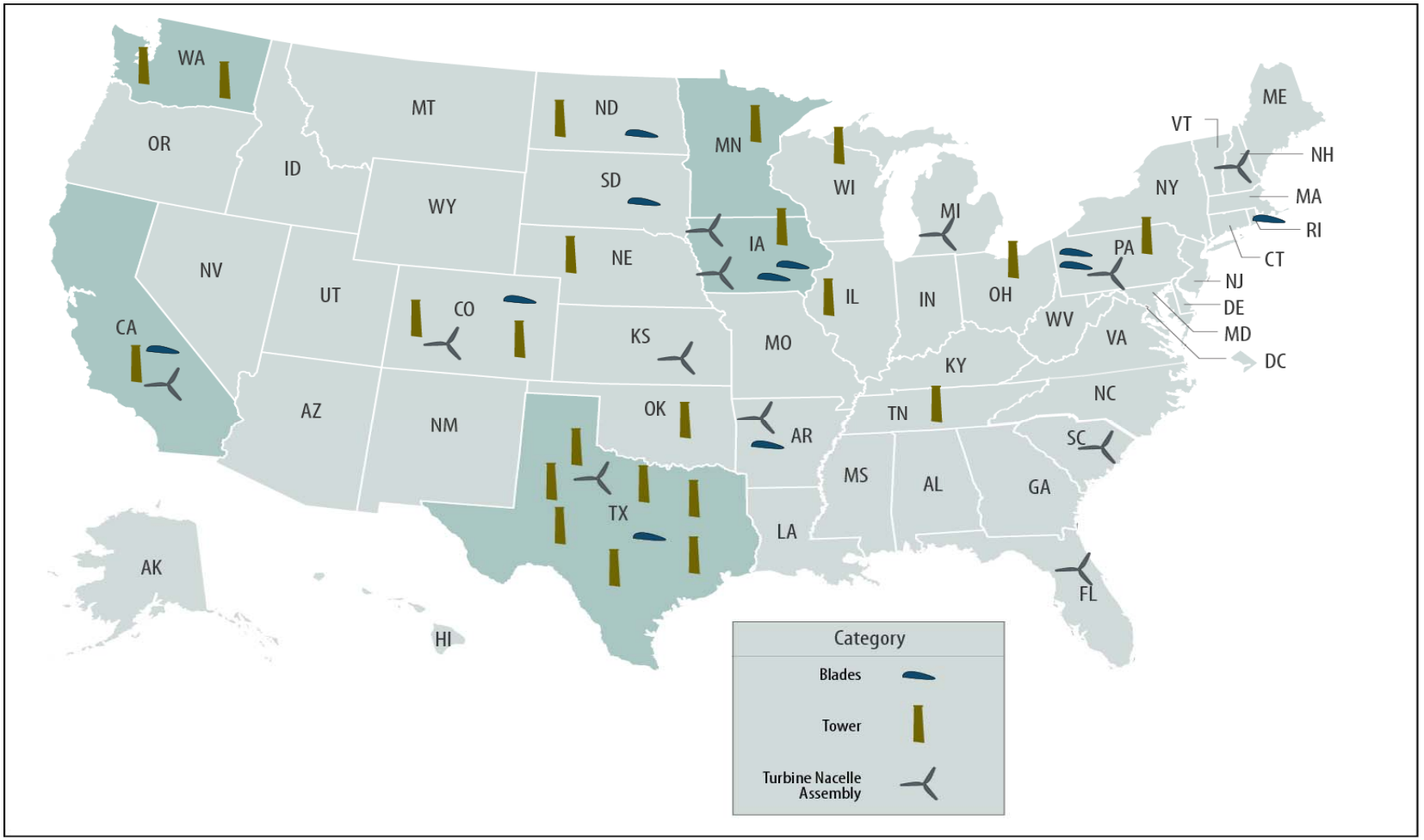
[77] "A-Power Still Plans U.S. Factory, but Financing Not Assured," *Recharge News*, April 29, 2011.

[78] AWEA, *Policy and Manufacturing: Demand-Side Policies Will Fuel Growth in the Wind Manufacturing Sector*, 2011, p. 5, http://www.thenewnorth.com/resources/mwgpolicypaper.pdf.

[79] Ryan Wiser and Mark Bolinger, *2010 Wind Technologies Market Report*, Lawrence Berkeley National Laboratory, June 2011, pp. 23, http://www.windpoweringamerica.gov/filter_detail.asp?itemid=3207.

Figure 3. Wind Turbine Manufacturing Facilities in the United States

By Tower, Blade and Turbine Nacelle Assembly, 2010



Source: CRS based on data from AWEA. The map shows the 45 online tower, blade, and turbine nacelle assembly facilities at year-end 2010. It does not show almost 350 facilities that produce wind components such as power transmissions, generators, gearboxes, or bearings.

Note: The five highlighted states are the top states in U.S. wind power capacity installations.

U.S. Wind Turbine Manufacturing Employment

In 2010, the wind turbine manufacturing sector supported an estimated 20,000 manufacturing jobs nationwide. This was only about one-fourth of U.S. employment related to wind energy manufacturing. The majority (some 60%) of the 75,000 full-time workers employed directly and indirectly in the wind power industry at the end of 2010 worked in finance and consulting services, contracting and engineering services, and transportation and logistics.[80] About 3,500 jobs were in construction and 4,000 were in operations and maintenance. The number of manufacturing jobs has been relatively flat over the past three years, even as total employment in wind energy declined, according to figures from AWEA (see **Figure 4**).[81]

Wind turbine manufacturing is responsible for a very small share of the 11.5 million domestic manufacturing jobs in 2010, well under 1%. It seems unlikely, even given a substantial increase in U.S. manufacturing capacity, that wind turbine manufacturing will become a major source of manufacturing employment. In 2008, the U.S. Department of Energy forecast that if wind power were to provide 20% of the nation's electrical supply in 2030, U.S. turbine assembly and component plants could support roughly 32,000 full-time manufacturing workers in 2026.[82] AWEA's more optimistic projection is that the wind industry could support three to four times as many manufacturing workers as at present if a long-term stable policy environment were in place, which implies a total of 80,000 jobs.[83] Further employment growth in the sector is likely to depend not only upon future demand for wind energy, but also on corporate decisions about where to produce towers, blades, nacelles, and their most sophisticated components, such as gearboxes, bearings, and generators.

[80] AWEA employment data were provided to CRS via email on August 29, 2011 and are based on surveys and modeling.

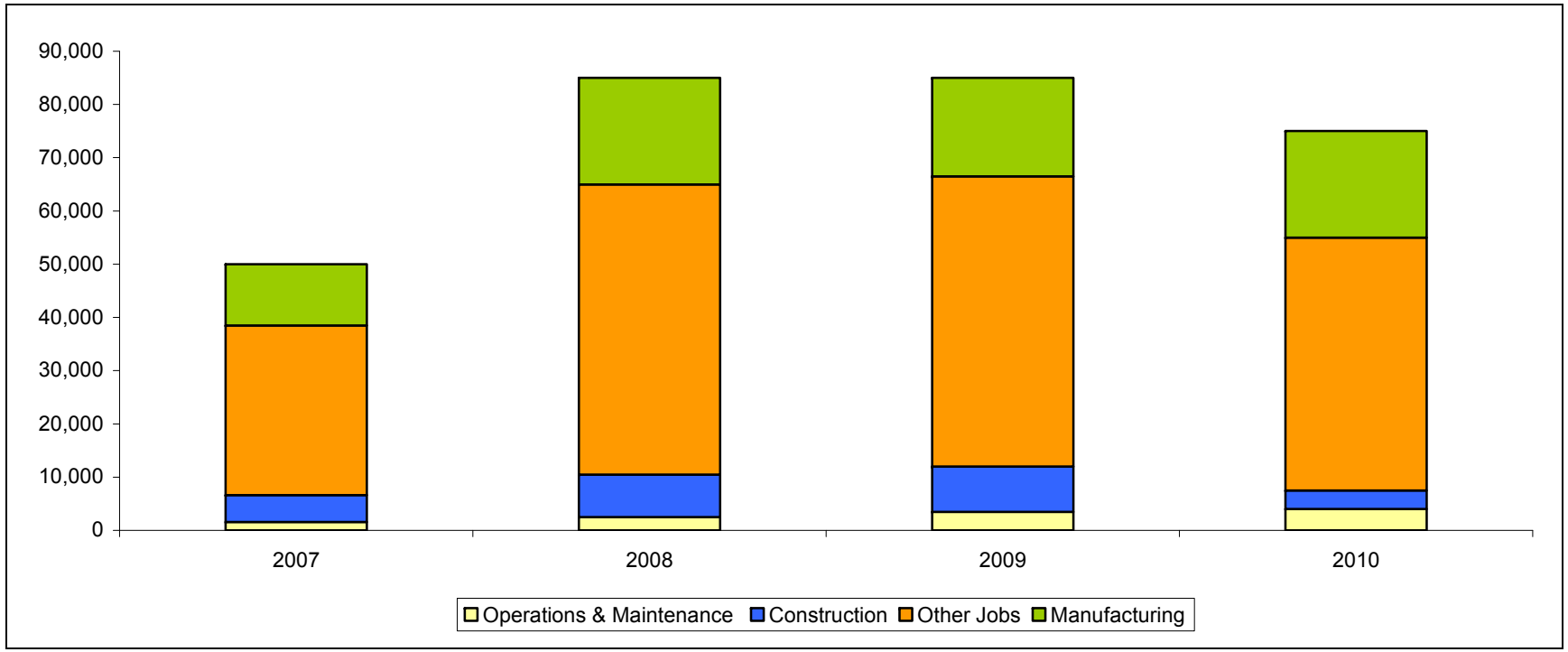
[81] AWEA, *U.S. Wind Industry Annual Market Report, 2010*, 2010, p. 36. AWEA is the only source of nationwide employment statistics, as the U.S. government does not currently track employment in the wind industry. Measurement of employment in wind turbine manufacturing is complicated by the fact that no industry codes exist to isolate wind power establishments or wind turbine and wind components establishments. The North American Industry Classification System (NAICS) places wind turbine manufacturers within the Turbine and Turbine Generator Set Units manufacturing industry (NAICS 333611), which comprises "establishments primarily engaged in manufacturing turbines (except aircraft) and complete turbine generator set units, such as steam, hydraulic, gas, and wind." The Bureau of Labor Statistics reports 26,800 total jobs in this industry in 2010, with employment increasing every year since 2005, when it had 19,300 employees. AWEA estimates imply that the overwhelming majority of jobs in NAICS 333611 are wind turbine related, but the accuracy of this assumption is uncertain.

[82] U.S. Department of Energy, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*, July 2008, p. 207, http://www.20percentwind.org/20percent_wind_energy_report_revOct08.pdf. DOE estimates are based on major component assumptions that by 2030 80% of blades, 50% of towers, and 42% of turbines installed in the United States would be manufactured domestically.

[83] AWEA, *Policy and Manufacturing: Demand-Side Policies Will Fuel Growth in the Wind Manufacturing Sector*, 2011, p. 9, http://www.thenewnorth.com/resources/mwgpolicypaper.pdf.

Figure 4. Wind Energy Employment Trends

2007-2010



Source: AWEA, *U.S. Wind Industry Annual Market Report*, 2010.

Note: Other jobs include financial and consultant services, developers and development services, contracting and engineering services, and transportation and logistics.

Wind Turbine Equipment Trade

U.S. Imports

As part of their global business strategies, wind turbine manufacturers continue to source a significant share of components outside the United States.[84] Imports of wind-powered generating sets, the main wind category covering fully assembled wind turbines and including other components such as blades and hubs when they are imported with the nacelle, grew from $482.5 million in 2005 to a peak of $2.5 billion in 2008. In 2009 and 2010, imports of wind-powered generating sets dropped to $2.3 billion and then fell by another 46% to $1.2 billion (see **Figure 5**).[85] An analysis of U.S. wind equipment trade by the U.S. International Trade Commission identified several explanations for the recent decline in U.S. imports of wind-powered generating sets, which include fewer wind turbine installations; decreasing prices; and the opening of new production facilities in the United States.[86]

The majority of imported wind-powered generating sets comes from Europe. In 2010, Denmark was the leading source of wind-powered generating sets, accounting for over half (57%) of all imports into the United States. Italy, Spain, and Germany combined accounted for another 18% (see **Figure 5**). India was another primary supplier at 21%. Japan, South Korea, and China accounted for very small shares of U.S. imports.

It appears that South Korean wind turbine manufacturers like Samsung, Hyosung, and Unison have ambitions to become leading exporters to the U.S. market and other global markets.[87] China has exported only a small number of wind turbines, just 13 worldwide in 2010.[88] However, Chinese manufacturers such as Sany, Mingyang, and Sinovel are expected to increase their exports of turbines to the United States and other markets.[89] Also, European turbine assemblers

[84] Gerald Susman and Amy Glasmeier, "*Industry Structure and Company Strategies of Major Domestic and Foreign Wind and Solar Energy Manufacturers: Opportunities for Supply Chain Development in Appalachia*," Smeal College of Business, November 20, 2009, p. 38, http://www.arc.gov/assets/research_reports/WindandSolarEnergy.pdf.

[85] Precisely tracking trade flows in the wind industry is complicated because the standard Harmonized Commodity Coding and Classification System (HS) does not have separate harmonized trade categories for all wind turbines and their components. Wind turbines and components are classified under several HS codes. Wind-powered generating sets (HS 8502.31) is the main category, which includes fully assembled wind turbines, but may also cover components such as blades and hubs when they are imported with the nacelle. However, when imported separately other individual turbine components (e.g., generators (HS 8501.64), towers (7308.20), and blades and other components (8412.90 and 8503.00) may be traded under other HS headings. Importantly, goods that are not used in wind turbines are also included in these categories. But, the ITC reports, wind accounts for a significant portion of trade in each dual use category and appears to be a major driver of import growth in those HS headings. For a complete discussion see, USITC, "*Wind Turbines: Industry and Trade Summary*," by Andrew David, June 2009.

[86] Andrew David, *Shifts in U.S. Wind Turbine Equipment Trade in 2010*, U.S. International Trade Commission, USITC Executive Briefing on Trade, June 2011, http://www.usitc.gov/publications/332/executive_briefings/wind_EBOT_commission_review_final2.pdf.

[87] Dr. Rimtalg Lee, *Status and Forecast of Wind Energy In Korea*, San Francisco, CA, March 2, 2009, pp. 7-9, http://www.asiapacificpartnership.org/pdf/PGTTF/wind-event/March_2/StatusnForecastofWindEnrgyKorea.pdf.

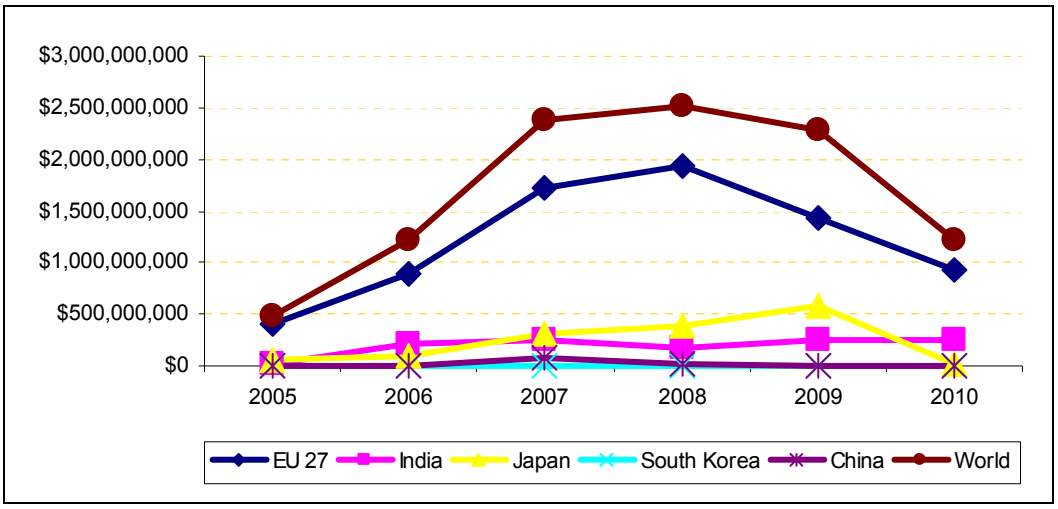
[88] "Wind Energy Goldwind Wins Two Wind Turbines U.S. Deals," April 27, 2011. http://www.evwind.es/noticias.php?id_not=11331.

[89] Li Junfeng, Shi Pengfei, and Gao Hu, *2010 China Wind Power Outlook*, Chinese Renewable Energy Industries Association, October 1, 2010, pp. 33-42, http://www.greenpeace.org/eastasia/publications/reports/climate-
(continued...)

such as Vestas are now looking to open plants in China to supply the Chinese market, and possibly global markets.[90] Concerns about the quality of Chinese-made turbines and parts have prevented more rapid adoption of Chinese components. This may change as Chinese wind turbine products improve and as more foreign manufacturers establish operations in China.

Figure 5. U.S. Imports of Wind-Powered Generating Sets, Select Countries

2005-2010



Source: Global Trade Atlas. These statistics only cover wind-powered generating sets (HS 8502.31), not other wind-related components such as blades, towers, or other components if they are imported separately.

Notes: The import statistics are shown on a domestic consumption basis.

Increasingly, China's efforts to foster wind turbine manufacturing are becoming an irritant in the bilateral relationship. The United Steelworkers (USW) filed a claim in September 2010 that China's green technology policies are direct violations of China's World Trade Organization (WTO) obligations.[91] In June 2011, after the World Trade Organization panel upheld a U.S. complaint, the Office of the U.S. Trade Representative (USTR) announced that China will end a program of wind power equipment grants that required Chinese wind turbine manufacturers that received them to use domestic parts and components instead of foreign-made parts and components.[92] In addition, the USW has raised other issues concerning Chinese government policies affecting trade and investment in "green technology" industries.

(...continued)

energy/2010/wind-power-report-english-2010/.

[90] Vestas, Company Structure, Vestas China, http://www.vestas.com/en/about-vestas/company-structure/vestas-china.aspx.

[91] United Steelworkers, *United Steelworkers' Section 301 Petition Demonstrates China's Green Technology Practices Violate WTO Rules*, http://assets.usw.org/releases/misc/section-301.pdf.

[92] China's Special Fund for Wind Power Equipment Manufacturing provided individual grants ranging from $6.7 million to $22.5 million to Chinese wind turbine manufacturers in exchange for using domestic parts and components instead of imported ones. For more information on China's Special Fund see USTR's June 7, 2011 press release, "China Ends Wind Power Equipment Subsidies Challenged by the United States in WTO Dispute," http://insidetrade.com/iwpfile.html?file=jun2011%2Fwto2011_1868a.pdf.

U.S. imports of other wind-related equipment, such as towers and blades, followed a similar pattern to wind-powered generating sets, with increases from 2005 to 2008 followed by a drop in 2009 and again in 2010. But although more of these large components are being produced domestically, imports remain significant. Canada, Mexico, China, Vietnam, and South Korea were the main sources of imported towers and lattice masts in 2010.[93] Brazil and Mexico led in blade imports in 2010,[94] thanks to shipments from Tecsis in Brazil and VienTek in Mexico.[95] Some turbine components, such as bearings and gearboxes, are relatively easier to transport, and wind turbine assemblers might be more likely to continue to use global sourcing strategies for these less bulky components.

Domestic Content

Estimates by various analysts indicate that U.S. content accounts for 50% to 60% of the value of the average wind turbine installed in the United States.[96] In a July 2010 report, the ITC found that based strictly on the main three components of wind turbines—wind-powered generating sets, blades, and towers—imports dropped from 64% of the U.S. market in 2006 to 32% in 2009.[97] AWEA reports the share of parts manufactured domestically has doubled from around 25% at the end of 2004 and beginning of 2005 to approximately 50% by 2009.[98]

Public statements by major wind turbine assemblers appear to support the view that U.S.-made turbines will have increasing domestic content. For example, Gamesa reports that its domestic content on U.S.-made wind turbines is nearly 60%.[99] Vestas has stated that it expects that 80% to 90% of the content of its turbines will be manufactured domestically, including components from suppliers.[100] Analysts at the Lawrence Berkeley National Laboratory concluded that because of the increase in U.S.-based wind turbine and component manufacturing, among other reasons, "the share of domestically manufactured wind turbines and components has grown in recent years, while the import share has witnessed a corresponding drop."[101] These researchers found that the

[93] Wind towers are classified under towers and lattice masts (HS 7308.20). Not all the towers in this category are wind towers.

[94] Wind blades are classified under the tariff lines for parts of other engines and motor (HS 8412.90) and parts of generators (HS 8503.00). Not all shipments in this category are wind-related.

[95] VienTek is a joint venture between Mitsubishi and TPI Composites with two wind blade manufacturing plants located in Mexico. For more information see, http://www.mpshq.com/facilities/vientek.html.

[96] Precisely how many wind turbine components are made in the United States and how many are imported is a debatable issue. U.S. content need only be disclosed on a few products, namely automobiles, textiles, wool, and fur products. For most other products, no law requires disclosure of domestic content. In the case of automobiles, the American Automobile Labeling Act (AALA) requires automobile assemblers to include labels that specify the percentage value of the U.S./Canadian parts content of each vehicle sold in the United States.

[97] The ITC notes that "its numbers are based on estimates of the value of the wind turbine market and may not be an exact percentage of domestic content, but they do serve as an indicator of the trend in imports as a share of the market." Andrew S. David, *Impact of Wind Energy Installations on Domestic Manufacturing and Trade*, U.S. International Trade Commission, July 2010, pp. 16-17, http://www.usitc.gov/publications/332/working_papers/ID-25.pdf.

[98] AWEA, *Winds of Change*, A Manufacturing Blueprint for the Wind Industry, June 2010, p. 13, http://www.awea.org/_cs_upload/learnabout/publications/5088_1.pdf.

[99] *Wind Energy in Pennsylvania*, House Republican Policy Committee Hearing, June 11, 2010, p. 2. http://www.pagoppolicy.com/Display/SiteFiles/112/Hearings/6_11_10/Giannelli_Testimony_6_11_10.pdf.

[100] Vestas, Annual Report 2010, p. 20.

[101] Ryan Wiser and Mark Bolinger, *2010 Wind Technologies Market Report*, Lawrence Berkeley National Laboratory, June 2011, p. 25, http://www.windpoweringamerica.gov/filter_detail.asp?itemid=3207.

overall import fraction declined from 65% in 2005-2006 to 40% in 2009-2010. They state that the size and stability of the U.S. wind power market in the future will determine whether this trend continues.[102]

U.S. Exports

Future growth of the U.S. wind turbine industry also depends on foreign markets. A goal of the Obama Administration is to demonstrably increase renewable energy and energy efficiency exports like wind turbines over the next five years.[103] Exports of wind-powered generating sets from the United States to the world remain relatively small at only $142.1 million in 2010, up from $3.6 million in 2005, according to figures compiled by the USITC.[104]

The U.S. production base for wind turbine equipment does not yet allow for significant exports because most of the existing capacity is focused on fulfilling domestic demand. But if domestic production capacity continues to expand, the possibility of supplying foreign markets increases.

The Western Hemisphere may be especially attractive to U.S.-based exporters of wind turbine equipment. While the Latin American markets are currently small, they are expected to grow. AWEA reports that U.S.-based manufacturers can be competitive in exporting nacelles and wind subcomponents to Brazil and other markets in the region.[105] A counter-trend is that wind turbine assemblers also are localizing production in the potentially large Brazilian market, including manufacturers like GE and Gamesa. This might limit exports from the United States to Central and South America.

If U.S. manufacturers begin to export more wind turbine equipment to foreign markets, they will have to contend with import tariffs, non-tariff barriers, and domestic industry subsidies. Tariff rates in some major markets are disproportionately higher than U.S. tariffs. For instance, the U.S. duty rate for wind-powered generating sets is 2.5%, compared to 8% in China and South Korea, 7.5% in India, and 2.7% in the European Union.[106] Subsidies and non-tariff barriers in major overseas markets like China are another potential constraint on U.S. exports.[107]

Several U.S. government programs are designed to encourage the export of renewable energy products, such as direct loans provided to wind manufacturers by the Export-Import Bank of the

[102] Ibid, p. 28.

[103] National Export Initiative, *Renewable Energy and Energy Efficiency Export Initiative*, December 2010, http://export.gov/reee/eg_main_023036.asp.

[104] Andrew David, *Shifts in U.S. Wind Turbine Equipment Trade in 2010*, U.S. International Trade Commission, USITC Executive Briefing on Trade, June 2011, http://www.usitc.gov/publications/332/executive_briefings/wind_EBOT_commission_review_final2.pdf.

[105] AWEA, *Wind Industry Global Markets and Export Potential*, March 1, 2011, http://export.gov/reee/eg_main_030992.asp.

[106] World Trade Organization, Tariff Analysis Online, http://www.wto.org/english/tratop_e/tariffs_e/tariff_data_e.htm. If the proposed free trade agreement between the United States and South Korea were approved their respective tariffs on wind-powered generating sets would be eliminated immediately upon implementation of the agreement.

[107] Clean energy policies in China, Japan, and South Korea are detailed in a November 2009 study by the Breakthrough Institute and the Information Technology & Innovation Foundation, *"Rising Tigers Sleeping Giant: Asian Nations Set to Dominate the Clean Energy Race by Out-Investing the United States"* http://thebreakthrough.org/blog/Rising_Tigers.pdf.

United States.[108] For example, Clipper Windpower exported 27 wind turbines to Mexico in 2010[109] and Gamesa will export 51 wind turbines to Honduras in 2011[110] backed by direct loans from the Ex-Im Bank of $80.7 million and $159 million, respectively.

Federal Support for the U.S. Wind Power Industry

Worldwide the wind power industry is driven by various types of government support, which range from tax credits to incentive policies like feed-in tariffs.[111] These incentives have been much larger in several foreign countries than in the United States, which has helped to spur the manufacturing of wind turbines in Europe and Asia.

In Europe, feed-in tariffs[112] are among the policy tools that have been used to promote wind power, and have been credited by industry advocates like the European Wind Energy Association[113] with driving renewable energy growth, particularly in Denmark, Spain, and Germany. However, faced with current fiscal realities, including a global recession and large budget deficits, some European countries have reduced their wind power feed-in tariffs and are taking a more critical look at their renewable energy policies.[114] For instance, in 2010, Spain announced it would reduce its wind subsidies by 35% from January 1, 2011, to January 1, 2013.[115] What these changes might mean for European manufacturers, and their overseas production strategies, remains to be seen. As many of the largest European manufacturers are already export oriented and rank among the largest and most competitive manufacturers in the world, the impact might be limited.

[108] More information about the Export-Import Bank's Environmental Exports Program can be accessed at http://www.exim.gov/products/policies/environment/success.cfm.

[109] Export-Import Bank of the United States, "Clipper Windpower Transaction is Named Ex-Im Bank Deal of the Year," press release, March 11, 2010, http://www.exim.gov/pressrelease.cfm/4EB6A01A-B9E1-FABF-D9409670AEB9668D/.

[110] Export-Import Bank of the United States, "Gamesa is Named Ex-Im Bank's Renewable-Energy Exporter of the Year," press release, March 29, 2011, http://www.exim.gov/pressrelease.cfm/032C7631-BE53-FF36-5BDBAFD2E3943DA8/.

[111] A comprehensive overview of policy instruments used by various governments to promote renewables, including wind power, can be found on the Renewable Energy Policy Network site at http://www.ren21.net/RenewablesPolicy/PolicyInstruments/tabid/5608/Default.aspx.

[112] A feed-in tariff, or FIT, is a renewable energy policy that typically offers a guarantee of payments to project owners for the total amount of renewable energy they produce; access to the grid; and stable, long-term contracts (15-20 years). For more information see workshop presentation, Renewable Energy Feed-in Tariffs: An Analytical View, by Toby Couture, May 28, 2009. http://www.energy.ca.gov/2009_energypolicy/documents/2009-05-28_workshop/presentations/01_Couture_Feed-in_Tariff_Wkshop_May_28_09.pdf.

[113] European Wind Energy Association, *Support Schemes for Renewable Energy*, *A Comparative Analysis of Payment Mechanisms in the EU*, 2002, p. 31, http://www.ewea.org/fileadmin/ewea_documents/documents/projects/rexpansion/050620_ewea_report.pdf.

[114] At least three studies have raised questions about the costs associated with Europe's support of its renewable energy sectors. A report by a Spanish academician, Dr. Gabriel Calzada, *Study of the Effects on Employment of Public Aid to Renewable Energy Sources*, argued that Spain's policies were an economic failure and cost many jobs. Another report by a Danish think tank, CEPOS, *Wind Energy: The Cost for Denmark*, also pointed to the costs of subsidizing Denmark's wind power industry. A third report by the German think tank, Rheinisch-Westfälisches Institut for Wirtschaftsforschung (RWI), *Economic Impacts from the Promotion of Renewable Energies: The German Experience*, argues that aid by the German government for wind power is now three times the cost of conventional electricity.

[115] Ben Backwell, "Subsidies to be Cut for Spain's Wind and Thermal Solar Sector's," *Recharge News*, July 5, 2010.

China's Renewable Energy Law, which took effect in 2006, is one measure that has driven growth in the domestic market.[116] China introduced a feed-in tariff for wind power generation in 2009.[117] The Chinese government also implemented various policies to encourage the development of local manufacturing and technology development.[118]

In the United States, various federal policies also have been instrumental in the development of a domestically based wind power sector, including:

- the production tax credit (PTC)/Investment Tax Credit (ITC), which will expire at the end of 2012;
- an advanced energy manufacturing tax credit (MTC), which reached its funding cap in 2010 (no additional funds were allocated to continue with the MTC);
- the Section 1603 Treasury Cash Grant Program, which requires that wind projects begin construction by December 31, 2011, and be placed in service by December 31, 2012; and
- the Section 1705 Loan Guarantee Program for commercial projects, which includes manufacturing facilities that employ "new or significantly improved" technologies.

The wind industry asserts that a national renewable electricity standard (RES) is needed to create long-term stability and to continue to attract investment in new turbine production facilities. **Table 5** provides an overview of selected federal programs affecting the U.S. wind power industry.

Table 5. Selected Energy Programs Affecting the U.S. Wind Industry

Program	Expiration Deadlines for Wind Generation/Manufacturing Projects
Production Tax Credit	December 31, 2012
Investment Tax Credit[a]	December 31, 2012
Advanced Manufacturing Tax Credit	Capped at $2.3 billion; 100% Allocated
1603 Cash Grant in Lieu of Tax Credit[b]	December 31, 2011 (begin construction) December 31, 2012 (placed in service)
1705 Loan Guarantee Program	September 30, 2011 (commence construction)
Bonus Depreciation Schedule	December 31, 2011, for 100% first-year bonus depreciation December 31, 2012, for 50% bonus

Source: Wind Energy Manufacturers Association, Supply Chain Issues from Tier 1 Suppliers and Component Makers, http://www.slideshare.net/LeslieFeen/supply-chain-issues-from-tier-1-suppliers-and-component-makers-wind-power-manufacturing-amp-supply-cha

[116] For a detailed discussion of China's green energy policies, see CRS Report R41287, *China and the United States—A Comparison of Green Energy Programs and Policies*, by Richard J. Campbell.

[117] GWEC, *Global Wind Report Annual Market Update 2010*, April 2011, pp. 30-33, http://www.gwec.net/index.php?id=180.

[118] Eric Martinot, *Renewable Power for China: Past, President and Future*, 2010, p. 6, http://www.martinot.info/Martinot_FEP4_prepub.pdf.

a. The taxpayer who presumably is the owner of the relevant wind power project placed in service prior to December 31, 2012, can opt for a 30% ITC in lieu of the PTC. The 30% ITC for small commercial wind energy property extends through December 31, 2016.

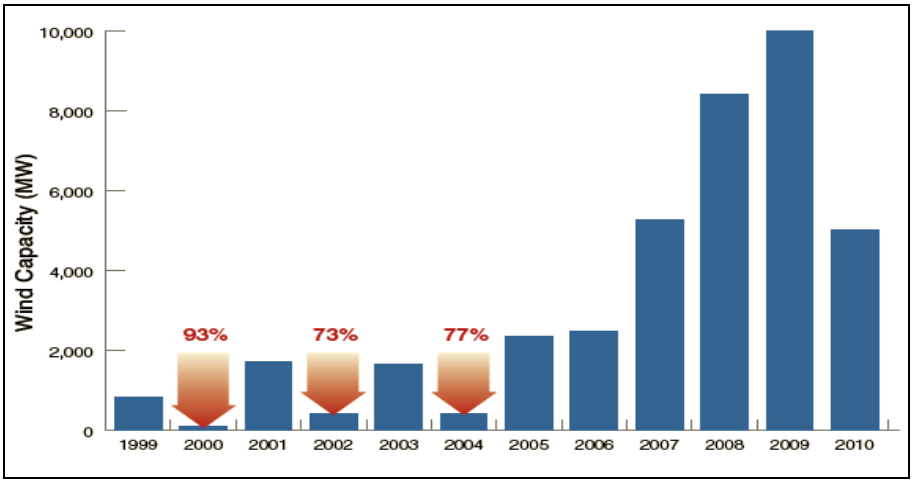
b. The taxpayer owning the relevant wind power project can opt for a 30% cash grant from the U.S. Department of Treasury instead of a PTC, then select a one-time cash grant instead of tax credits.

Production Tax Credit (PTC)/Investment Tax Credit (ITC)

The PTC, the main policy tool in the deployment of U.S. wind power, was first adopted during the Administration of President George H. W. Bush as part of the Energy Policy Act of 1992 (P.L. 102-486). It has been a significant driver of the recent growth of the U.S. wind industry. In each of the years during which the PTC lapsed (2000, 2002, and 2004), meaning that it expired prior to being renewed, the level of additional deployed wind capacity slowed or collapsed when compared to the previous year's total: 93% in 2000, 73% in 2002, and 77% in 2004 (see **Figure 6**).[119] Yet, when the PTC incentive was extended in 2004, 2007, and 2009, the industry responded positively, increasing wind power capacity compared to the previous year. 2010 was an exception to this trend with a drop in wind capacity of nearly 50% from 2009, even with the PTC in place.

Figure 6. History of the Production Tax Credit

By Annual Capacity Additions, 1999-2010



Source: AWEA, Production Tax Credit, What is the Production Tax Credit?

Congress provided a three-year extension of the PTC through December 31, 2012, as part of the American Recovery and Reinvestment Act. The PTC provides an inflation-adjusted per kilowatt-hour (kWh) income tax benefit over the first 10 years of a wind project's operations, which in 2010 was 2.2 cents per kWh, and is a critical factor in financing new wind farms. In order to qualify, a wind farm must be completed and start generating power while the credit is in place, which would be by the end of 2012.[120] The stimulus bill also allows wind project developers to

[119] AWEA, *Production Tax Credit*, What is the Production Tax Credit?, p. 1, http://www.awea.org/_cs_upload/issues/federal_policy/7785_1.pdf.

[120] Ibid.

elect to receive a 30% investment tax credit (IRC §48) in place of the PTC if the projects are placed in service prior to the end of 2012.[121]

AWEA advocates for a long-term extension of the PTC to encourage long-term investment in the industry, which it claims would allow for continued growth of domestic turbine manufacturing. The Governors' Wind Energy Coalition has called for a seven-year extension of the PTC.[122] Given the uncertainty about the continuation of the PTC beyond 2012, along with other tax benefits, some in the industry have begun to refer to 2013 as "the valley of death."[123] They worry that industry support programs will end without any replacement policies.

Advanced Energy Manufacturing Tax Credit (MTC)

The Advanced Energy Manufacturing Tax Credit, also referred to as Section 48C of the Internal Revenue Code, was authorized in Section 1302 of the American Recovery and Reinvestment Act.[124] The MTC provided a 30% credit for companies for investments in new, expanded, or reequipped clean energy domestic manufacturing facilities built in the United States. Wind, solar panels, and electric vehicle batteries were among the 183 projects funded through the MTC before reaching its cap of $2.3 billion in 2010. The Obama Administration has requested another $5 billion for the 48C tax program. An extension of the MTC has been proposed through the Security in Energy and Manufacturing Act of 2011 (S. 591), or SEAM Act. It includes one significant change from the original MTC; higher priority would be given to facilities that manufacture—rather than assemble—goods and components in the United States.[125]

Fifty-two wind manufacturing projects were awarded $364 million in tax credits under the MTC program.[126] Beneficiaries included many manufacturers that were already active, or that had announced that they intend to open new facilities, in the United States. Selected manufacturers of wind turbines, blades, towers, and gears that received tax credits under the 48C program are listed in **Appendix C**.

[121] Internal Revenue Service Notice 2009-52, Election of Investment Tax Credit, Coordination with Department of Treasury Grants for Specified Energy Property in Lieu of Tax Credits, http://www.irs.gov/pub/irs-drop/n-09-52.pdf.

[122] Letter from Governor's Wind Energy Coalition to The Honorable Barak Obama, President of the United States, July 20, 2011, http://www.governorswindenergycoalition.org/assets/files/President%20Obama%20Wind%20Energy%20Letter%20%28July%2024,%202011%29.pdf.

[123] Gloria Gonzalez, *U.S. Renewables Industry Searches for More Tax Breaks as Grants End*, Wind Energy Manufacturers Association , June 20, 2011, http://wema.membershipsoftware.org/blog_home.asp?Display=98.

[124] For more information see White House, *Fact Sheet: $2.3 Billion in New Clean Energy Manufacturing Tax Credits*, January 8, 2010, http://www.whitehouse.gov/the-press-office/fact-sheet-23-billion-new-clean-energy-manufacturing-tax-credits.

[125] "SEAM Act Will Build U.S. Wind Supply Chain Says Industry Group," *Industry Week*, May 12, 2010. http://www.industryweek.com/articles/seam_act__will_help_build_u-s-_wind_supply_chain_says_industry_group_21813.aspx?SectionID=2.

[126] White House, *The Recovery Act: Transforming the American Economy Through Innovation, Promoting Clean, Renewable Energy: Investments in Wind and Solar*, http://www.whitehouse.gov/recovery/innovations/clean-renewable-energy.

Other Wind-Related Programs

Tax benefits for wind projects include accelerated tax depreciation and bonus depreciation; the latter allowed wind farm owners to write off more than 50% of the capital costs of building a wind farm in 2008, 2009, and 2010. The 2010 Tax Act[127] increased the first-year bonus depreciation to 100% for new qualified property acquired and placed in service between September 8, 2010, and December 31, 2011, rather than 50% for the qualifying property. Bonus depreciation drops to the lower 50% rate in 2012.[128]

Another ARRA incentive is a grant system administered by the U.S. Treasury Department. In lieu of tax credits, wind projects can receive a cash payment of up to 30% of the qualified capital costs. The Section 1603 Treasury cash grant program allows developers to opt for a cash payment instead of a tax break. To qualify, construction must begin by December 31, 2011.[129] Wind projects under construction by year-end 2011 must be placed in service by December 31, 2012. Many in the wind industry are crediting the grants for keeping the sector healthy during the 2008 and 2009 recession.[130] A detailed discussion of the Section 1603 program can be found in CRS Report R41635, *ARRA Section 1603 Grants in Lieu of Tax Credits for Renewable Energy: Overview, Analysis, and Policy Options*, by Phillip Brown and Molly F. Sherlock.

The Section 1705 loan program, a temporary ARRA program administered by the Department of Energy, is another financing program which authorizes loan guarantees for certain renewable energy projects, including wind projects. The program expires on September 30, 2011. So far, 32 projects have been completed or received conditional commitments; five were wind generation or wind manufacturing projects. The combined wind commitments totaled $1.6 billion, comprising 9% of the $18.8 billion in 1705 program funding.[131] The Caithness Shepherds Flat wind generation project, which upon completion will be the largest onshore wind farm in the world, received a $1.3 billion loan.[132] GE will manufacture the wind turbines. Loan guarantees were also extended to three other wind generation projects: Kahuku Wind Power, Granite Reliable, and Record Hill Wind (see **Table 6**). One wind manufacturing project—an expansion of the Nordic Windpower assembly plant in Idaho—received a conditional commitment of $16 million in 2009. Nordic planned to design and manufacture an innovative two-bladed utility-scale wind turbine at the Idaho facility, but in late 2010, Nordic Windpower announced that it would relocate its production facilities to Kansas City, MO, to be closer to its market.[133] To receive the loan guarantee the project must be under construction by September 30, 2011.

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[127] The Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 (P.L. 111-312) was signed by President Obama on December 17, 2010.

[128] Ryan Wiser and Mark Bolinger, *2010 Wind Technologies Market Report*, Lawrence Berkeley National Laboratory, June 2011, p. 61.

[129] Criteria for the start of construction are detailed in a U.S. Treasury guidance document, which can found on the Treasury Department's 1603 Grant Program website at http://www.treasury.gov/initiatives/recovery/Pages/1603.aspx.

[130] Mark Bolinger, Ryan Wiser, and Naim Darghouth, *Preliminary Evaluation of the Impact of the Section 1603 Treasury Grant Program on Renewable Energy Deployment in 2009*, Ernest Orlando Lawrence Berkeley National Laboratory, April 2010, p. ii, http://eetd.lbl.gov/ea/emp/reports/lbnl-3188e.pdf.

[131] Solar generation or solar manufacturing comprised the overwhelming majority (85%) of the 1705 loan guarantee projects funded at $15.9 billion by the Department of Energy. A list of the 1705 Loan Program projects can be found at https://lpo.energy.gov/?page_id=45.

[132] Department of Energy, "DOE LPO Finalizes Deal on the world's Largest Wind Project to Date," press release, December 17, 2010, https://lpo.energy.gov/?p=1955.

[133] According to the Department of Energy, Nordic's wind turbine, which uses two blades, represents a significantly (continued...)

Table 6. 1705 Loan Guarantees for Wind Generation and Manufacturing Projects

Project	Technology	Loan Guarantee Amount	Date of Agreement	Location	Status
Nordic Windpower USA, Inc.	Wind Manufacturing	$16 million	July 2009	ID	Conditional Commitment
Caithness Shepherds Flat	Wind Generation	$1.3 billion	October 2010	OR	Closed
Granite Reliable	Wind Generation	$135.8 million	June 2011	NH	Conditional Commitment
Kahuku Wind Power, LLC.	Wind Generation	$117 million	July 2010	HI	Closed
Record Hill Wind	Wind Generation	$102 million	August 2011	ME	Closed

Source: U.S. Department of Energy, Loan Programs Office, https://lpo.energy.gov/?page_id=45

Notes: The 1705 loan guarantee program expires on September 30, 2011.

State Renewable Portfolio Standards

State renewable portfolio standards (RPS) are also credited with encouraging the growth of the U.S. wind energy industry. As of June 2011, mandatory RPS programs existed in 29 states and the District of Columbia.[134] A portfolio standard creates demand for renewable energy by requiring companies that sell electricity to retail customers to obtain a specified share of their electricity from renewable generation.[135] The U.S. wind industry has long called for a national standard to increase investor confidence in the sector's long-term prospects. No such measure has passed Congress, although national renewable standards have been passed by the Senate on three occasions and by the House of Representatives once.[136]

Conclusion

The expansion of U.S. wind power generation will depend, at least in part, on government policy decisions. If state and federal governments continue to support wind generation, manufacturing of wind generating equipment in the United States is likely to increase. The production costs of U.S. plants that make turbine components appear to be competitive with those in other countries, and

(...continued)

improved technology that would be more reliable and less costly to manufacture, install, operate, and maintain than competing systems.

[134] U.S. Department of Energy, *2010 Wind Technologies Market Report*, June 2010, p. 62.

[135] U.S. Environmental Protection Agency, *Renewable Portfolio Standards Fact Sheet*, April 2009. http://www.epa.gov/chp/state-policy/renewable_fs.html

[136] To read more about the debate over a National Renewable Electricity Standard see CRS Report R41493, *Options for a Federal Renewable Electricity Standard*, by Richard J. Campbell.

the difficulty and expense of transporting very bulky products over long distances serves as an obstacle to import competition.

Nonetheless, there are several obstacles that may impede the expansion of wind energy manufacturing in the United States. One is the history of policy-induced boom-and-bust cycles in wind energy investment, which may lead wind turbine manufacturers and component suppliers to conclude that future U.S. demand for their products is too uncertain. Another significant challenge affecting the sector's future is the availability of adequate transmission for power generated by wind farms. Most wind farms are located at a distance from the urban areas where most electricity is consumed, and a shortage of transmission capacity could hamper wind farm creation or expansion. Congress may wish to evaluate the seriousness of transmission issues in the context of other federal efforts to support wind generation.

The structure of the wind manufacturing industry is also likely to undergo significant change. As is typical in budding industries, a large number of companies now compete in wind manufacturing. Mergers and failures are likely to lead to consolidation as the sector matures. As this report describes, competition in the wind turbine sector from new Asian entrants will likely become more significant in future years, but it is unclear whether many of these companies have the technological abilities and financial resources to become significant players in the market.

Appendix A. Global Wind Turbine Manufacturers

Table A-1. Global Wind Turbine Manufacturers by Original Equipment Manufacturers (OEMs)

Top 10 by Annual Market Share (installed capacity), 2008, 2009, 2010

Manufacturer	Location of Headquarters	2008	Manufacturer	Location of Headquarters	2009	Manufacturer	Location of Headquarters	2010
Vestas	Denmark	17.8%	Vestas	Denmark	12.5%	Vestas	Denmark	14.8%
GE	U.S.	16.7	GE	U.S.	12.4	Sinovel	China	11.1
Gamesa	Spain	10.8	Sinovel	China	9.2	GE	U.S.	9.6
Enercon	Germany	9	Enercon	Germany	8.5	Goldwind	China	9.5
Suzlon	India	8.1	Goldwind	China	7.2	Enercon	Germany	7.2
Siemens	Germany	6.2	Gamesa	Spain	6.7	Suzlon	India	6.9
Sinovel	China	4.5	Dongfang	China	6.5	Dongfang	China	6.7
Acciona	Spain	4.1	Suzlon	India	6.4	Gamesa	Spain	6.6
Goldwind	China	3.6	Siemens	Germany	5.9	Siemens	Germany	5.9
Nordex	Germany	3.4	Repower	Germany	3.4	United Power	China	4.2

Sources: U.S, International Trade Commission and BTM Consult, Recharge, *BTM Consult Says Vestas Consolidated Lead in 2010,* March 30, 2011.

Notes: Market share data is reported in MW terms and is based on installations in the year in question, not on turbine shipments or orders.

Appendix B. Selected Examples of U.S. Wind Turbine Production Facilities

Table B-1. Examples: U.S. Turbine Production Facilities

Wind Turbine Manufacturer/Headquarters	U.S. Location	Wind Turbine Production Facilities
Gamesa (Spain)	Pennsylvania	Gamesa, the first foreign-based wind turbine manufacturer to set up full production facilities in the United States, opened a plant at a former U.S. Steel factory in Ebensburg, PA, in 2005. Gamesa also operates a nacelle manufacturing plant in Fairless Hills, PA. It invested over $175 million in these plants and received $15 million in state subsidies and tax credits. U.S. employment exceeds 800.
Suzlon (India)	Minnesota	Suzlon opened a rotor blade manufacturing facility in Pipestone, MN, in 2006, with an investment of $8.5 million, its first manufacturing facility outside India. That plant, which once employed over 500 workers, was idled in 2010, and most of its workers have been laid off. Suzlon is in the process of acquiring the German manufacturer REpower.
Siemens (Germany)	Iowa/Kansas	Siemens operates a wind turbine blade manufacturing facility in Fort Madison, IA, which it opened in 2007. In 2010, Siemens invested $50 million in a new nacelle production facility in Hutchinson, KS, where it expects to employ 400 workers.
Vestas (Denmark)	Colorado	Vestas opened a blade production plant in Windsor, CO, and an R&D center in Louisville, CO, in 2010. By the end of 2011, Vestas expects to open another blade manufacturing plant in Brighton, CO. Total employment is expected to reach 2,500 workers. Vestas received an incentive package of approximately $4 million to invest in Colorado from various state and local agencies, including grants, tax rebates, and job-training funds.
Nordex (Germany)	Arkansas	Nordex opened a nacelle production assembly plant in 2010, which represented a $40 million investment. It expects to open a blade manufacturing plant in 2012 in Jonesboro, AR. Nordex states U.S. employment could potentially reach 1,000.
Acciona (Germany)	Iowa	Acciona opened a $30 million nacelle assembly plant in 2007 in West Branch, IA. In 2009, Acciona reduced its workforce at the plant by nearly 60 workers.[c]
Mitsubishi (Japan)	Arkansas	Mitsubishi expects to open its first nacelle assembly facility in Fort Smith, AR, in 2012, with an investment of approximately $100 million. It expects to employ 400 workers. This would be its first nacelle manufacturing assembly facility outside Japan.

Source: Compiled by CRS from various sources including company annual reports, press releases, news reports, and information from AWEA.

a. Gamesa Is Named Ex-Im Bank's Renewable-Energy Exporter Of The Year," press release, March 29, 2011, http://www.exim.gov/pressrelease.cfm/032C7631-BE53-FF36-5BDBAFD2E3943DA8/.

b. Vestas, Annual Report 2010, p. 20.

c. Josie Garthwaite, "*Wind Layoffs Continue: Acciona Cutting a Third of Workers at Iowa Plant,"* March 20, 2009. http://gigaom.com/cleantech/wind-layoffs-continue-acciona-cutting-a-third-of-workers-at-iowa-plant/.

Appendix C. 48C Manufacturing Tax Credit

Table C-1. Selected Wind Manufacturers Receiving Section 48C Manufacturing Tax Credit

Applicant	Tax Credit Requested	State	Project Description
Siemens	$28,328,379	IL	Siemens will manufacture the mechanical drives, gears, pinions, and other components for gearboxes for wind turbines.
Nordex	$22,153,500	AR	Nordex built its first facility for wind turbines in 2010.
Merrill Technologies Group	$22,021,500	MI	Merrill Technologies will invest $73 million in advanced manufacturing equipment to support the production of nacelles for Northern Power's new 2.2 MW utility-scale wind turbine.
Vestas	$21,600,000	CO	Vestas Towers will produce tubular wind towers that support wind turbines.
Vestas	$21,589,200	CO	Vestas Blades produces blades for wind turbines used in the production of wind energy.
Tindall Corporation	$16,750,500	SC	Tindall Corporation will build a facility to manufacture concrete tower bases and concrete towers for wind turbines.
Winergy	$12,786,000	IL	Winergy will build a new facility to manufacture power transmission equipment and gearboxes for wind turbines.
Brevini	$12,750,000	IN	Brevini Wind will establish a new manufacturing facility that will produce main drive gearboxes for wind turbine manufacturers.
Vela Gear Systems	$11,604,440	MI	Vela Gear will build a plant to produce advanced wind turbine parts with improved technology.
Vestas	$8,580,600	CO	Vestas Blades will produce blades for wind turbines.
Hexcel Corporation	$8,139,510	CO	Hexcel Corporation will establish a technologically advanced manufacturing facility to produce high-performance epoxy, glass, and carbon fiber composite materials.
TPI Composites	$5,135,241	NE	TPI will operate a new manufacturing facility to produce the next generation wind turbine blades made by combining reinforcing fibers from glass or carbon, resin, foam, and balsa wood.
Mistubishi Power Systems	$5,100,000	AR	Mitsubishi will create a new facility that will manufacture nacelles for 2.4MW wind turbines.

Applicant	Tax Credit Requested	State	Project Description
Siemens	$4,331,700	KS	Siemens will expand a wind turbine blade manufacturing facility. The expanded facility will be capable of producing both 45 meter and 49 meter blades for the Siemens SWT-2.3mw wind turbine.
TPI Composites	$3,902,921	IA	TPI is expanding its manufacturing facility in order to fill the anticipated greater demand for composite wind turbine blades from its customer General Electric and GE's wind farm customers.
Siemens	$3,450,900	IA	Siemens will build a new manufacturing plant for assembly of wind turbine nacelles and hubs for Siemens wind turbines.
Nordic Windpower	$3,000,000	ID	Nordic Windpower will establish manufacturing operations for an innovative wind turbine that uses two blades and a patented teeter-hub technology that dampens loads. Nordic moved its production
Alstom	$2,725,800	TX	The factory will produce and assemble the complete nacelle for wind turbines (including hub, gearbox, frames, generator, electrical convertor, etc.) for its 60Hz North American product line.

Source: Strategic Partnerships, Inc. http://www.spartnerships.com/reports/ARRA%20Energy%20Manufacturing%20Tax%20Credit%20Awards.pdf.

Notes: A tax credit is a "dollar for dollar" reduction in tax liability. As an example, if a manufacturer earns $10 million and owes $3.5 million in taxes, then a $1million tax credit would reduce the company's tax liability from $3.5 million to $2.5 million.

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