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Wind Turbines

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PREFACE

The United States International Trade Commission has initiated its current Industry and Trade Summary series of reports to provide information on the rapidly evolving trade and competitive situation of the thousands of products imported into and exported from the United States. Over the past 20 years, U.S. international trade in goods and services has risen by almost 400 percent. International supply chains have become more global and competition has increased. Each Industry and Trade Summary addresses a different commodity/industry and contains information on trends in consumption, production, and trade, and an analysis of factors affecting industry trends and competitiveness in domestic and foreign markets. This report on wind turbine manufacturing primarily covers the period 2003 through 2008.

ABSTRACT

This report addresses trade and industry conditions for wind turbine manufacturing for the period 2003 to 2008.

- *Annual U.S. wind turbine installations* increased from 1,672 to 8,545 megawatts (MW) from 2003 to 2008 due to the growing cost competitiveness of wind energy, advances in wind technology, and government policies. The United States was the global leader in installations in 2008, with 31 percent of global wind turbine installations. China (6,300 MW, 23 percent of installations), India (1,800 MW, 7 percent), Germany (1,665 MW, 6 percent), and Spain (1,609 MW, 6 percent) were second through fifth, respectively, in installed wind capacity. Installations represent the size of the market for wind turbines.
- *Domestic production capacity* increased due to the growth of the U.S. wind energy market from 2003 to 2008. Five companies (Acciona, Clipper, CTC/DeWind, Gamesa, and GE) currently manufacture nacelles in the United States (the nacelle houses the generator and gearbox). Six more companies are planning to open nacelle plants in 2009 or 2010. There are at least 10 blade and 15 tower manufacturers with plants open or planned.
- *Manufacturing employment* increased to about 20,000 in 2008. Hourly wages in wind turbine plants generally average between $13 and $20. Some manufacturers announced layoffs in late 2008 and early 2009 due to the financial crisis.
- *Competition* in the U.S. market increased. The number of turbine manufacturers with U.S. sales increased from five in 2003 to 13 in 2008. U.S.-based General Electric (GE) was the leading manufacturer in the U.S. market in 2008 with 43 percent of the market, followed by Danish manufacturer Vestas with 13 percent, and German manufacturer Siemens with 9 percent. U.S.-based Clipper Windpower began production in 2006 and had a 2008 market share of 7 percent.
- *Factors that affect demand* for wind turbines include energy prices, availability of project financing, and government policies such as renewable portfolio standards and the production tax credit. Insufficient transmission capacity, difficulties in obtaining permits to transport turbines, periodic expirations of the production tax credit, and financing constraints due to the financial crisis may be impediments to future U.S. wind energy development. The American Recovery and Reinvestment Act mitigates some of these constraints by expanding and extending tax credits, making wind eligible for additional financing, and investing in transmission.
- *The United States is a net importer* of wind turbines and major components. *U.S. imports* of wind-powered generating sets increased from $356 million in 2003 to $2.5 billion in 2008 (more than 600 percent) while *U.S. exports* increased from $0.7 million in 2003 to $22.1 million in 2008. The U.S. trade deficit in 2008 for wind turbines was $2.5 billion. Denmark and Spain accounted for a combined 55 percent of imports in 2008. The largest U.S. export markets were China (73 percent of exports) and Brazil (27 percent).
- *The United States trails Europe and Asia* in the manufacturing and export of wind turbines and components. Denmark, Germany, India, Japan, and Spain accounted for a combined 91 percent of global exports of wind-powered generating sets in 2008.

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ACRONYMS

ACORE	American Council on Renewable Energy
AEE	Spanish Wind Energy Association
AWEA	American Wind Energy Association
CTC	Composite Technology Corporation
DOE	Department of Energy
DSIRE	Database of State Incentives for Renewables and Energy Efficiency
EERE	DOE Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EWEA	European Wind Energy Association
EWT	Emergya Wind Technologies
GW	Gigawatt
GWEC	Global Wind Energy Council
IEA	International Energy Agency
IPP	Independent Power Producer
ITC	Investment Tax Credit
kW	Kilowatt
kWh	Kilowatt hour
MW	Megawatt
MWh	Megawatt hour
NERC	National Electric Reliability Council
NREL	National Renewable Energy Lab
PTC	Production Tax Credit
RPS	Renewable Portfolio Standard
R&D	Research and Development
RD&D	Research, Development, and Demonstration

INTRODUCTION

U.S. wind turbine manufacturing and trade are rapidly expanding due to growing domestic demand for wind turbines. Annual U.S. wind turbine installations[1] increased from 1,672 to 8,545 megawatts (MW) (over 400 percent) from 2003 to 2008, leading to a growth in imports and rising investment in U.S. production by American, European, and Asian companies.[2] New U.S. manufacturing plants are primarily intended to meet domestic demand, but some U.S. manufacturers are beginning to examine export opportunities or open overseas manufacturing plants.

This Summary analyzes utility scale wind turbine[3] manufacturing, investment, and trade from 2003 to 2008.[4] The first section analyzes the U.S. manufacturing industry, domestic employment, and the supply chain. The second section examines competition in the U.S. market, turbine demand, and government policy. The final sections analyze U.S. import and export trends, foreign industry, foreign markets, and global trade treatment.

The growing importance of the wind industry is reflected in U.S. trade flows and U.S. manufacturing production. From 2003 to 2008, imports of wind-powered generating sets increased more than 600 percent to $2.5 billion annually, while domestic wind turbine sales of the largest U.S. manufacturer, GE, rose by over 300 percent from 2003 to 2008.[5] The number of competitors in the U.S. market increased from five in 2003 to 13 in 2008.[6] At least 11 manufacturers now have nacelle (box 1) assembly plants open or planned in the United States, only one of which had domestic manufacturing capabilities in 2003. There has been a similar expansion in production of blades and towers.

U.S. exports are limited, but there are some indications that the presence of U.S. companies in overseas markets is growing. U.S. exports of wind-powered generating sets increased from $0.7 million in 2003 to $22.1 million in 2008.[7] Companies are establishing U.S. manufacturing plants with the intention of serving markets throughout North and South America and some U.S. companies have invested in foreign production in order to enter overseas markets.

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[1] For the purposes of this report, wind turbine installations represent the size of the market for finished wind turbines, including nacelles, blades, and towers. Nacelles, blades, and towers are shipped separately to the construction site, where the wind turbine is erected or installed. Generally, data on annual wind turbine installations cited in this report are net capacity: megawatts of wind capacity added minus megawatts of wind capacity from turbines that are decommissioned. However, the number of turbines decommissioned each year in the United States and other countries is generally small.

[2] American Wind Energy Association (AWEA), *Annual Wind Industry Report: Year Ending 2008*, 4.

[3] For the purposes of this report, "wind turbine" refers to utility scale wind turbines. Utility scale (or large) wind turbines are turbines with a generating capacity of more than 100 kW. Small wind turbines are manufactured by different companies and are generally marketed to residential and commercial customers rather than utilities and large power producers.

[4] The typical period examined for an Industry and Trade Summary is five years. However, there was a significant drop in installations in 2004 due to the expiration of the production tax credit. Therefore, 2003 provides a more appropriate baseline for this analysis.

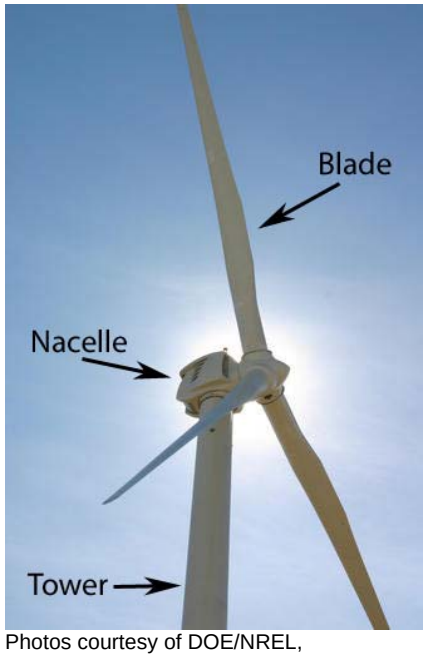
[5] Wind turbines are classified under "wind-powered generating sets" in the Harmonized Tariff Schedule of the United States (HTS). Wind-powered generating sets include nacelles and, when imported with the nacelle, other components such as blades.

[6] Compiled from official statistics of the U.S. Department of Commerce; AWEA, "Annual Rankings Demonstrate," May 12, 2005; and AWEA, *Annual Wind Industry Report*, 10.

[7] Compiled from official statistics of the U.S. Department of Commerce.

The financial crisis has led to a decrease in demand in the short term, but long-term demand will likely rebound due government policies that support renewable energy, the recovery of the credit markets, and the return to the market of tax equity investors. There are several impediments to further wide scale deployment of wind turbines, but manufacturers are moving ahead with planned investments in U.S. production in the expectation that the market will grow in the long term.

BOX 1 Wind Turbine Components



Photos courtesy of DOE/NREL, Credit – Lee Fingersh

Blades: Most wind turbines have three blades, though there are some with two blades. Blades are generally 30 to 50 meters (100 to 165 feet) long, with the most common sizes around 40 meters (130 feet). Longer blades are being designed and tested. Blade weights vary, depending on the design and materials—a 40 meter LM Glasfiber blade for a 1.5 MW turbine weighs 5,780 kg (6.4 tons) and one for a 2.0 MW turbine weighs 6,290 kg (6.9 tons).

Controller: There is a controller in the nacelle and one at the base of the turbine. The controller monitors the condition of the turbine and controls the turbine movement.

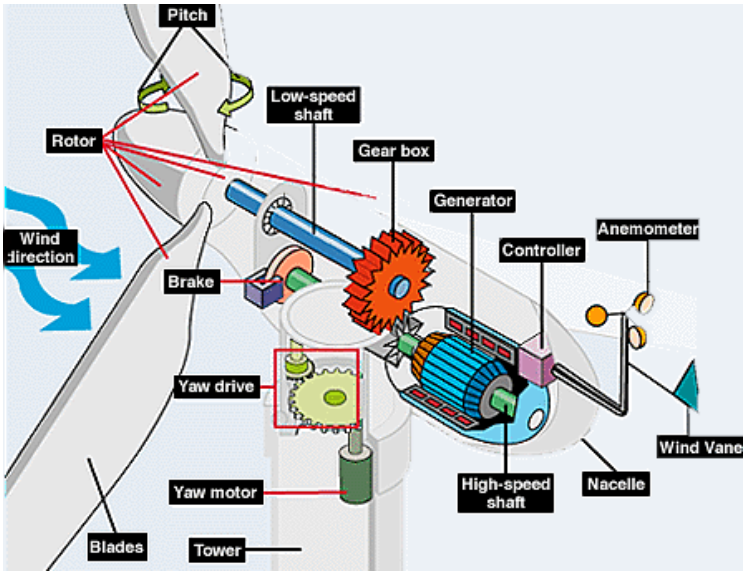
Gearbox: Many wind turbines have a gearbox that increases the rotational speed of the shaft. A low-speed shaft feeds into the gearbox and a high-speed shaft feeds from the gearbox into the generator. Some turbines use direct drive generators that are capable of producing electricity at a lower rotational speed. These turbines do not require a gearbox.

Generators: Wind turbines typically have a single AC generator that converts the mechanical energy from the wind turbine's rotation into electrical energy. Clipper Windpower uses a different design that features four DC generators.

Nacelles: The nacelle houses the main components of the wind turbine, such as the controller, gearbox, generator, and shafts.

Rotor: The rotor includes both the blades and the hub (the component to which the blades are attached).

Towers: Towers are usually tubular steel towers 60 to 80 meters (about 195 to 260 feet) high that consist of three sections of varying heights. (There are some towers with heights around 100 meters (330 feet)).



Source: DOE, EERE Web site. http://www.eere.energy.gov (accessed April 1, 2009).

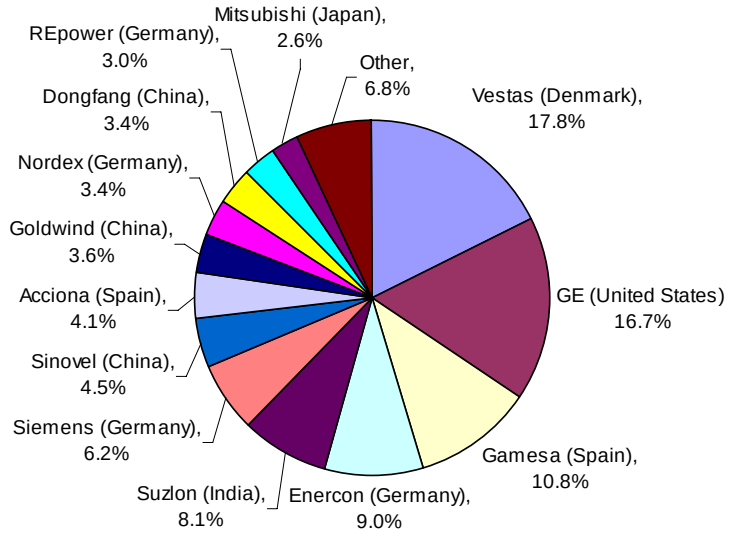
Sources: Danish Wind Industry Association Web site. http://www.windpower.org (accessed various dates); industry official, interview by Commission staff, October 30, 2008; LM Glasfiber Web site. http://www.lmglasfiber.com (accessed March 7, 2009); and U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE) Web site. http://www.eere.energy.gov (accessed April 1, 2009).

INDUSTRY PROFILE

The U.S. wind turbine manufacturing industry is rapidly expanding due to the increase in wind turbine installations in the United States. The number of original equipment manufacturers (OEMs) (box 2) assembling nacelles in the United States increased from one in 2003 to five in 2008 (table 1).[8] Six more OEMs are expected to open plants in 2009 or 2010. OEMs currently produce turbines in the United States that range between 1.5 and 2.5 megawatts (MW).[9] The range of sizes produced in the United States will expand in 2009 and 2010. Acciona Windpower plans to begin production of a 3.0 MW turbine in 2009 and two of the new facilities will produce turbines of 1 MW or less.[10]

BOX 2 Global Original Equipment Manufacturers

Global wind turbine market share, by OEM, 2008



The global wind turbine manufacturing industry is dominated by a small number of OEMs. The top five OEMs, Vestas, GE, Gamesa, Enercon, and Suzlon, had a combined 62 percent of the global market in 2008. GE is the leading U.S.-based supplier and was second in the world in market share in 2008. Most other companies are European and Asian OEMs. Many European OEMs are among the most mature and competitive global companies. Manufacturing capacity in Asia is growing rapidly and five Asian companies are now among the 13 largest OEMs.

Source: BTM Consult, *International Wind Energy Development: World Market Update 2008*, 24.

Domestic OEMs are expanding production or entering the industry for the first time. General Electric Co. (GE) is the largest company in the U.S. market, with 43 percent of the market[11] in 2008 and nacelle assembly plants (boxes 3 and 4) in California, Florida, and South Carolina.[12] U.S.-based Clipper Windpower produced its first wind turbines in

[8] OEMs are companies that design wind turbines and sell the turbines under their name (e.g., Acciona, Clipper, GE, Siemens, and Vestas). Wind project developers contract with OEMs for the delivery of the entire turbine, which includes the nacelle, blades, and tower. OEMs usually produce the nacelle in-house, while blades and towers are produced either by the OEM or to the OEM's specifications by a supplier.

[9] A kilowatt (kW) is a thousand watts, a megawatt (MW) is a thousand kW, and a gigawatt (GW) is a thousand MW. A kilowatt hour (kWh) or a megawatt hour (MWh) is one kW or one MW of electricity over a one hour period of time. According to the American Wind Energy Association (AWEA), one megawatt is enough electricity to power 225 to 300 homes per year. AWEA Web site. http://www.awea.org (accessed April 1, 2009).

[10] Norfleet, "Acciona Unveils 3 MW Turbine," October 1, 2008.

[11] Market share in the United States is calculated based on the percent of wind turbine installations.

[12] GE plans to produce its 2.5 MW turbine, which it will introduce to the U.S. market in 2010, in Florida. GE, "Proven in Europe and Asia," May 4, 2009; Schoof, "Wind Turbine Imports Increase; Can U.S. Factories Catch Up?" April 10, 2009; and AWEA, *Annual Wind Industry Report*, 10.

2006 and had 7 percent of the U.S. market in 2008.[13] Composite Technology Corporation (CTC) purchased European wind turbine manufacturer EU Energy, now DeWind, in 2006 and subsequently established manufacturing operations in the United States.[14] Other U.S. companies are considering entering the industry. For example, Vermont based Northern Power Systems, which currently produces a 100 kW wind turbine, is developing a 2.2 MW turbine for the U.S. market.[15]

TABLE 1 U.S. nacelle manufacturing plants, operational and planned, 2009

Company	Plant Location(s)	Turbine Size (MW)	Production Capacity (Turbines)	Status	Headquarters
Acciona Windpower	Iowa	1.5 and 3.0	400	Operational	Spain
Clipper Windpower	Iowa	2.5	More than 400	Operational	United States
CTC/DeWind	Texas	2.0	500	Operational	United States
Emergya Wind Technologies	Arkansas	750 or 900 kW	NA	Expected to begin production in 2009	Netherlands
Fuhrlander	Montana	2.5	NA	Expected to begin production in 2009 or 2010	Germany
Gamesa	Pennsylvania	2.0	500	Operational	Spain
General Electric	California, Florida, South Carolina	1.5 and 2.5	NA	Operational	United States
Nordex	Arkansas	2.5	300	Expected to begin production in 2010	Germany
Nordic Windpower	Idaho	1.0	240	Expected to begin production in 2009	United Kingdom
Siemens	Kansas	2.3	650	Expected to begin production in 2010	Germany
Vestas Wind Systems	Colorado	NA	1,400	Expected to begin production in 2010	Denmark

Sources: Compiled from AWEA publications, media reports, press releases, and interviews.

Notes: NA: Not available. Acciona is expected to begin production of the 3.0 MW turbine in Iowa in 2009 and GE is expected to introduce the 2.5 MW turbine to the U.S. market in 2010. Some of the manufacturing plants may also produce blades and other components. Emergya Wind Technologies (EWT) nacelles will be assembled in Arkansas by Wind & Water Technology. Blades will be manufactured at the same facility by EWT subsidiary Polymarin Composites. CTC/DeWind turbines are manufactured by TECO Westinghouse Motor Company in Texas.

[13] Industry official, interview by Commission staff, October 29, 2008; AWEA, *Annual Wind Industry Report*, 10.

[14] In the United States, DeWind turbines are manufactured by TECO Westinghouse Motor Company in Texas under a contract with Composite Technology Corporation (CTC). Composite Technology Corporation, *Form 10-K/A*, May 20, 2008.

[15] Northern Power Systems, "Northern Power Parent," September 25, 2008.

BOX 3 Production Methods

OEMs typically have unique designs for wind turbine nacelles and the leading global OEMs manufacture nacelles in-house. A few companies license wind turbine designs to other companies and several companies contract out nacelle manufacturing. Blades and towers may be produced in-house or by outside suppliers. Nacelles, blades, and towers are shipped directly from the manufacturing plant to the construction site.

Nacelles: The plants that produce nacelles are primarily assembly facilities. Nacelle components are produced (in-house or by outside suppliers) to the specifications of the OEM and then assembled at the nacelle plant. The assembly of a nacelle takes less than a week. With high demand in 2008, U.S. plants generally operated two to three shifts per day and five to seven days per week.

Blades: Wind turbine blades are advanced in design, but labor intensive in the manufacturing process. OEMs usually have unique designs for blades. Manufacturing includes labor intensive processes like adding layers of fiberglass to blade molds and finishing the edges of blades. It takes about one week to produce a blade.

Towers: OEMs design the wind turbine towers. Towers usually have 3 sections, each consisting of metal rings that are thickest at the bottom of the tower and are conical in shape since towers taper slightly from the base to a narrower opening at the top. During the manufacturing process plated sheets are cut, rolled into the conical shape and then welded into rings. Rings are then welded together and painted. Platforms, ladders and other accessories are added prior to shipping.

Nacelles, blades, and towers are shipped from the plant directly to the construction site, where they are installed by the project developer. Trucks are the most common method of transport, with specialized trailers required for transporting large pieces like nacelles and blades. Rail and barge shipping are less expensive and avoid the complicated permitting process associated with shipping heavy and oversized products across multiple states, but are used less frequently since they usually do not go to the construction site.

A rotor is installed on a wind turbine (left) and a blade for a GE turbine is transported to the National Renewable Energy Lab (right).

Photos courtesy of DOE/NREL, Credit – Jim Green (left) and Klaus Obel (right).

Sources: Industry officials, interviews by Commission staff, October 29, 2008; industry officials, interviews by Commission staff, October 30, 2008; industry official, interview by Commission staff, Washington, DC, September 24, 2008; industry official, telephone interview by Commission staff, December 10, 2008; "Expanding Inwards," *Win[d]*, May 8, 2008, 4–7; Gamesa Web site. http://www.gamesa.es (accessed January 15, 2008); LM Glasfiber Web site. http://www.lmglasfiber.com (accessed March 5, 2009); DOE, EERE, *20% Wind Energy by 2030*, 33; Kajrup and Flamholz, "Bending the Wind," August 14, 2003; Port of Houston, *2003 Annual Report*, 26-29; Wise, "Port Services are Essential to Wind Energy Logistics: Niche Services are Available in an Emerging Growth Market," March 2006; and Siemens, "Siemens Begins Transportation of Blades by Rail," March 4, 2009.

Many foreign OEMs are localizing nacelle production in the United States in order to take advantage of the growing market, reduce transportation costs,[16] minimize the risks associated with currency fluctuations, ease logistical challenges associated with exporting large nacelles and components, and avoid import duties.[17] Spanish OEMs Acciona Windpower and Gamesa established manufacturing plants in Iowa and Pennsylvania, respectively, and are the only two foreign-based OEMs currently assembling nacelles in the United States.[18] However, six other European OEMs—Emergya Wind Technologies, Fuhrlander, Nordex, Nordic Windpower,[19] Siemens, and Vestas—are planning to open assembly plants.[20]

BOX 4 Raw Materials

Steel is the primary material used in wind turbines, but there is also significant use of adhesives, aluminum, blade core materials, concrete, copper, and fiberglass. Rising commodity prices drove up production costs until the fall of 2008, but the financial crisis has put downward pressure on commodity prices.

Wind turbine raw materials, percent by weight, including blades and towers

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

Source: DOE, *20% Wind Energy by 2030*, 63.

Note: Numbers may not add to 100 percent due to rounding.

Supply Chain

The U.S. wind turbine supply chain consists of a combination of in-house production and outsourcing (figure 1), with many European suppliers strongly positioned in the supply chain. Most OEMs manufacturing in the United States want to localize important pieces of the supply chain in order to reduce transportation costs and logistical difficulties, avoid import duties, and mitigate the risks associated with currency fluctuations.[21] As a result, European suppliers are investing in U.S. production and U.S. companies are entering the wind turbine manufacturing industry as suppliers to OEMs.

[16] Due to the size and weight of wind turbine components, transportation can be expensive. For example, the cost to ship 120 Acciona wind turbines from Spain to the port in Duluth, Minnesota in 2007 was $13.7 million (10 million euros). This is an average cost of over $110,000 per turbine. According to GE, logistics can account for 20 percent of the cost of a wind turbine. "High-level Transport, the Latest Big Challenge," Winter 2007/2008, 18; GE Energy Infrastructure, Energy and Commerce written testimony, February 26, 2009, 4.

[17] Industry official, interview by Commission staff, October 30, 2008; industry official, telephone interview by Commission staff, December 10, 2008.

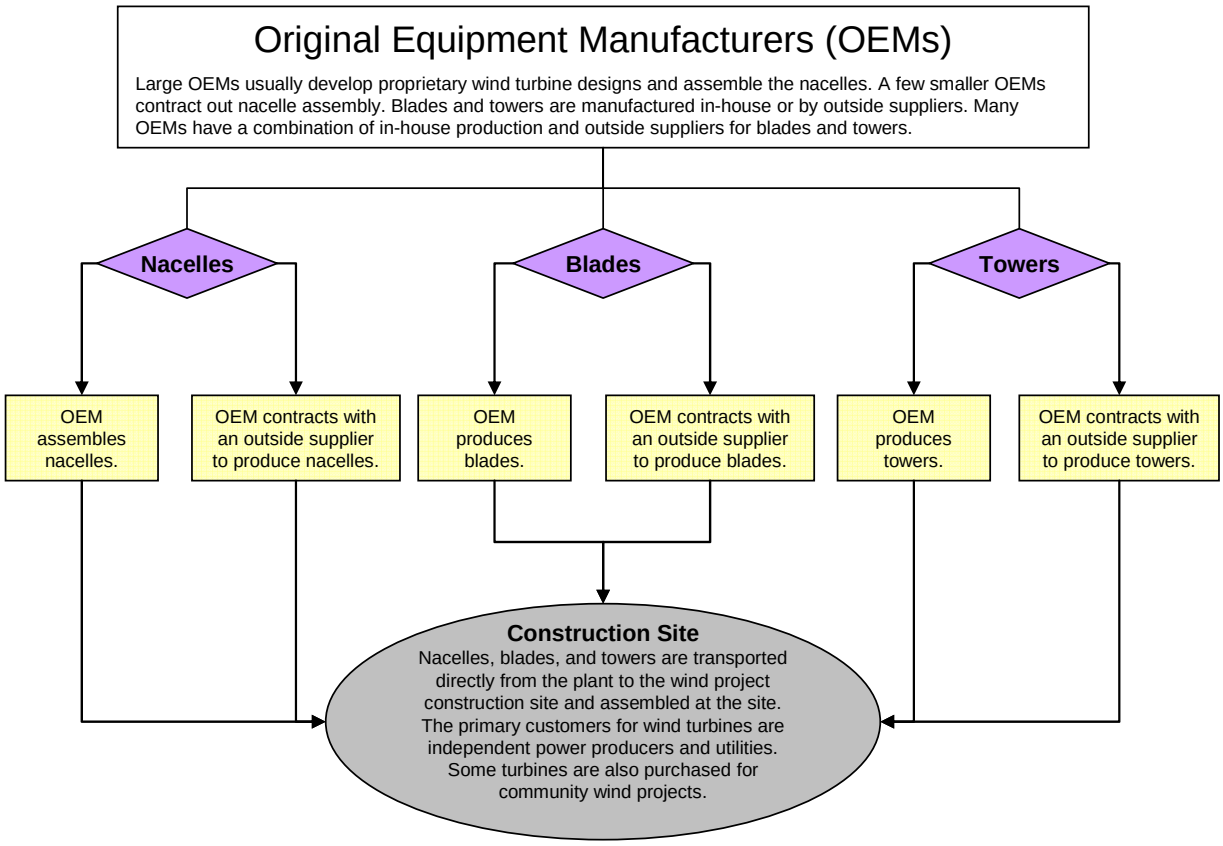
[18] OEMs' investment in U.S. blade and tower plants will be discussed later.

[19] Nordic Windpower is established in the United Kingdom, but its corporate officers are generally based out of the United States.

[20] Compiled from press releases and media reports.

[21] Industry official, interview by Commission staff, October 29, 2008; industry official, interview by Commission staff, Washington, DC, September 24, 2008; and industry official, telephone interview by Commission staff, December 10, 2008.

FIGURE 1 Wind turbine production process



Source: Prepared by USITC staff.

The rapid growth in global demand in the last few years strained the wind turbine supply chain. In response, some OEMs expanded and diversified their supply chain while others enhanced in-house production capabilities through investments in new manufacturing facilities or purchases of major component suppliers. Different business models have led to different degrees of vertical integration by company and by component. Suzlon, for example, has pursued a strategy of in-house production and vertical integration for most major components. GE is less vertically integrated than Suzlon, leveraging its experience and competitive advantage in supply chain management to build its wind turbine supply chain. Siemens falls in the middle. Unless all production is in-house, companies usually have at least two suppliers for key components.

Nacelle Components

Rising demand in the last few years has led to a shortage of key nacelle components such as gearboxes, large bearings, and large castings (table 2). For example, lead times could be 16 to 18 months for bearings and 40 weeks for gearbox components.[22] There are several components that only a small number of companies are able to produce to the specifications of the wind turbine manufacturing industry and these companies found it difficult to meet sharply rising demand. OEMs' efforts to build their supply chain and/or

[22] European Wind Energy Association (EWEA), "Supply Chain: The Race to Meet Demand," January/February 2007, 29, 30, 34.

in-house production capacity, together with the flattening of demand that resulted from the financial crisis, have reduced pressure on the supply chain. Most companies now find that while supplies are tight, they are able to get the components that they need. BTM Consult[23] forecasts that supply chain constraints for key components are likely to abate by 2012.[24]

TABLE 2 Supply chain status, nacelle components, 2006, 2008, and 2012 forecast

	2006	2008	2012 (E)
Bearings	Constraint	Constraint	Exceeds Demand
Castings/Forgings	Constraint	Constraint	Exceeds Demand
Gearboxes	Constraint	Exceeds Demand	Exceeds Demand
Generators	Exceeds Demand	Exceeds Demand	Exceeds Demand

Sources: BTM Consult, "The International Wind Industry 2008–2012," August 11, 2008; EWEA, "Supply Chain: The Race to Meet Demand," November 2006, 27.

Notes: E: Estimated. Constraint is defined here as a shortage or production capacity and demand roughly equal.

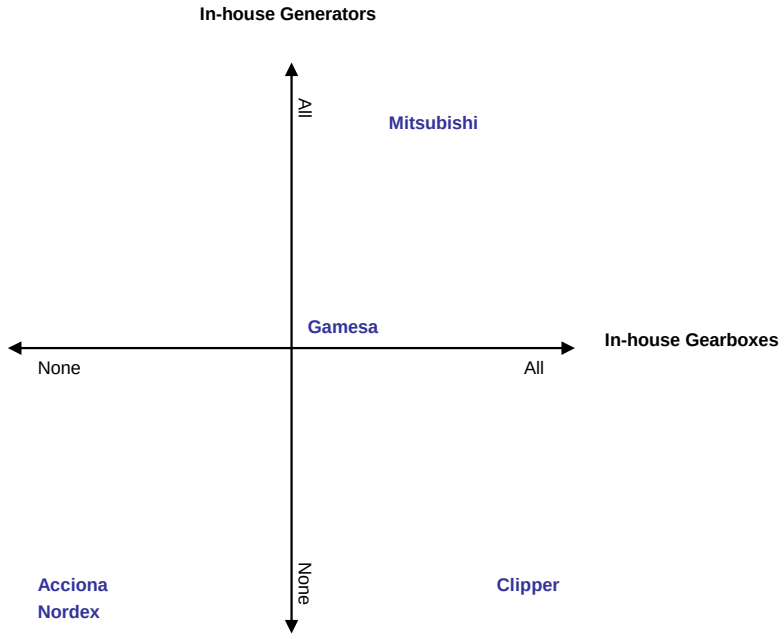
The supply chain for nacelle components reflects the different sourcing strategies and levels of vertical integration of OEMs. Looking at the same three companies, Suzlon purchased major drive train and gearbox manufacturer Hansen in 2006 and is expanding in-house production of components such as control panels and generators. Siemens purchased Flender and its drive system and generator manufacturing subsidiaries Winergy and Loher, but has not pursued the same extent of vertical integration as Suzlon. GE outsources a larger percentage of components, but does rely on a combination of in-house production and outsourcing for some components (e.g., gearboxes and generators).[25] Other companies demonstrate the same variation in the extent of vertical integration. For example, Acciona does not produce any gearboxes or generators in-house, while Gamesa produces around half of each in-house (figure 2).

[23] BTM Consult is a Danish consulting company focused on the wind energy sector. BTM Consult statistics are widely cited in the wind turbine industry.

[24] Industry official, telephone interview by Commission staff, December 10, 2008; BTM Consult, "The International Wind Power Industry 2008–2012," August 11, 2008.

[25] Suzlon, *Investor Presentation*, December 2008; EWEA, "Supply Chain," 29, 30, 34.

FIGURE 2 Vertical integration, gearbox and generator manufacturing, five companies, 2008



Sources: Compiled from interviews, company documents and Web sites, and Magee, "Wind Turbine Supply Chain."

Notes: Clipper assembles gearboxes on site, but the main components are provided by suppliers. Figures 2–4 are based on companies for which information is publicly available. Not all companies make this information available for all components. Therefore, there is variation in the OEMs used in each example.

The extent of market concentration, shortages, and domestic manufacturing capability varies by component:

Bearings: There is a shortage of bearings for the main shaft, gearbox, and pitch and yaw control. Only a few manufacturers are capable of producing the large bearings needed for wind turbines.[26]

Castings: There is a shortage of casting suppliers in the United States that can make the size needed for the wind turbine manufacturing industry. Currently, most of the suppliers that produce large castings are in Europe, though OEMs are actively looking to qualify local casting suppliers.[27]

Gearboxes: During the peak of wind turbine demand, there was a significant shortage of gearboxes. OEMs indicate supplies remain tight, but that shortages have abated.[28] The international gearbox market is very concentrated, with three European companies, Winergy (now part of Siemens), Hansen (now part of Suzlon), and Moventas, supplying multiple OEMs and controlling a significant share of the market. A group of at least half a dozen smaller, independent companies also supply gearboxes or are entering the market. In order to ensure adequate supplies, some companies have pursued a strategy of

[26] Industry official, interview by Commission staff, October 29, 2008; EWEA, "Supply Chain," 30; and BTM Consult, "The International Wind Power Industry 2008–2012."

[27] Industry official, interview by Commission staff, October 29, 2008; industry official, telephone interview by Commission staff, December 10, 2008.

[28] Industry officials, interviews by Commission staff, October 29, 2008; BTM Consult, "The International Wind Power Industry 2008–2012."

vertical integration (though none of the major OEMs meet all of their needs through in-house production). European manufacturers are expanding production in the United States. Moventas plans to build a new plant in Minnesota, Winergy is expanding production in Illinois, and Brevini plans to build a plant in Indiana.[29] Two U.S. manufacturers, K&M Machine Fabricating and Brad Foote, have entered the industry.

Generators: There is limited market concentration among generator suppliers. Generators are usually supplied all or in part by external suppliers and are available in adequate quantities.[30] The leading generator suppliers are European companies such as ABB, Ingeteam, Siemens (via its purchase of Flender), and Elin, though a few OEMs outside of Europe have in-house manufacturing capabilities.[31] In North America there is limited manufacturing capability, with no known investments in generator manufacturing in the United States by European companies.[32]

Blades

Many OEMs produce some blades in-house, but the extent of vertical integration varies by manufacturer (figure 3). Some companies outsource all blades (e.g., Clipper), while other OEMs produce all of their blades in-house (e.g., Suzlon). Most companies fall somewhere between these two extremes. OEMs usually have their own blade design and outside suppliers produce blades to their specifications. [33]

FIGURE 3 Vertical integration, blade manufacturing, four companies, 2008

Sources: Compiled from company documents and Web sites.

The U.S. supply chain for blades includes (1) OEMs with in-house production capabilities, (2) established European suppliers, (3) U.S. companies in related industries that are entering the wind manufacturing industry, and (4) relatively new suppliers outside of Europe and the United States. The first two groups are increasingly meeting U.S. demand by investing in production in the United States and North America. Combined with the entry into the market by U.S. companies in related industries, this has led to substantial growth in domestic manufacturing capabilities.

There are currently at least 12 open or planned blade manufacturing facilities in the United States (table 3). 11 of these 12 plants were opened or announced since 2003. Six

[29] Agliata, "Moventas coming to Rice County Friday," September 5, 2008; Sandley, "BREVINI: Firm to Bring 455 High-Paying Jobs," October 8, 2008; and industry official, telephone interview by Commission staff, December 10, 2008.

[30] EWEA, "Supply Chain," 27–28, 30; BTM Consult, "The International Wind Power Industry 2008–2012."

[31] Industry official, interview by Commission staff, October 29, 2008; Magee, "Wind Turbine Supply Chain Trends and Component Tiers," December 9, 2008.

[32] Clipper imports generators from Mexico. GE has in-house production for generators, but it is not known whether this manufacturing is in the United States.

[33] Industry official, telephone interview by Commission staff, December 10, 2008; industry official, interview by Commission staff, October 29, 2008; industry official, interview by Commission staff, October 30, 2008; and Suzlon, *Investor Presentation*.

OEMs (Gamesa, Nordex, Siemens, Suzlon, Vestas, and Emergya Wind Technologies via subsidiary Polymarin Composites) have or are establishing their own U.S. blade manufacturing facilities. European company LM Glasfiber, the largest global supplier with 25 percent of the world market, has two manufacturing facilities in the United States and one in Canada.[34] At least three U.S. companies, TPI Composites, Molded Fiberglass, and Knight and Carver, have made the transition from related areas to become suppliers to OEMs. TPI Composites and Molded Fiberglass have supply agreements with GE.[35]

TABLE 3 Representative list of open or planned blade manufacturing plants in the United States, 2009

Company	Location	Headquarters	OEM/Supplier
Gamesa	Pennsylvania	Spain	OEM
Knight and Carver	South Dakota	United States	Supplier
LM Glasfiber	Arkansas, North Dakota	Denmark	Supplier
Molded Fiberglass	South Dakota	United States	Supplier
Nordex	Arkansas	Germany	OEM
Polymarin Composites	Arkansas	Netherlands	OEM
Siemens	Iowa	Germany	OEM
Suzlon	Minnesota	India	OEM
TPI Composites	Iowa	United States	Supplier
Vestas	Colorado (2)	Denmark	OEM

Sources: Complied from AWEA publications, media reports, news releases, and company Web sites.

Notes: This is a representative list and may not include all blade manufacturers. If there is more than one plant in the state, the number of plants is listed in parentheses. Some facilities may also produce other components such as nacelles. Polymarin Composites is a wholly owned subsidiary of Emergya Wind Technologies. Bureau van Dijk, Orbis Companies Database (accessed various dates).

While the U.S. manufacturing base has expanded, OEMs also source blades from outside the United States. For example, some OEMs ship blades from Europe, TPI Composites formed a joint venture with Mitsubishi in Mexico that supplies blades for Mitsubishi turbines in the United States, and LM Glasfiber has a manufacturing facility in Canada that can supply blades. In addition, Brazilian company Tecsis is a major supplier to the wind turbine manufacturing industry, providing blades for at least three OEMs in the U.S. market, including blades that it supplies as part of a reported 4 year, $1 billion agreement with GE.[36]

Towers

OEMs tend to be less vertically integrated in tower production than in blade production due, at least in part, to the fact that more companies have the expertise and capabilities necessary to make towers.[37] For this same reason, there are more independent tower producers than blade producers. As with blades, some OEMs outsource all tower production while others have in-house production (figure 4). Companies that produce both blades and towers in-house tend to have a lower percentage of in-house blade production than in-house tower production.

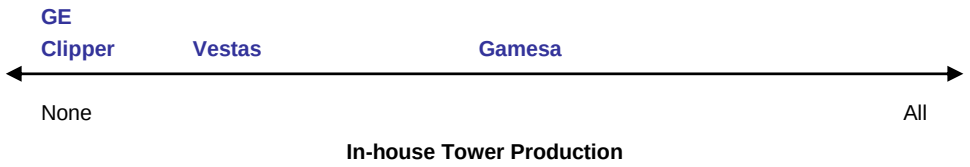
[34] Grande, "Wind Power Blades Energize Composites Manufacturing," October 2008.

[35] "GE Energy Announces Two New U.S. Wind Turbine Blade Facilities," January 1, 2008.

[36] Business Week Company Insight Center. http://investing.businessweek.com (accessed November 24, 2008); industry officials, interviews by Commission staff, October 29, 2008; and TPI Composites, "Mitsubishi/TPI Open Second Wind Blade Plant," October 24, 2007.

[37] EWEA, "Supply Chain," 30.

FIGURE 4 Vertical integration, tower manufacturing, four companies, 2008



Sources: Compiled from Magee, "Wind Turbine Supply Chain," December 9, 2008 and company documents and Web sites.

The U.S. supply chain for towers consists of the same four groups that comprise the supply chain for blades, but there is a different allocation of market share between the groups:

(1) OEMs with in-house production facilities: OEMs produce towers in-house for the U.S. market, but in-house production makes up a smaller percentage of the U.S. market than in-house production of blades.

(2) Established European suppliers: Information on the extent to which European suppliers are exporting to the United States is limited. The proportion of tower manufacturing facilities in the U.S. that are owned by European suppliers is small.

(3) U.S. manufacturers: U.S. companies in related industries are entering the market for towers in greater numbers than companies are entering blade manufacturing.[38]

(4) Suppliers outside of Europe and the United States: Producers in Canada, Mexico, and Asia have significant U.S. market share. At least one Asian company has invested in U.S. production.

U.S. tower production has expanded rapidly, primarily due to investment by OEMs and U.S. companies in related industries. There are at least 15 companies producing or planning to produce towers at 20 locations (table 4). Two European OEMs and one European tower manufacturer have established or are planning to open U.S. manufacturing plants. Eleven U.S. companies manufacture towers at 16 U.S. plants and one U.S. company established a joint venture with a Japanese company to manufacture towers in the United States.

[38] According to the EWEA, the expertise to enter wind tower manufacturing is widely available, so OEMs are more likely to source towers locally than many other components. This has probably contributed to U.S. companies entering tower manufacturing more rapidly than blade manufacturing. Ibid., 30.

TABLE 4 Representative list of open or planned tower manufacturing plants in the United States, 2009

Company	State	Headquarters	OEM/Supplier
Aerisyn Inc	Tennessee	United States	Supplier
Ameron	California	United States	Supplier
Bergen Southwest Steel	Texas	United States	Supplier
DMI	North Dakota, Oklahoma	United States	Supplier
Dragon Wind	Colorado	United States	Supplier
Gamesa	Pennsylvania	Spain	OEM
Katana Summit	Nebraska	Japan and United States (joint venture)	Supplier
Martifer	Texas	Portugal	Supplier
Northstar Wind Towers	Nebraska	United States	Supplier
RTLC Windtower	Texas	United States	Supplier
SMI & Hydraulics	Minnesota	United States	Supplier
T. Bailey	Washington	United States	Supplier
TowerTech (Broadwind)	South Dakota, Texas, Wisconsin	United States	Supplier
Trinity Structural Towers	Illinois, Iowa, Texas	United States	Supplier
Vestas Wind Systems	Colorado	Denmark	OEM

Sources: AWEA publications, news releases, media reports, and company Web sites.

Note: This is a representative list and may not include all tower manufacturers.

OEMs often source towers locally due to high transportation costs and the risk of exchange rate fluctuations, but OEMs also source towers for the U.S. market from Canada, Mexico, and Asia. Towers from Asia may be cheaper for projects on the West Coast than towers made at distant U.S. plants and, by maintaining suppliers in Asia, OEMs have more flexibility in their supply chain.[39] China, Indonesia, Korea, and Vietnam are among the major producers of wind towers for the U.S. market. For example, Dongkuk S&C in Korea and CS Wind Tower Company, a Korean company with manufacturing in Vietnam and China, have supplied Vestas and the U.S. market.[40] In Canada, there are at least three companies (Hitachi, DMI Industries, and Marmen) capable of supplying towers for the U.S. market.[41] Trinity Structural Towers is capable of supplying the U.S. market from Mexico.[42]

Entering the Supply Chain

There is substantial interest among U.S. manufacturers outside the wind turbine manufacturing industry in becoming suppliers to OEMs, a trend that has accelerated as companies negatively affected by the financial crisis and the recession look to diversify

[39] Industry official, telephone interview by Commission staff, December 10, 2008.

[40] Ibid.; Port of Longview, "Port of Longview Handles Siemens Wind Turbines," March 26, 2007; Caldwell, "Port Windfall: Wind Farm Imports Buoy Economy," March 16, 2003; "Building Relationships with Asia," Fall 2006, 1. "Vestas' Wind Turbine Towers go from Ship to Rail in Longview," August 19, 2003; Unison Company Web site. http://www.unison.co.kr (accessed November 25, 2008); and "A Fresh Look at Quality," November 2008, 37–39.

[41] DMI Industries, "DMI Industries Increases Production at Fort Erie Plant," October 22, 2008; "Hitachi Canadian Industries Selects Portable Circular End Mills for Wind Towers," January 5, 2009; and Marmen Web site. http://www.marmen.qc.ca (accessed February 2, 2009)

[42] Allen, "Wind towers help fill sails at Trinity Industries," December 21, 2007.

their customer base. But the financial crisis has made it more difficult to enter the industry. While OEMs want to add local suppliers, becoming a supplier is expensive and challenging due to the need to reinvest and retool plants and to demonstrate the ability to expand as the OEMs grow. The current financial environment makes it difficult to access the capital necessary to overcome these barriers.[43] The American Recovery and Reinvestment Act (Stimulus Bill) attempts to make it easier for manufacturers to enter wind turbine and other renewable manufacturing industries by creating a 30 percent tax credit for retooling manufacturing facilities or investing in new manufacturing plants.[44]

OEMs note that potential suppliers are often unfamiliar with the large size of wind turbine components and the reliability and quality requirements.[45] Wind turbine components must meet a high quality threshold given the twenty year life expectancy of the turbine and expense of replacing components in an installed turbine. As a result, there is an extensive qualification process that can take 2 to 3 months for simple parts and 12 to 15 months for more complicated parts. Some companies have representatives on-site at suppliers around the world to ensure that products meet quality requirements.[46]

Despite these challenges, most OEMs are confident in the skills and capabilities of U.S. industry and the ability of U.S. companies to make the transition to wind.[47] Anecdotal evidence and data for individual states indicate the growth in nacelle, blade, and tower manufacturing has led to growth in the number of companies in the U.S. producing materials or components for nacelles, blades, and towers. For example, Clipper Windpower produced its first wind turbines in Iowa in 2006 and now has about 90 in-state suppliers. The number of wind turbine manufacturing industry suppliers in Ohio increased from fewer than 12 in 2004 to about 37 in 2007 to more than 50 in 2008.[48] In Colorado, Hexcel and Creative Foam Corp. are establishing manufacturing plants to supply the new Vestas blade plants.[49]

Location of Nacelle, Blade, and Tower Plants

Proximity to markets and access to multiple shipping options are two of the most important factors for manufacturers in deciding where to establish manufacturing facilities. Due to the size and weight of nacelles, blades, and towers, proximity to markets is important in reducing shipping costs, minimizing logistical difficulties, and avoiding permitting challenges that increase with the distance from the construction site.[50] The largest markets in the United States (figure 5) tend to be in the central United States in

[43] Industry official, interview by Commission staff, October 29, 2008.

[44] ACORE, "Overview, Renewable Energy Provisions, American Recovery and Reinvestment Act of 2009."

[45] Industry official, interview by Commission staff, October 29, 2008; industry official, telephone interview by Commission staff, December 10, 2008.

[46] Industry official, telephone interview by Commission staff, December 10, 2008; industry official, interview by Commission staff, October 29, 2008; and Clipper Windpower, *2007 Annual Report*, 22.

[47] Industry official, interview by Commission staff, October 29, 2008.

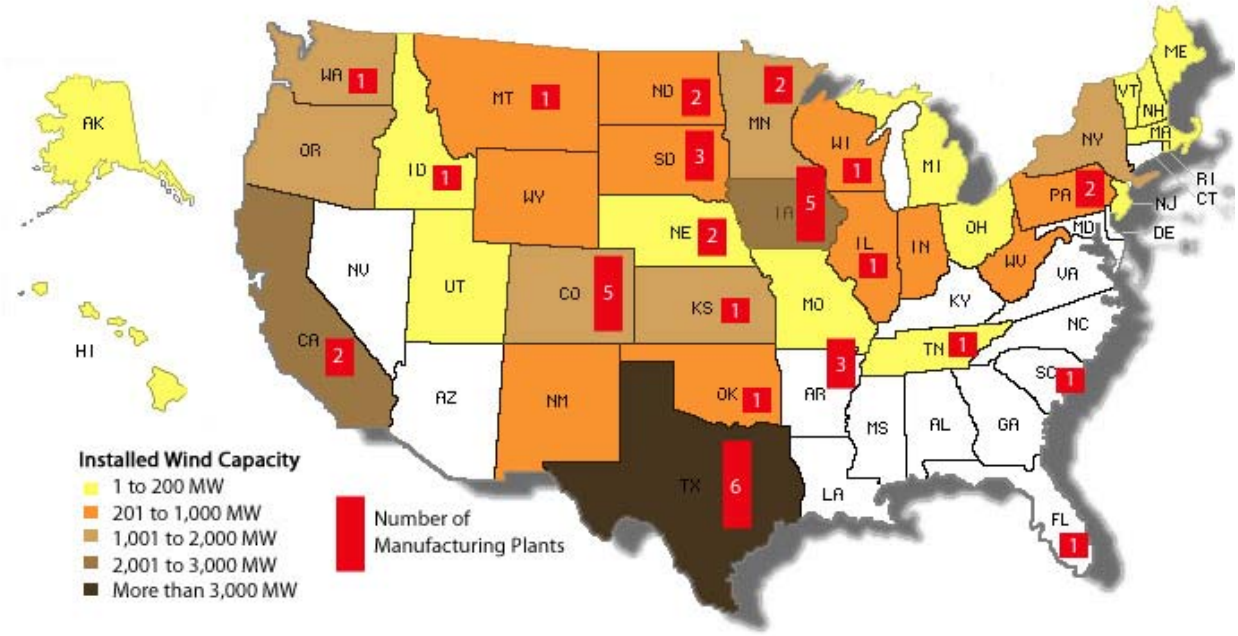
[48] Industry official, interview by Commission staff, October 30, 2008; Ohio Business Development Coalition, "Ohio Manufacturing Companies," November 13, 2007; Ohio Department of Development, "Ohio Windpower Conference," November 10, 2004; and Maves, "Wind Industry in Ohio and Supply Chain Opportunities," 2008.

[49] "Hexcel Breaks Ground on New Colorado Facility," February 24, 2009; "Creative Foam Getting Ready to Put Down Colorado Roots," March 10, 2009.

[50] Industry officials, interviews by Commission staff, October 30, 2008; industry official, telephone interview by Commission staff, December 10, 2008; and press releases and media reports.

close proximity to the best and most widely available onshore wind resources (figure 6) or on the West Coast. Therefore, most manufacturing plants are located near large markets (figure 5).

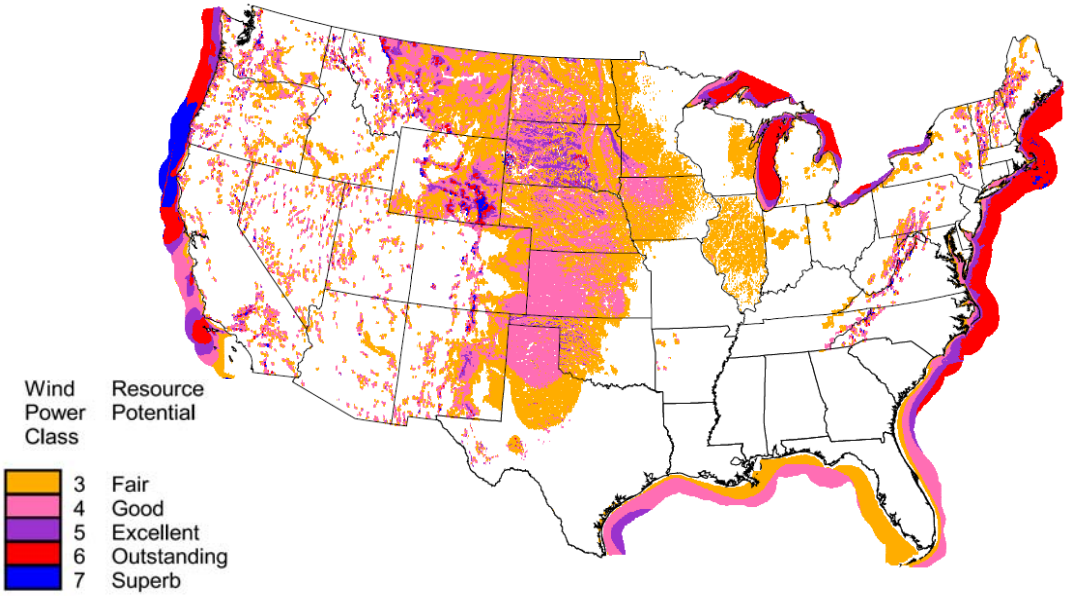
FIGURE 5 Installed wind capacity and location of blade, nacelle, and tower manufacturing plants, by state, March 2009



Sources: AWEA Web site. http://www.awea.org/projects (accessed various dates); see Tables 2, 3, and 4 for manufacturing plant data; and map template from DIY Maps Web site. http://monarch.tamu.edu/~maps2/ (accessed various dates).

Note: In several cases, blades and nacelles are produced in the same plant. These plants are only listed once. Based on a representative list of manufacturing plants. The map may not include every plant in the United States. However, it does provide a good representation of the distribution of manufacturing activities.

FIGURE 6 National Renewable Energy Lab (NREL) wind resources map



Source: Department of Energy, Wind Powering America Web site. http://www.windpoweringamerica.gov (accessed various dates).

Notes: Areas with marginal (class 2) and poor (class 1) wind resources are not shown. While some of the best wind resources are off the East and West Coasts, no offshore turbines have been installed in the United States.

Companies also consider the availability and adequacy of shipping options when making location decisions. Companies ship most often by truck and want to be close to a good interstate system, but multiple shipping options are also important. Therefore, companies generally locate near rail lines and/or waterways that offer lower cost shipping options. Proximity to suppliers and other companies in the wind turbine manufacturing industry are also considerations.[51]

The quality of the workforce, availability and quality of worker training programs, proximity to good community colleges, traditional employment base (e.g., history of manufacturing), and labor and operating costs are also important in location decisions.[52] Political support, positive relationships with state and local officials, and financial incentives are also considerations, and state and local governments have offered extensive incentives to attract these industries. State and local support includes property tax abatements, sales tax reductions, low interest loans, and support for worker training. In some cases, local governments have made investments in infrastructure, such as extending railroads and improving highway ramps. Some states have offered support for R&D and the deployment of new technology.[53]

[51] Ibid.
[52] Ibid.
[53] Ibid.

Employment

Employment in wind turbine manufacturing increased from 2003 to 2008, but was negatively affected by the financial crisis and recession in late 2008 and early 2009. In 2008, manufacturing employment was about 20,000, a significant increase from employment in 2007.[54] The number of wind related jobs among GE suppliers increased from about 2,000 in 2008 to over 4,000 in 2009.[55]

The recession and the financial crisis led to layoffs in late 2008 and early 2009. At least eight wind turbine manufacturing industry plants laid off workers and two plants closed between November 2008 and March 2009 (table 5). As a result, 803 out of 2,797 jobs (29 percent) at these plants were lost.[56] In addition to the job losses, planned expansions of several plants were postponed and a few companies delayed new plant construction. However, not all jobs losses were due to the recession and the financial crisis. Gamesa laid off about 180 workers involved in blade production at one Pennsylvania plant with the intention of expanding production at another U.S. plant that can make larger blades. LM Glasfiber laid off about 150 employees and closed one of its two plants in Arkansas, but this was a facility that was originally intended to be temporary and was only kept open due to the high level of demand in 2008.[57] In addition, many planned investments remain unaffected and are still moving forward. For example, Vestas broke ground on nacelle and blade factories in Colorado in March 2009.[58] In total, new manufacturing facilities announced in 2008 could lead to about 4,000 additional jobs in the long term.[59]

TABLE 5 Reported wind turbine manufacturing job losses, November 2008–March 2009

	Plants w/Layoffs	Plants Closed	States with Layoffs	Original Employment at Affected Plants	Approximate Layoffs
Nacelle Plants	2	0	Iowa (2)	578	148
Blade Plants	3	1	Arkansas (2), Pennsylvania, South Dakota	1440	360
Tower Plants	3	1	North Dakota, Oklahoma (2), Tennessee	779	295
Total	**8**	**2**		**2,797**	**803**

Sources: Compiled from press releases and media reports.

Note: Number in parentheses indicates the number of plants in the state affected (if more than one). Layoffs at one of the nacelle plants include global layoffs for that OEM. However, most of these layoffs were expected to affect the U.S. manufacturing plant.

Manufacturers (nacelle, blade, and tower) generally seek skilled workers in areas such as mechanical and electrical assembly or workers with specific skills that translate into wind energy manufacturing (e.g., previous manufacturing or related experience).[60] Manufacturers often look for locations with community college systems that provide good technical training for workers. In addition, manufacturers train workers on site and

[54] Total employment in the wind energy industry, including manufacturing, construction, and services, increased from about 50,000 in 2007 to about 85,000 in 2008. AWEA, *Annual Wind Industry Report*, 17.

[55] GE Energy Infrastructure, Energy and Commerce written testimony, February 26, 2009, 4.

[56] Compiled from press releases and media reports.

[57] Ibid.

[58] "Vestas Opens Two Manufacturing Facilities In Colorado," March 26, 2009.

[59] AWEA, *3rd Quarter 2008 Market Report*, October 2008, 18–19.

[60] Industry official, interview by Commission staff, October 30, 2008; industry official, interview by Commission staff, October 29, 2008; and press releases and media reports.

multinational corporations often have exchange programs with employees from overseas coming to newly opened U.S. plants and U.S. employees going overseas for training.[61]

Based on 12 manufacturing plants for which information was publicly available, average hourly wages in manufacturing plants (nacelle, blade, and tower) are generally between $13 and $20 (table 6).[62] The median of the average hourly wage rate at the twelve companies was $15.

TABLE 6 Estimated average hourly wages at 12 manufacturing plants

	Sample Size	Average Hourly Wage Range
Nacelle Plants	3	$15 to $20
Blade Plants	6	$13 to $17
Tower Plants	2	$15 to $16
Nacelle and Blade Plants	1	$17
Total	**12**	**$13 to $20**

Sources: Compiled from press releases and media reports and Kelly, "Wind Energy Update," June 26, 2008.

Note: The date of the reported wages varies, but they are generally from 2007 and 2008.

Research and Development

As an emerging technology that is on the verge of price competitiveness with traditional sources of power, research and development (R&D) is critical to the wind turbine industry. OEMs are developing and testing (a) new multi-MW onshore wind turbines, (b) offshore wind turbine models, and (c) turbines that can operate in low wind or very cold climate conditions. Through their R&D programs, OEMs also seek to (1) optimize nacelle, blade, and component designs and materials, (2) improve the reliability of wind turbines, (3) improve turbine technology, and (4) tailor turbines for local markets. Corporate spending on R&D varies and comparisons across companies may be unreliable given potentially different definitions and accounting methods; however, reported expenditures do give a sense for spending on R&D. Vestas spent $175 million (119 million Euros, 2.0 percent of revenue)[63] on R&D in 2008, Suzlon spent $3.4 million (0.2 percent of sales) on R&D in the fiscal year ending in 2008, and Clipper spent $21.1 million on R&D in 2008 (3 percent of revenue). U.S. companies GE and Clipper have R&D capabilities in the United States and Siemens and Vestas plan to open U.S. R&D facilities.[64]

[61] Industry official, interview by Commission staff, October 29, 2008; press releases and media reports.

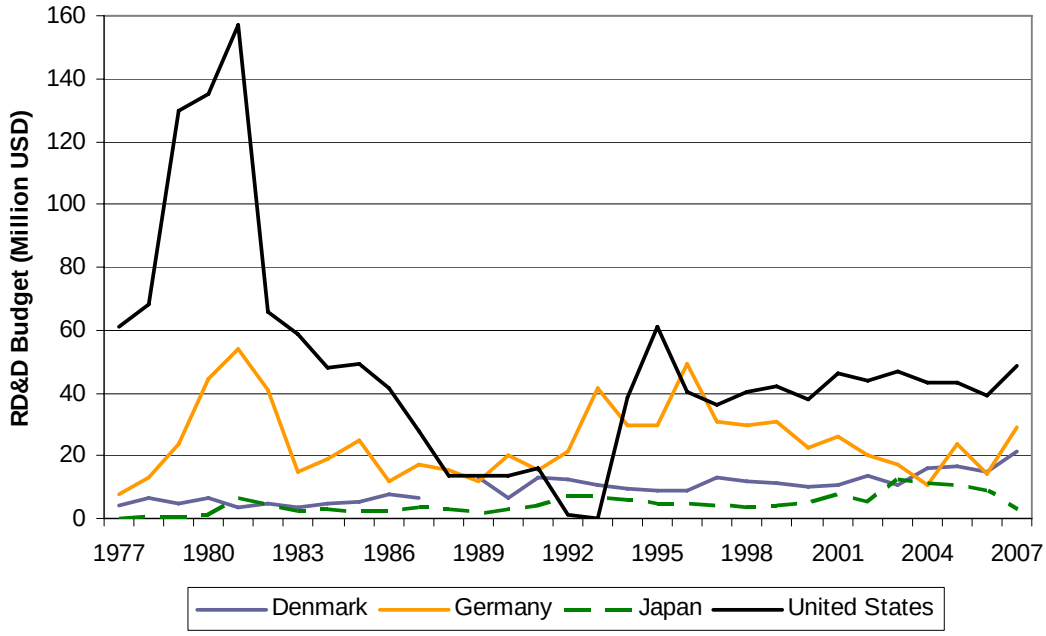
[62] Based on companies for which information on wages was publicly available. Since this sample was not scientifically selected and there may be differences in the data reported (e.g., which types of workers are included), this should be viewed as a rough estimate. Where possible, managerial workers were excluded from the comparison but, in some cases, it was not clear whether managerial workers were included in the average wage rates. In one case, a wage range was given. For this company, the mid-point of that range was used as the average wage.

[63] Expenditures converted to U.S. dollars based on the average daily exchange rate for the year. Exchange rate source: Federal Reserve Web site. http://www.federalreserve.gov (accessed various dates).

[64] Vestas, *Annual Report 2007*, 16–17, 60; Vestas, *Annual Report 2008*, 45; Suzlon, *Annual Report 2007–2008*, 29–30; REpower Systems, *Annual Report 2007*, 51–52; Nordex, *Annual Report 2007*, 31; Clipper Windpower, *Annual Report 2007*, 10; Clipper Windpower, *Annual Report 2008*, 11; and Siemens, "Siemens to Open Wind Turbine Research Center in Boulder, Colorado," June 3, 2008.

Government programs and public-private collaboration through national laboratory systems aid the development of wind technology and the testing of new wind turbine models. The United States generally budgets more money for wind energy research, development, and demonstration (RD&D) than other countries with competitive wind industries (figure 7). From 2003 to 2007, the average annual U.S. wind energy RD&D budget was $44 million, while Germany's was $19 million, Denmark's was $16 million, and Japan's was $9 million.[65] However, U.S. funding has been highly inconsistent over time and is currently lower than funding for solar and biomass research, which received an average of $102 million and $114 million, respectively, from 2003 to 2007. Comparing renewable energy RD&D expenditures as a whole to nuclear and fossil fuel RD&D expenditures, cumulative renewable energy RD&D expenditures from 1974 to 2007 were significantly less than RD&D expenditures for nuclear energy and fossil fuels and, on an annual basis, were lower throughout most of the period. In 2007, the U.S. RD&D budget for nuclear energy was $629 million, for fossil fuels $367 million, and for renewable energy $416 million.[66]

FIGURE 7 Wind energy RD&D budget for select countries, 1977–2007



Sources: International Energy Agency (IEA), IEA Energy Technology R&D Statistics Service (accessed various dates).

Notes: 1988 data for Denmark are not available. Data are in constant 2007 U.S. dollars at the 2007 exchange rate.

Globalization

OEMs have entered global markets through a combination of exports and overseas production. OEMs often prefer to establish overseas production facilities since there are high transportation costs and logistical challenges associated with exporting nacelles,

[65] International Energy Agency (IEA), IEA Energy Technology R&D Statistics Service (accessed various dates).

[66] Ibid.

blades, and towers.[67] According to a recent survey of turbine manufacturers, more than 40 percent of companies indicated that the best way to enter new markets is through joint ventures. Another 40 percent indicated that the best way is through a subsidiary, while less than ten percent prefer to export.[68] As a reflection of this, large OEMs and blade manufacturers tend to produce in at least two of the major global markets, though tower manufacturers are less likely to produce outside their home region (figure 8).

FIGURE 8 Global production locations, eleven companies, 2009

	Asia		Europe					North America		
	China	India	Denmark	Germany	Poland	Portugal	Spain	Canada	Mexico	U.S.
Acciona	Nacelles						Nacelles (2) Blades			Nacelles
Clipper										Nacelles
Gamesa	Nacelles Blades						Nacelles (4) Blades (5) Towers (4)			Nacelles Blades Towers
GE	Nacelles			Nacelles			Nacelles	Nacelles		Nacelles (3)
Siemens			Nacelles Blades (2)							Nacelles Blades
LM Glasfiber	Blades (2)	Blades (2)	Blades (2)		Blades		Blades (3)	Blades		Blades (2)
Molded Fiberglass										Blades
TPI Composites	Blades								Blades (2)	Blades
DMI								Towers		Towers (2)
Martifer						Towers				Towers
Trinity Industries									Towers	Towers (3)

Source: Compiled from company Web sites and media reports.

Notes: Nacelles highlighted in gray, blades in blue, and towers in beige. The number in parentheses represents the number of manufacturing plants in the country (if there are multiple plants). Several of the plants are under construction. This figure is limited to companies that manufacture in the United States. As a result, it may appear to over represent the percent of global production that takes place in the United States. It does not include all companies that manufacture in the United States.

Despite the preference of OEMs for local production, it is not feasible to establish production facilities in every market and large increases in global trade in the last few years indicate that companies can profitably export wind turbines and components. Companies make decisions about whether to export or establish local production facilities based on factors such as the proximity of the market to existing plants, transportation costs, comparative labor and production costs, the local supply base, the favorability and

[67] Industry official, interview by Commission staff, Washington, DC, September 24, 2008; industry official, telephone interview by Commission staff, December 10, 2008; and industry official, telephone interview by Commission staff, November 17, 2008.

[68] Multiple responses possible. HUSUM WindEnergy, "WindEnergy Study 2008."

stability of the exchange rate, trade barriers and duties, and the size and stability of the market.[69]

Among U.S. producers, two strategies are emerging. First, U.S. manufacturers, including both U.S.-based companies and foreign companies with U.S. manufacturing facilities, are beginning to export products, primarily to smaller, emerging markets in North and South America. Many of the new U.S. manufacturing plants were established with the intention of serving both the U.S. market and other markets in North and South America.[70]

Second, U.S. companies are investing in foreign production facilities in key wind energy markets. GE has manufacturing plants (some inherited from its purchase of Enron Wind) in Canada, China, Germany, Spain, and the United States.[71] The facilities are located in large wind markets and, in the case of Canada, Spain, and China, countries with local content requirements at the local or national level.[72] Clipper established an R&D center in the United Kingdom to design a 7.5 MW offshore wind turbine that may be also produced in the United Kingdom.[73]

Some U.S.-based companies view the Chinese market as providing the best opportunity outside the United States. Several U.S.-based producers have established manufacturing locations in China in order to enter the market. For example, GE established a nacelle plant in China; blade manufacturer TPI Composites established a Chinese manufacturing plant following an agreement to supply blades to GE; and Timken established a joint venture in China to produce bearings.[74] Despite this growth, wind turbine production in China by U.S. companies is significantly less than production by European companies.[75]

U.S. MARKET

The United States wind turbine market is rapidly expanding and is now the largest in the world in terms of annual wind turbine installations. Annual installed capacity increased from 1,672 MW in 2003 to 8,545 MW in 2008 (figure 9).[76] Wind energy makes up a growing portion of new electricity generation capacity, accounting for 35 percent of capacity additions in 2007.[77] Wind energy accounts for a small but growing portion of

[69] Industry officials, interviews by Commission staff, October 29, 2008; industry official, interview by Commission staff, October 30, 2008; industry official, telephone interview by Commission staff, December 10, 2008; and press releases and media reports.

[70] Industry official, telephone interview by Commission staff, December 10, 2008; press releases and media reports.

[71] GE Web site. http://www.ge.com (accessed various dates).

[72] Local content requirements are discussed below.

[73] Clipper Windpower, "Clipper Leads on Technology and Size," October 8, 2007.

[74] GE Web site. http://www.ge.com (accessed various dates); Timken, "Timken and XEMC," December 9, 2007; and TPI Composites, "TPI Composites and GE Energy Reach Agreement," April 12, 2007.

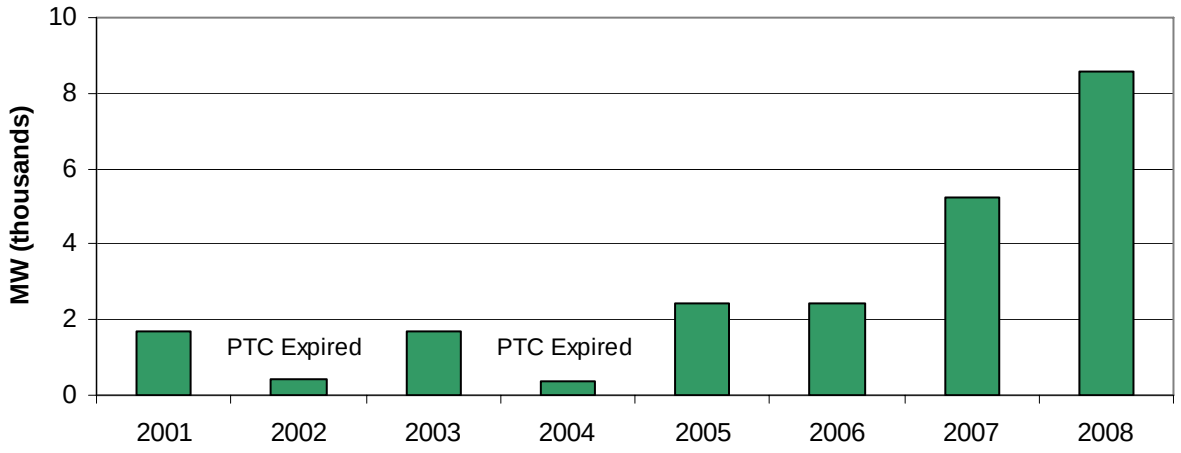
[75] While GE is the sole U.S.-based OEM with manufacturing facilities in China, several Europe-based OEMs (e.g., Acciona, Gamesa, and Vestas) have manufacturing facilities in China. Blade manufacturer LM Glasfiber has two manufacturing plants in China. LM Glasfiber Web site. http://www.lmglasfiber.com (accessed April 7, 2009); EWEA, "Global Markets: The World Catches up with Europe," July/August 2008, 28; and Acciona Web site. http://www.acciona.com (accessed various dates).

[76] More than 5,100 wind turbines were installed in 2008. AWEA, *Annual Wind Industry Report*, 4, 10.

[77] Based on generator nameplate capacity additions. Generator nameplate capacity is the manufacturer rated maximum output. Energy Information Administration (EIA), *Capacity Additions, Retirements and Changes by Energy Source*, January 21, 2009; EIA Web site. http://www.eia.doe.gov (accessed various dates).

total U.S. electricity generating capacity, increasing from less than one percent in 2003 to 1.7 percent in 2007.[78] The Department of Energy has set a goal of generating 20 percent of U.S. electricity from wind by 2030.[79]

FIGURE 9 Annual installed wind energy capacity, 2001–08



Source: AWEA, *Annual Wind Industry Report*, 10.

Note: Wind turbine installations declined in 2002 and 2004 because the production tax credit (PTC), one of the primary incentives for wind installations, expired.

Currently, the U.S. market is almost entirely for onshore wind turbines since they are less expensive to install and maintain, and easier to site than offshore wind turbines. In the United States, there are also ample available onshore sites. However, offshore wind turbine installations in the United States are likely to grow in the long term since the United States has excellent offshore wind resources close to major population centers.[80]

Wind Turbine Suppliers and Market Competition

The number of OEMs in the U.S. market is expanding as the size of the domestic market grows. The number of OEMs in the U.S. market increased from five in 2003 to 13 in 2008.[81] U.S.-based GE maintained its position as the leading OEM in the U.S. market from 2003 to 2008, but market growth and the market entry of additional OEMs reshaped the market share of competitors. In 2003, the three leading competitors in the U.S. market were GE, Vestas, and Mitsubishi, with 55, 30, and 12 percent of the market, respectively

[78] Based on MW of electric net summer capacity. EIA, *U.S. Electric Net Summer Capacity, 2003–2007*, April 2009.

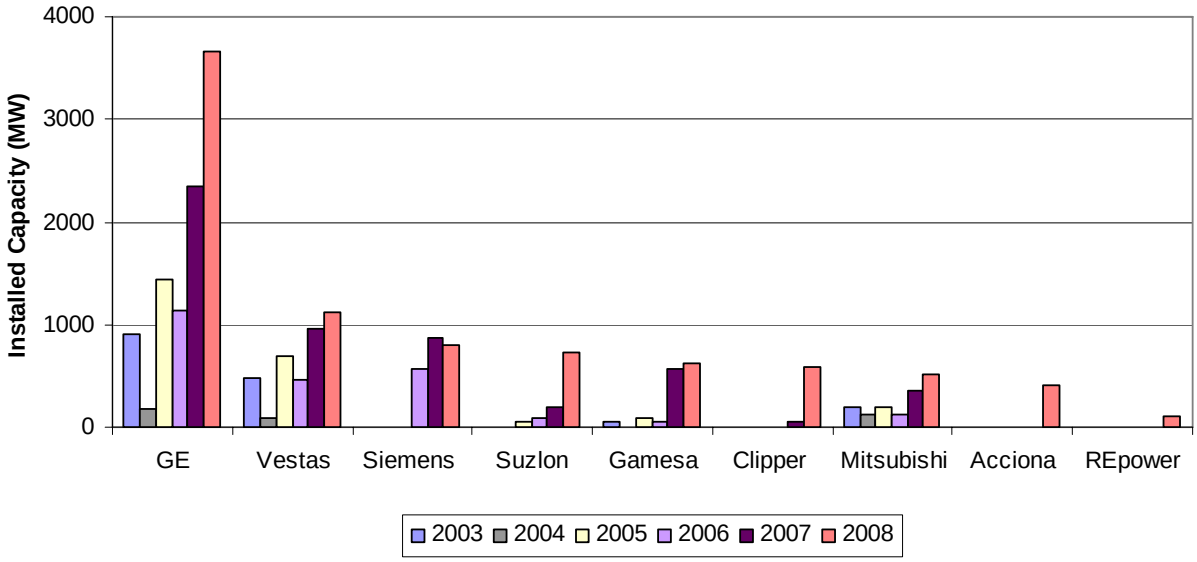
[79] See U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), *20% Wind Energy by 2030*, July 2008.

[80] Industry official, interview by Commission staff, Washington, DC, September 24, 2008; industry official, interview by Commission staff, October 29, 2008; industry official, telephone interview by Commission staff, November 10, 2008; and industry official, telephone interview by Commission staff, November 24, 2008.

[81] Two of the five suppliers in 2003, Vestas and NEG Micon, merged in 2004. In addition, there were companies without sales in 2003 that were in the market in previous years. For example, Bonus Energy, acquired by Siemens in 2004, had significant U.S. sales in the early 2000s and Nordex turbines were installed in 2000. The merger of Vestas and NEG Micon and purchase of Bonus by Siemens are part of a pattern of acquisition of OEMs. For example, GE purchased its wind business from Enron, Suzlon acquired REpower, CTC acquired EU Energy (now DeWind), and Gamesa acquired Spanish competitor Made. AWEA, "Annual Rankings Demonstrate"; AWEA, *Annual Wind Industry Report*, 10.

(figure 10). Each of these companies had strong sales growth between 2003 and 2008, but the market share of each company also decreased due to other companies entering the market and companies already in the market increasing their market share. GE installations increased from 903 MW in 2003 to 3,657 MW in 2008 (305 percent), though its market share decreased from 55 percent to 43 percent. Vestas was second in the U.S. market in 2008 with 1,120 MW installed, followed by Siemens (791 MW), and Suzlon (736 MW). Gamesa was fifth in the market in 2008 with 616 MW, followed by U.S.-based Clipper Windpower (595 MW), which had strong sales growth in only its second year of sales. Mitsubishi fell from third to seventh in installed capacity from 2003 to 2008, despite installations increasing from 201 to 516 MW. New market entrants Acciona (410 MW) and REpower (102 MW) had strong sales. Four other companies (Fuhrlander, DeWind, AWE, and Baoding Huide) entered the U.S. market for the first time and had installations of 10 MW or less. Nordex is opening a U.S. plant and was active in the U.S. market in prior years.[82]

FIGURE 10 Installed wind turbines by manufacturer, 2003–08



Source: AWEA.

Notes: Does not include companies with 10 MW or less installed. Vestas installations in 2003 include turbines manufactured by NEG Micon, which subsequently merged with Vestas.

Several other OEMs have indicated their intention to sell turbines in the United States, suggesting that the number of competitors in the wind turbine market will further increase. Nordic Windpower and Emergya Wind Technologies have announced plans for domestic manufacturing facilities that can serve the U.S. market. AAER, a Canadian company, recently started production in Quebec and signed several agreements in 2008 to supply individual 1.5 MW turbines to U.S. customers. Hyundai licensed designs from a subsidiary of American Semiconductor Corporation (AMSC) for a 1.65 MW turbine that it plans to start producing for the U.S. market.[83] Hitachi, which manufactures wind turbine towers in Canada, plans to introduce a 2.0 MW turbine, designed with Fuji Heavy

[82] Ibid.; Soaring Wind Energy Web site. http://www.soaringwindenergy.com (accessed December 23, 2008).

[83] Broehl, "Korean Giant Enters Turbine Manufacture," November 2008, 37.

Industries, into the U.S. market in the next few years.[84] Vermont based Northern Power Systems is developing a 2.2 MW turbine for the U.S. market.[85] Even if some of these companies do not successfully enter the U.S. market, it seems likely that the number of competitors will increase in the next few years.

As new companies enter the market and OEMs invest in U.S. production, competition in the U.S. market will likely continue to increase. Most OEMs maintain proprietary designs, and wind turbines are differentiated by a number of factors including price, reliability, capacity, efficiency, and availability. Three of these factors, capacity, reliability, and price, are discussed below.

Capacity: The wind turbine market is shifting toward larger wind turbines capable of generating more electricity. The average size of wind turbines installed in the United States increased from 0.71 MW in 1998–99 to 1.65 MW in 2007 and the number of turbines over 1 MW increased from 0.3 percent of wind turbines in 1998–99 to 89 percent in 2007.[86] GE's 1.5 MW turbine is the most commonly installed turbine. The largest turbine installed in 2008 was 3.0 MW.[87]

Reliability: With an expected life of 20 to 25 years, wind turbine reliability is an important concern for customers. Wind turbine maintenance is expensive, both in terms of the cost of repairs and lost generating time, so customers want to buy turbines that will require minimal maintenance.[88]

Price: U.S. wind turbine prices went through a substantial period of decline in the 1980s and 1990s, reaching a low point of about $700/kW ($700,000/MW) between 2000 and 2002, according to an analysis by Lawrence Berkeley National Lab. Since that time, turbine prices have increased to as much as $1,240/kW in 2007 ($1,240,000/MW) due to rising prices for commodities (e.g., copper and steel), tight supply of key components, and a weak U.S. dollar. In addition, rising turbine demand and tight supply gave OEMs more pricing power.[89] Wind turbine prices appear to have leveled off in 2008 and may decrease due to the effects of the financial crisis (the decline in demand and material prices), improvements in the supply chain, and expansions in global manufacturing capacity. Vestas, for example, significantly expanded its manufacturing capacity to meet rising global demand, but now has excess capacity. Project developers are indicating that it is easier to secure turbines than it was before the credit crisis and that they expect OEMs to have less pricing power in the next few years.[90]

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[84] Hitachi Power Systems America Web site. http://www.hitachipowersystems.us (accessed December 16, 2008).

[85] Northern Power Systems, "Northern Power Parent."

[86] Wiser and Bolinger, *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007*, May 2008, 12.

[87] AWEA, *Annual Wind Industry Report*, 15.

[88] Industry official, telephone interview by Commission staff, December 10, 2008.

[89] Industry official, interview by Commission staff, October 29, 2008; Wiser and Bolinger, *Annual Report*, 19, 21; Liebreich, "Food for Thought-Abu Dhabi," November 6, 2008; and Merrill Lynch, *Wind Turbine Manufacturers: Here Comes Pricing Power*, August 10, 2007, 15–16.

[90] Macalister, "World's Biggest Turbine-Maker Says Global Downturn Slashing Demand," January 21, 2009; "EDP Renewables Sees Wind Turbine Prices Easing," November 5, 2008; Scott, "A Chill Wind Blows through Wind Power," January 12, 2009; Ucilia Wang, "Wind Turbine Shortage Over?" October 23, 2008; and Liebreich.

Wind Turbine Customers

The primary customers for wind turbines are independent power producers (IPPs) and utilities, with some community wind farms also purchasing turbines (box 5). These customers purchase wind turbines primarily for commercial electricity generation and, in many cases, place large orders, as evidenced by the fact that the average size of wind farms completed in 2008 was about 70 MW.[91] At the end of 2007, IPPs owned 84 percent of cumulative installed wind capacity, utilities owned 14 percent, and community ownership was 2 percent. The four largest owners[92] of wind farms at the end of 2008 were U.S.-based IPP NextEra Energy Resources (formerly FPL Energy) with 6,290 MW, Spain-based IPP Iberdrola Renewables with 2,063 MW, U.S.-based MidAmerican Energy with 1,940 MW, and Portugal-based IPP Energias de Portugal with 1,873 MW.[93]

BOX 5 Wind Project Terminology

Community Wind Farms: Wind projects that have community ownership rather than ownership by a utility or an independent power producer.

Independent Power Producers (IPPs): A company that produces power that it sells to electric utilities.

Institutional Tax Equity Investors: Firms that invest in wind energy to utilize the PTC to offset other sources of income. Examples include GE Financial Services, New York Life, Morgan Stanley, and Wells Fargo.

Power Purchase Agreement: A long-term agreement for the sale of energy from a power producer to a utility.

Wholesale Power Prices: The price of electricity sold by electric generators to utilities.

Note: For more on institutional tax equity investors, see Wiser and Bolinger, *Annual Report*, 14.

Wind turbine customers also include large power users, like universities and military bases, that install turbines to generate electricity for their own use. These customers often purchase a single turbine with a power output suited to their energy demand. For example, the U.S. Marine Corps Logistics Base in Barstow, California installed a single AAER wind turbine.[94] For some companies, such as Nordic Windpower and AAER, marketing products to these customers is an important part of their business strategy.

Factors Affecting Wind Turbine Demand

The primary wind turbine customers, utilities and IPPs, have a choice of power generation options. IPPs and utilities are investing in wind as one of the options to meet a portion of rising domestic electricity demand. Wind is an abundant, clean energy source, with wind turbine installations closely tied to government mandates for renewable energy, the ability to finance wind projects, and the cost-competitiveness of wind energy. The ability to finance projects and the cost-competitiveness of wind energy are closely tied to federal tax policies. These factors affect wind turbine installations and, therefore, the demand for wind turbines.

[91] AWEA, *Annual Wind Industry Report*, 14.

[92] Owners are defined by AWEA as the managing owner, an owner that manages whether or not they own 100 percent of the project.

[93] AWEA, *Annual Wind Industry Report*, 11.

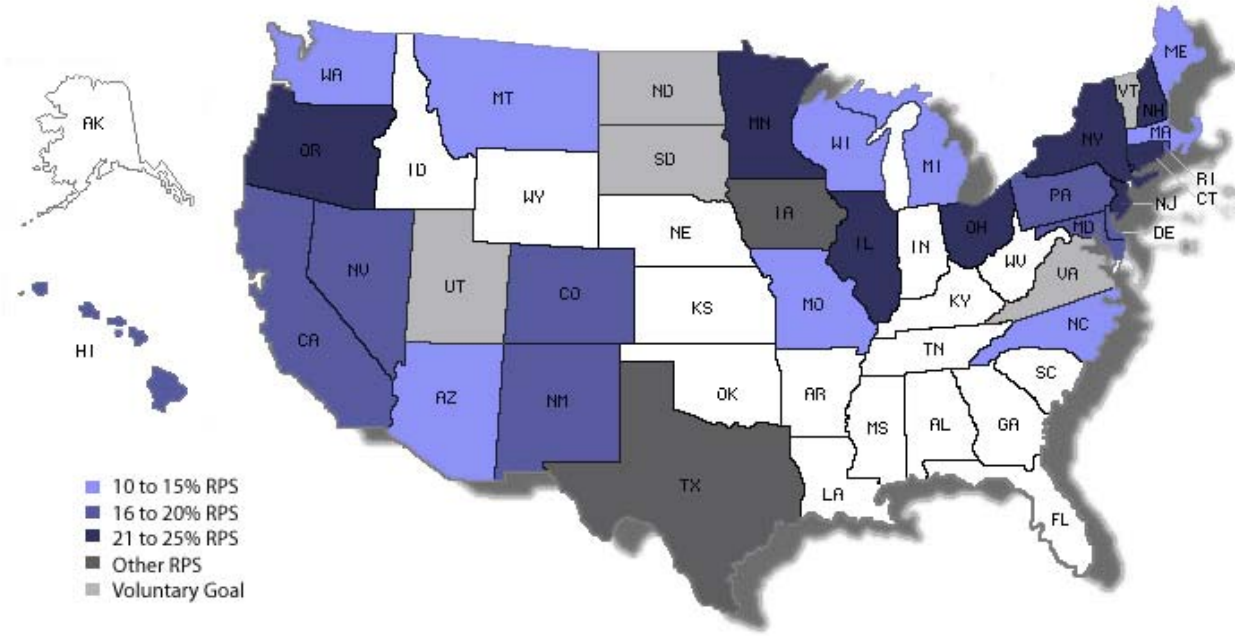
[94] AAER, "AAER's First Wind Turbine Begins Power Generation in California," March 20, 2009.

Government Mandates

One significant factor that has spurred the development of wind energy is the passage of renewable portfolio standards (RPS) at the state level. RPS mandate a certain percentage of electricity from renewable sources (usually 10 to 25 percent) by a particular date (generally between 2015 and 2025). Twenty-eight states and the District of Columbia have passed RPS (figure 11) and five states have established voluntary goals.[95] These RPS encourage the construction of wind farms by IPPs and utilities, thereby increasing demand for wind turbines.

In addition, utilities are investing in wind and other renewable energy sources as a way to hedge against the possibility of future national carbon regulation. One study found that utilities in the West are considering the potential impact of carbon regulation and, as a result, are including investment in renewable energy in their plans.[96]

FIGURE 11 State renewable portfolio standards



Source: North Carolina Solar Center, NC State University. Database of State Incentives for Renewables and Efficiency (accessed various dates); map template from DIY Maps Web site. http://monarch.tamu.edu/~maps2/ (accessed various dates).

Note: Iowa's RPS is 105 MW and Texas's RPS is 5,880 MW by 2015. Colorado, New Mexico, and Oregon have lower standards for certain small, cooperative, and/or municipally owned utilities. Massachusetts requires 15 percent of electricity from renewable sources by 2020. The Massachusetts RPS is scheduled to increase by one percent per year after 2020. The District of Columbia's RPS is 20 percent by 2020

[95] North Carolina Solar Center, NC State University, Database of State Incentives for Renewables and Efficiency (DSIRE) (accessed various dates).

[96] Levesque, "Utilities Owning, Buying more Wind, Planning for Carbon Regulations," June 5, 2008.

Electricity Prices

The federal production tax credit (PTC), the maturation of wind technology, and rising fossil fuel prices have made wind energy increasingly competitive with prices from traditional energy sources. On a national basis, wind power prices are competitive with wholesale power prices. Wind power prices decreased from $63/MWh in 1999 to $40/MWh in 2007, with prices reaching a low point in 2005 and rising slightly in 2006 and 2007 due to rising wind turbine prices and higher costs for newly installed wind projects.[97] Once a wind project is installed, the price of power is usually stable over time, while changes in fossil fuel prices can affect the price of electricity from coal and natural gas plants. Compared to the annual range of wholesale wind power prices from 2003 to 2007, wind power prices were either below or at the low end of the range each year.[98] One of the key factors in reducing wind energy prices to the point where they are competitive with wholesale power prices is the inclusion of the PTC, a tax credit for the generation of renewable energy that is equivalent to about 2.1 cents/kWh over the twenty year life of a wind project.[99]

There may be variations in the competitiveness of wind energy in different regions since wholesale power prices are not the same everywhere in the country. At the regional level, the cost competitiveness of wind energy will vary depending on factors such as the primary type of electricity generation (e.g., coal, natural gas, nuclear) currently in use, quality of wind resources, and costs of installing wind turbines.[100] The price competitiveness of wind energy for project developers has a significant impact on wind turbine installations and, consequently, domestic wind turbine demand.

Financing

Project developers need access to significant capital in order to finance wind projects. There are a number of different methods that are used to finance large wind projects in the United States. Some projects are financed through loans or bonds. Increasingly common in the lead up to the financial crisis, however, were a variety of financing mechanisms that involved investment by institutional tax equity investors. Institutional tax equity investors are firms that invest in wind power projects in order to use the PTC to offset other income. These tax investors are a significant source of financing for wind energy projects.[101]

The financial crisis demonstrates the impact of financing constraints on wind project construction in the United States. As noted earlier, the financial crisis has led to a decrease in wind project construction and a consequent downturn in demand for wind turbines. The financial crisis has made it more difficult for project developers that finance projects themselves to finance new wind energy projects. However, projects that rely on investment by institutional tax equity investors who use the PTC to offset income and

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[97] Wiser and Bolinger, *Annual Report*, 16–19.

[98] Ibid., 19–20.

[99] Wiser, Bolinger, and Barbose, *Using the Federal Production Tax Credit to build a Durable Market for Wind Power in the United States*, November 2007, 1–3; Bailey and Broehl, "Tax Driven Wind Investment Gets Scarce in America," November 2008, 29.

[100] Wiser and Bolinger, *Annual Report*, 19–20; industry official, telephone interview by Commission staff, November 10, 2008.

[101] For more information on project financing, see Harper, Karcher, and Bolinger, "Wind Project Financing Structures: A Review & Comparative Analysis," September 2007.

reduce taxes are the most severely impacted. The declining financial health of many of these investors has resulted in a rapid decline in the use of the PTC and a shrinking in the number of tax equity investors. With less money available, the pace of development will likely slow in the short term.[102]

This has led to a decrease in demand for wind turbines, at least in the short term. The pace of new orders has slowed and some OEMs have reported that developers have delayed or cancelled orders.[103] In the longer term, OEMs expect demand to revive as developers seek to meet state RPS, tax equity investment begins to return, and companies start to take advantage of the incentives in the Stimulus Bill.[104] In addition, the negative effects of the financial crisis in the U.S. market will likely be somewhat offset by declining prices for turbines and increased supply of turbines.[105] The Stimulus Bill has a number of provisions that are directly targeted at mitigating the impact of the financial crisis on wind project financing:

Production Tax Credit (PTC): Extends the expiration date of the PTC from the end of 2009 to the end of 2012.

Investment Tax Credit (ITC): Makes wind energy project developers eligible for either a 30 percent tax credit for investment in new wind energy projects or a federal grant equal to the value of the ITC.

Accelerated Depreciation: Extends accelerated depreciation for wind projects through 2009.

Other: Provides for other loan guarantees, bonds, and R&D funding.[106]

Other

Several other factors, including transmission capacity, the intermittence of wind energy, policy stability, transportation permitting, and wind farm siting, affect wind farm construction and, therefore, demand for wind turbines. Many of these factors may be impediments to the long-term growth of the wind industry.

Transmission Capacity: Because the major wind corridor is in the central United States, wind projects are often distant from the areas with the highest electricity demand. There is currently insufficient transmission capacity to bring this wind energy to population centers. There are also issues regarding access to the grid for renewable energy and in

[102] Bailey and Broehl, 29; "State of the Tax Equity Market," November 2008; Wiser and Bolinger, *Annual Report*, 14; Scott, "A Chill Wind"; industry official, interview by Commission staff, October 30, 2008; industry official, telephone interview by Commission staff, November 24, 2008; and GE Energy Infrastructure, 5.

[103] Macalister, "World's Biggest Turbine-Maker," January 21, 2009; DeWitte, "Clipper Turbine Works Lays off Workers," January 20, 2009; and Patel, "GE May Delay Wind Deliveries to 'Cautious' Clients," November 19, 2009.

[104] Industry official, interview by Commission staff, October 29, 2008; industry official, telephone interview by Commission staff, December 10, 2008.

[105] North Carolina Solar Center, DSIRE (accessed various dates).

[106] ACORE, "Overview, Renewable Energy Provisions, American Recovery and Reinvestment Act of 2009."

transmitting energy across regional grids. Smart grid technologies[107] that can better handle the variable loads from renewable energy generation are also needed. While there is clear consensus on the need for new transmission capacity, there are difficulties in siting new lines and uncertainty over who pays for them.[108] The Stimulus Bill includes some funding for transmission projects and grid modernization.[109]

Intermittence: Wind is an intermittent energy source, with the amount of energy generated varying depending on the available wind resources at a given time. While some studies indicate that this intermittence can be reasonably handled and more wind energy can be integrated into the electric grid, wind would benefit from a viable energy storage system.[110]

Policy Stability: Government policy has played an important role in spurring wind installations, but the production tax credit has expired several times since it was first passed in 1992. Uncertainty over the future of the PTC inhibits long-term planning and decreases the willingness of companies to invest in wind energy, which has a negative impact on the supply chain and domestic manufacturing capability.[111] An industry study illustrates the importance of the PTC for the wind energy industry—in the three years when the production tax credit lapsed (2000, 2002, and 2004), wind turbine installations fell by 73 to 93 percent (figure 9).[112] In 2008, the PTC was extended through the end of 2009. The Stimulus Bill extends the PTC through the end of 2012, providing for a period of continuity in wind energy policy.

Transportation and Permitting: A complicated and decentralized permitting process makes it difficult to arrange for the transportation of major turbine components to construction sites. Companies must apply for a permit in each state through which they transport nacelles, blades, and towers, and the ease of the application process varies by state. In addition, states and localities have different requirements, such as what time of day and days of the week products can be transported, and how many blades can be shipped per truck, that complicate transportation logistics.[113]

[107] The smart grid refers to a range of technologies that manage the flow of electricity in the grid. Smart grid technologies range from applications at the level of the individual homeowner to those that manage the flow of electricity in and across regional grids.

[108] Industry official, interview by Commission staff, Washington, DC, September 24, 2008; industry official, telephone interview by Commission staff, November 24, 2008; North American Electric Reliability Council (NERC), *2008 Long-Term Reliability Assessment*, October 2008, 15–17; and Batten and Manlove, *Identifying Hurdles to Renewable Electricity Construction*, December 18, 2008.

[109] ACORE, "Overview, Renewable Energy Provisions, American Recovery and Reinvestment Act of 2009."

[110] Utility Wind Integration Group, *Utility Wind Integration State of the* Art, May 2006; industry official, interview by Commission staff, Washington, DC, September 24, 2008.

[111] Industry official, telephone interview by Commission staff, December 10, 2008; industry official, interview by Commission staff, Washington, DC, September 24, 2008; Wiser, Bolinger, and Barbose, 1–3; and Bailey and Broehl, 29.

[112] Navigant Consulting, 18.

[113] Industry official, telephone interview by Commission staff, November 17, 2008; industry official, interview by Commission staff, October 30, 2008.

Siting: There is generally broad public support for the development of wind energy. A recent survey found that 82 percent of Americans would support a wind project in their community.[114] Landowners (often farmers and ranchers) are generally supportive of wind projects because they are compensated for use of their land and can receive roughly $3,000 to $6,000 per MW per year.[115] However, local residents are often concerned about the impact of a wind project on the local landscape, property values, wildlife, and the economy.[116]

U.S. TRADE

The United States is a net importer of wind turbines and major components. U.S. imports increased significantly from 2003 to 2008, while exports rose only slightly. The U.S. trade deficit for wind-powered generating sets (box 6) increased from $355 million in 2003 to $2.5 billion in 2008. The United States has the largest trade deficits with Denmark, Spain, Japan, Germany, and India, which are home to the major global turbine manufacturers.[117]

BOX 6 HTS Classification of Wind Turbines

The discussion of trade data in this report focuses on imports and exports of wind-powered generating sets. Wind turbines are classified under "wind-powered generating sets" (8502.31.0000) in the Harmonized Tariff Schedule of the United States (HTS). This provision includes wind turbine nacelles and components, such as blades and hubs, when they are imported with the nacelle. When imported separately, blades, hubs, generators, and other components are classified under other HTS provisions. This HTS provision includes both small and utility scale wind turbines, but small wind turbines generally represent a low percentage of wind turbine trade.

Imports of components will be discussed for three groups of goods—(1) generators (HTS provision 8501.64.0020), (2) towers (7308.20.0000), and (3) blades and other components (8412.90.9080 and 8503.00.9545). These components are classified under provisions that also include goods that are not used in wind turbines. But wind accounts for a significant portion of trade in each category and appears to be a major driver of import growth. A similar analysis of component exports is not included since wind exports represent a much smaller percentage of trade in these categories.

U.S. Imports

Wind-Powered Generating Sets (HTS 8502.31.0000)

Imports of wind-powered generating sets increased from $356 million in 2003 to $2.5 billion in 2008 (more than 600 percent) as the major European and Asian wind turbine producers entered or expanded their presence in the growing U.S. market (table 7). Five European countries (Denmark, Spain, Germany, the United Kingdom, and Portugal) and two Asian countries (Japan and India) accounted for 98 percent of all U.S.

[114] Saint Consulting Group, *2009 Saint Index*.

[115] Peterson, "Wind Energy Options for Farmers & Rural Landowners," June 27, 2008; Aarke and Haugen, *Wind Turbine Lease Considerations for Landowners*, February 2009, 3.

[116] DOE, *20% Wind Energy*, July 2008, 106, 116–118.

[117] Compiled from official statistics of the U.S. Department of Commerce.

imports in 2008.[118] Denmark and Spain accounted for a combined 55 percent of imports. Denmark continued to be the largest single source of imports, but imports from Denmark decreased from $966 million in 2007 to $707 million in 2008 while imports from Spain increased from $423 million to $669 million. Japan was the third largest source with 15 percent of imports ($378 million) in 2008, and Germany was fourth with 12 percent ($297 million).[119]

TABLE 7 U.S. imports of wind-powered generating sets (HTS 8502.31.0000), 2003–08, thousand dollars

	2003	2004	2005	2006	2007	2008	Percent Change 2003–08
Denmark	215,045	31,708	328,169	630,818	966,111	706,864	229
Spain	38,552	702	44,758	157,519	423,492	669,079	1,636
Japan	85,297	24,337	62,569	97,228	307,475	377,836	343
Germany	301	18	166	56,543	210,660	297,212	98,486
India	15,636	0	12,482	216,572	253,487	178,598	1 042
United Kingdom	57	2,903	23,390	39,689	129,789	137,110	240,765
Portugal	0	0	0	0	0	80,446	
Italy	3	0	8,667	651	0	33,721	1,148,817
China	40	14	36	7,997	85,248	14,327	35,830
All Other Countries	709	278	2,252	1,648	3,676	8,157	1,049
Total	**355,641**	**59,960**	**482,489**	**1,208,667**	**2,379,940**	**2,503,349**	**604**

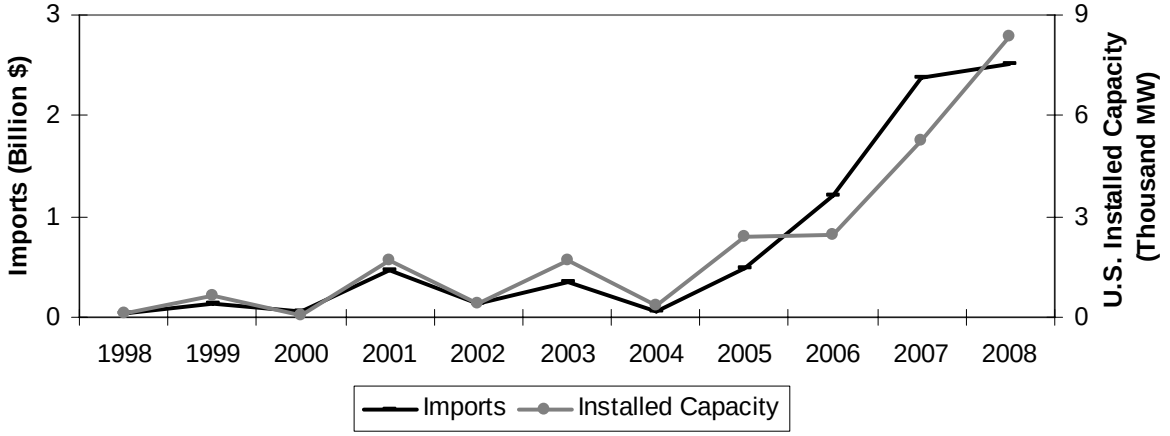
Source: Compiled from official statistics of the U.S. Department of Commerce.

Wind-powered generating set imports are correlated with wind turbine installations (figure 12). From 1998 to 2005, changes in wind-powered generating set imports were closely correlated with changes in wind turbine installations. That correlation appears to have subsequently weakened and, despite a significant increase in wind turbine installations in 2008, imports only slightly increased. Among the possible explanations are that many of the turbines installed in 2008 were imported in 2007, or that a rise in domestic manufacturing led to a reduction in imports. Rising domestic production is suggested by an increase in imports of AC generators—which are used in domestic wind turbine nacelle assembly (see below).

[118] Imports from a particular country are not necessarily associated with companies based in the country. Major producers have multiple global production sites, including in countries that are home to global competitors. Similarly, shifts in imports from one country to another do not necessarily indicate shifts in companies' market shares. Changes in import sources are often due to one or more of the OEMs shifting a proportion of turbines that they export to the United States from one production location to another.

[119] Compiled from official statistics of the U.S. Department of Commerce.

FIGURE 12 U.S. wind-powered generating set imports and installations, 1998–08



Sources: Compiled from official statistics of the U.S. Department of Commerce; AWEA, *Annual Wind Industry Report*, 4.

Generators (HTS 8501.64.0020)

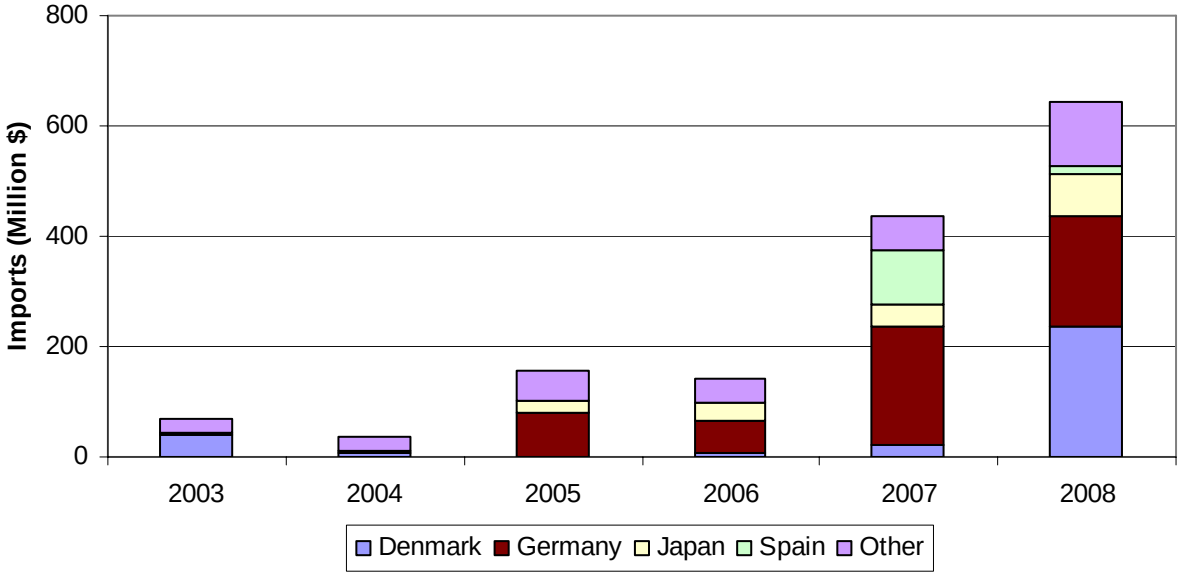
The rise in domestic production of nacelles has led to an increase in imports of generators for those nacelles. Imports of AC generators[120] with outputs from 750 to 10,000 kVA (the size most common in utility scale turbines) increased from $69.6 million in 2003 to $142.8 million in 2006 and then to $644.5 million in 2008 (figure 13).[121] Major import sources in 2008 were Denmark, Germany and Japan, which are home to major OEMs and generator manufacturers. Spain was the second largest source of imports in 2007, but U.S. imports from Spain declined by almost 90 percent from 2007 to 2008.[122]

[120] Imports of AC generators from 750 to 10,000 kVA are classified under tariff line 8501.64.0020.

[121] Compiled from official statistics of the U.S. Department of Commerce.

[122] The reason for this drop in imports is unclear, but there was considerable variation in imports from Spain during 2007. 100 percent of imports in 2007 took place between July and November 2007. Compiled from official statistics of the U.S. Department of Commerce.

FIGURE 13 U.S. imports of AC generators, 750–10,000 kVA (HTS 8501.64.0020), 2003–08



Source: Compiled from official statistics of the U.S. Department of Commerce.

Blades & Other Components (HTS 8412.90.9080 and 8503.00.9545)

U.S. imports of parts of motors and generators (which include blades and other turbine components)[123] increased from $363 million to $1.8 billion from 2003 to 2008 (figure 14).[124] There are significant imports of these components from European countries (Denmark, Germany, and Spain) that are home to major OEMs, blade manufacturers, and component producers. Imports from these three suppliers increased 565 percent from $87 million in 2003 to $576 million in 2008.[125] Brazil, Canada, and Mexico also are major sources of U.S. imports, likely because they are home to manufacturing plants for large independent blade producers, such as Tecsis (Brazil), the TPI-Mitsubishi joint venture VienTek (Mexico), and LM Glasfiber (Canada).[126] Imports from Brazil, Canada, and Mexico increased almost 400 percent from $154 million in 2003 to $763 million in 2007.[127]

[123] Imports of wind turbine blades, hubs, and certain other components are classified under the tariff lines for parts of other engines and motors (8412.90.9080) and parts of generators (8503.00.9545).

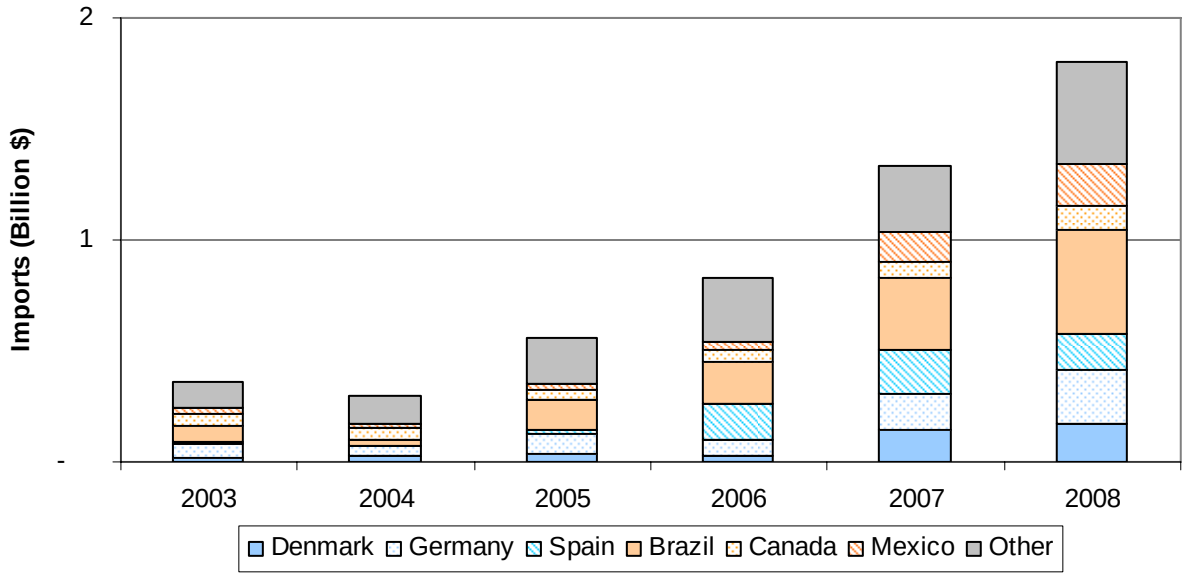
[124] Compiled from official statistics of the U.S. Department of Commerce.

[125] Ibid.

[126] Blades and components only represent a portion of trade with these countries and not all of the trade value for a particular country can be associated with a particular company.

[127] Compiled from official statistics of the U.S. Department of Commerce.

FIGURE 14 U.S. imports of parts of motors and generators (HTS 8412.90.9080 and 8503.00.9545), 2003–08



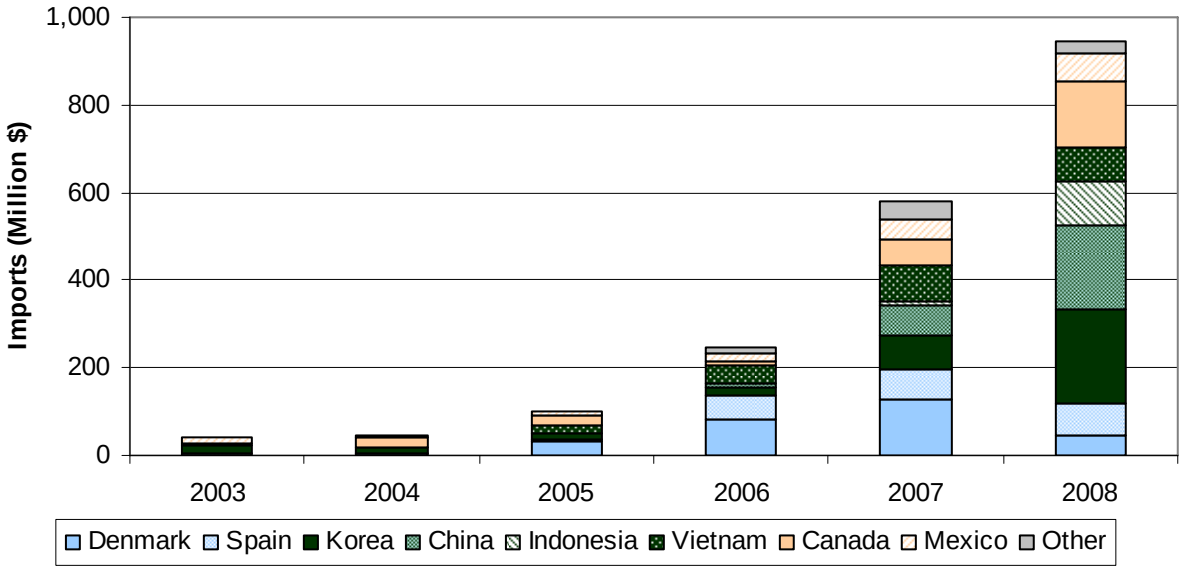
Source: Compiled from official statistics of the U.S. Department of Commerce.

Towers (7308.20.0000)

Towers are one of the components for which manufacturing capabilities are most readily available and the supply chain is the most diverse, with significant U.S. imports from Europe (Denmark and Spain), Asia (China, Indonesia, Korea, and Vietnam), Canada, and Mexico (figure 15).[128] Imports of towers and lattice masts increased from $41 million in 2003 to $944 million in 2008.[129] Asia, Canada, and Mexico are increasingly important in the supply chain for towers. Four Asian countries, China, Indonesia, Korea, and Vietnam, account for a combined 62 percent of towers and lattice masts imports in 2008. Canada and Mexico accounted for 23 percent of imports.[130] The share of imports from Denmark and Spain fell from 34 percent in 2007 to 13 percent in 2008, primarily due to a drop in imports from Denmark. Imports from Denmark increased from $2 million to $128 million in 2007 before declining to $44 million in 2008, possibly due to a change in sourcing strategy by OEMs.[131]

[128] Towers are classified under towers and lattice masts (7308.20.0000) in the HTS.
[129] Compiled from official statistics of the U.S. Department of Commerce.
[130] Ibid.
[131] Ibid

FIGURE 15 U.S. imports of towers and lattice masts (7308.20.0000), 2003–08



Source: Compiled from official statistics of the U.S. Department of Commerce.

U.S. Exports

U.S. exports of wind turbines were limited and sporadic, but anecdotal evidence suggests that export and overseas investment opportunities are growing. Exports of wind-powered generating sets increased from $746,000 in 2003 to $22.1 million in 2008 (table 8). Exports to China increased from $0 in 2006 to $16.2 million in 2008 and exports to Brazil rose from $0 in 2007 to $5.9 million in 2008. The only exports to Canada between 2003 and 2008 were in 2006, when exports totaled $83.3 million.[132]

TABLE 8 U.S. exports of wind-powered generating sets (HTS 8502.31.0000), 2003–08, thousand dollars

	2003	2004	2005	2006	2007	2008
China	0	0	0	0	12,837	16,202
Brazil	0	0	0	0	0	5,871
St Kitts-Nevis	0	0	0	0	675	0
Japan	742	0	0	0	646	0
Canada	0	0	0	83,310	0	0
Germany	0	4,398	3,626	0	0	0
All Other Countries	4	0	0	0	0	0
Total	**746**	**4,398**	**3,626**	**83,310**	**14,158**	**22,073**

Source: Compiled from official statistics of the U.S. Department of Commerce.

[132] Compiled from official statistics of the U.S. Department of Commerce.

There is anecdotal evidence that exports of turbines and blades are slowly expanding, particularly within the Americas. For example, Acciona Energy plans to source turbines for at least one of the wind farms that it is developing in Canada from its Iowa factory.[133] Clipper signed an agreement in 2008 to supply 27 wind turbines for a project in Mexico and CTC/DeWind exported ten 2 MW wind turbines to Chile in December 2008.[134] Nordic Windpower has an order for three 1 MW turbines for a wind farm in Uruguay.[135] In 2008, 48 blades were shipped from a North Dakota factory to Australia.[136] LM Glasfiber is reportedly shipping blades produced at its Arkansas facility to South America, and tower and other blade manufacturers have established U.S. manufacturing plants with the possibility of supplying markets throughout the Americas.[137]

U.S. and Foreign Trade Measures

U.S. Tariff and Nontariff Measures

The general rate of duty for wind turbines and components ranges between free and 3 percent (table 9). The rate of duty for wind-powered generating sets is 2.5 percent; for AC generators 2.4 percent; and for other parts of generators 3 percent. Towers and other parts of engines and motors (including some blades) enter free of duty.[138] There are no known U.S. nontariff measures (NTMs) that affect U.S. imports of wind turbines and components.

TABLE 9 Wind-turbines and components: Harmonized Tariff Schedule subheading, description and column 1 rate of duty as of January 31, 2009

HTS Subheading	Article Description	Rates of Duty
		General
7308.20.0000	Towers and lattice masts	Free
8412.90.9080	Other parts of engines and motors	Free
8501.64.0020	AC generators of an output exceeding 750 kVA but not exceeding 10,000 kVA	2.4%
8502.31.0000	Wind-powered electric generating sets	2.5%
8503.00.9545	Other parts of generators for use with machines of heading 8501 or 8502	3.0%

Source: Harmonized Tariff Schedule of the United States.

U.S. Government Trade Related Investigations

One patent infringement investigation related to wind turbines occurred during the period from 2003 to 2008 and one earlier order remains in effect. GE filed a complaint in February 2008 alleging violations of section 337 of the Tariff Act of 1930. The complaint

[133] Acciona Energy, "Acciona is Awarded the Construction of a 69-Million-Euro Wind Park," January 23, 2008.

[134] Clipper Windpower, "Clipper Windpower and EDF EN Sign Strategic Agreement," August 5, 2008; CTC, "Composite Technology's DeWind Ships Turbines," December 16, 2008; and CTC, "Composite Technology's DeWind Complete Turbines," December 29, 2008.

[135] Nordic Windpower, "Nordic Windpower Awarded Contracts," May 6, 2009.

[136] Port of Longview, "Port of Longview Handles Blades for Export," August 14, 2008.

[137] Bartels, "LM Glasfiber Dedicates Little Rock Factory," October 28, 2008; press releases and media reports.

[138] Items for which there are duties may enter free under certain trade agreements or policies.

alleges that Mitsubishi Heavy Industries, Ltd. and two related or subsidiary companies violated this act by importing variable speed wind turbines and components that infringe on GE patents. This case is pending.[139] An earlier complaint by Kenetech Windpower against Enercon GmbH resulted in an exclusion order prohibiting imports of certain unlicensed Enercon variable speed wind turbines and components until the expiration of the patent on February 1, 2011.[140] Enercon and GE, the current owner of the patent, reached a cross-licensing agreement in October 2004, but the exclusion order for the United States remains in effect.[141] As of December 2008, there are no orders in place or ongoing investigations as a result of countervailing duty or anti-dumping cases.

Foreign Tariff Measures

There is significant variation in foreign tariff rates for wind-powered generating sets (table 10). Duties on wind powered-generating sets range from free (e.g., Australia, Canada, Japan, Mexico, and South Africa) to 10 percent or more (e.g., India and Taiwan). The European Union's 2.7 percent tariff rate is similar to the 2.5 percent tariff rate applied by the United States. According to a recent World Bank study, applied tariffs on wind-powered generating sets, wind turbine generators, and towers average 3 percent among high-income WTO members (table 11). Among low- and middle-income countries, the average applied tariffs on generators and wind-powered generating sets are 5 percent. Duties on imported towers are somewhat higher at 10 percent.[142] Several countries have adjusted duties to encourage the import of components rather than fully assembled nacelles.[143]

TABLE 10 Applied tariff rates, wind-powered generating sets, 2008 unless otherwise noted

Country	Tariff Rate	Country	Tariff Rate
Australia[a]	Free	Japan	Free
Canada	Free	Mexico	Free
China[b]	8%	South Africa	Free
European Union	2.7%	South Korea[c]	8%
India	16%	Taiwan	10%

Sources: Compiled from International Customs Tariffs Bureau, APEC Tariff Database, and schedules of individual countries.

[a]Generating sets exceeding 500 kVA.
[b]As of 2004.
[c]As of 2004.

[139] ITC, *Certain Variable Speed Wind Turbines and Components Thereof*, Investigation No. 337-TA-641; ITC, "ITC Institutes Section 337 Investigation on Certain Variable Speed Wind Turbines and Components Thereof," March 25, 2008.

[140] The original order specified February 1, 2010, but the patent term was extended pursuant to 35 U.S.C. 154 (c). ITC, *Certain Variable Speed Wind Turbines and Components Thereof*, Investigation No. 337-TA-376; Commission order issued August 30, 1996; and USITC Web site. http://www.usitc.gov (accessed various dates).

[141] Enercon GmbH, "Joint Press Release," October 10, 2004.

[142] The World Bank, *International Trade and Climate Change: Economic, Legal, and Institutional Perspectives*, 2008, 130, 132.

[143] For example, see Lewis and Wiser, "A Review of International Experience with Policies to Promote Wind Power Industry Development," March 10, 2005, 49; Lewis, "A Review of the Potential International Trade Implications of Key Wind Power Industry Policies in China," October 2007, 3.

TABLE 11 Wind turbine bound and applied tariff rates, by income level, percent

HS Code	Article Description	Low- and Middle-Income WTO Members		High-Income WTO Members	
		Maximum Average Bound Tariffs	*Average Applied Tariff Rates*	*Maximum Average Bound Tariffs*	*Average Applied Tariff Rates*
7308.20	Towers and lattice masts	28	10	16	3
8501.64	AC generators of an output exceeding 750 kVA but not exceeding 10,000 kVA	28	5	16	3
8502.31	Wind-powered electric generating sets	26	5	16	3

Source: World Bank, *International Trade and Climate Change: Economic, Legal, and Institutional Perspectives*, 2008, 130–132.

Foreign Nontariff Measures

Local content requirements implemented at the national level in some countries and at the regional level in other countries are important nontariff measures.[144] Local content requirements generally mandate that a certain percentage of the value of installed wind turbines be produced locally. These requirements encourage the development of a local wind turbine manufacturing industry by making local producers more competitive and/or encouraging foreign producers to locate production in the market rather than exporting products to the market. Several of the countries with local content requirements (Canada, China, and Spain) will be discussed in more detail below.

FOREIGN INDUSTRY PROFILES

European OEMs have historically dominated the global wind turbine manufacturing industry and, along with GE, lead the industry today. Three of the four largest suppliers of wind turbines in 2008 were based in Europe (figure 16). Vestas (Denmark), Gamesa (Spain), and Enercon (Germany) ranked first, third, and fourth, respectively, in global wind turbine installations in 2008. U.S.-based GE, which also has manufacturing and assembly facilities in Canada, China, Germany, and Spain, and wind research centers around the world, was the second largest supplier of wind turbines. These four companies were the four largest global suppliers in 2004 as well. During 2004 to 2008, however, GE gained global market share due to the growth of the U.S. market and became the world's second largest supplier.[145] Three other European companies, Siemens, Acciona, and Nordex, are also among the top ten suppliers of wind turbines.[146]

Another significant change from 2004 to 2008 was the growth of Asian turbine manufacturers. Chinese companies Sinovel and Goldwind are now among the top ten

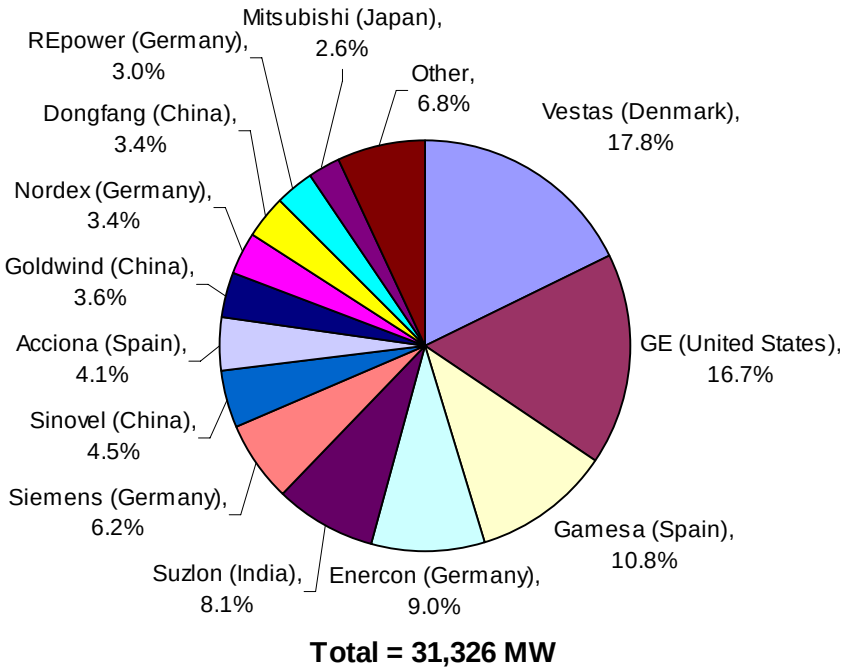
[144] For a discussion of the countries with local content requirements and more information about these requirements, see Lewis and Wiser, "Fostering a Renewable Energy Technology Industry," November 2005, 13–14. For Canada, see also "A Market Ready for the Next Big Step," October 2008, 6.

[145] Declining market shares generally do not reflect declining sales at companies since the size of the global wind turbine market increased from 8,133 MW in 2003 to 27,051 MW in 2008. GWEC, *Global Wind 2008 Report*, 10.

[146] BTM Consult, *International Wind Energy Development: World Market Update 2008*, 24; BTM Consult, "International Wind Energy Development: World Market Update 2004," March 31, 2005.

suppliers of wind turbines due to robust demand within China. Indian manufacturer Suzlon gained market share and is the fifth largest manufacturer. Chinese OEM Dongfang and Japanese OEM Mitsubishi are the eleventh and thirteenth largest manufacturers, respectively.[147]

FIGURE 16 Leading suppliers of wind turbines, 2008



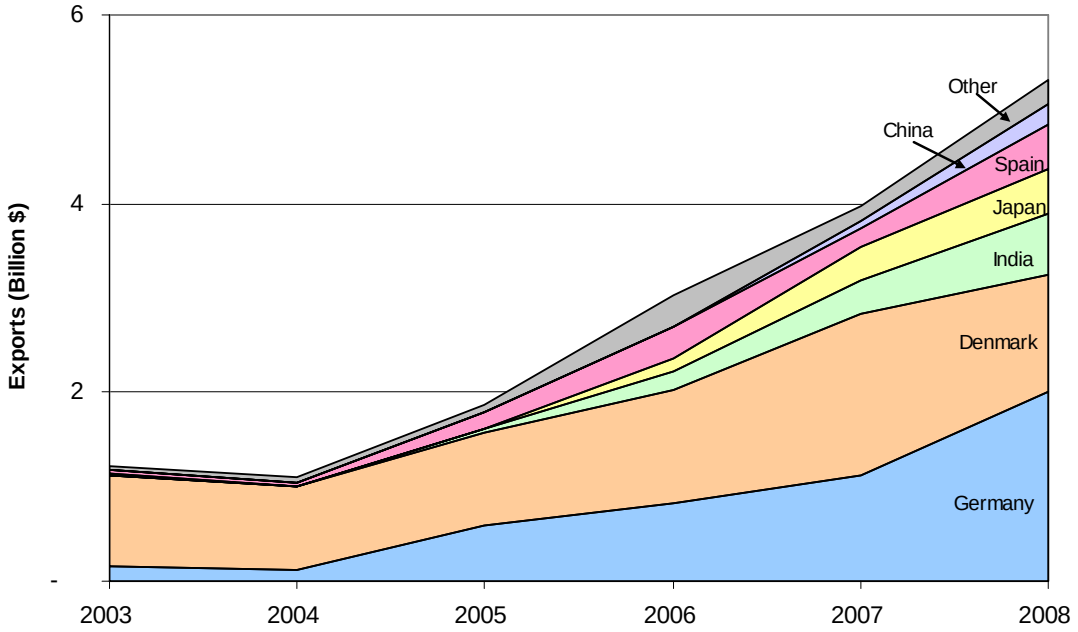
Sources: BTM Consult, *International Wind Energy Development: World Market Update 2008*, 24.

Note: BTM Consult data are based on the number of turbines delivered by OEMs. This may differ from the total number of turbines installed because not all turbines delivered in a particular year are installed in the same year. BTM Consult generally calculates market share as the number of turbines delivered in a year by a particular company divided by total global wind turbine installations. Since the number of installations often differs from the number of turbines delivered, this can result in a total market share for companies that is more or less than 100 percent. For the purposes of this report, which is concerned with manufacturing, the total number of turbines delivered, as reported by BTM Consult, is divided by the total global deliveries of wind turbines to calculate global market share. See BTM Consult, *International Wind Energy Development: World Market Update 2008*, 30.

Trade statistics confirm that European companies are strongly positioned in the wind turbine manufacturing industry, but that exports from other countries are also increasing. Denmark's exports of wind-powered generating sets increased by 29 percent, from $966 million in 2003 to $1.2 billion in 2008, but its global export share fell from 80 percent to 23 percent (figure 17). Germany's exports increased by over 1,100 percent from $164 million to $2.0 billion and its export share increased from 14 to 38 percent. Exports from India (12 percent of exports in 2008), Japan (9 percent), Spain (9 percent), and China (4 percent) also significantly increased.[148]

[147] Ibid.
[148] GTIS, Global Trade Atlas (accessed various dates).

FIGURE 17 Exports of wind-powered generating sets by country, 2003–08



Source: GTIS, Global Trade Atlas (accessed various dates).

Government policy often plays an important role in the development of a successful industry. According to Lewis and Wiser, policies that support the development of local manufacturing are often important in the development of a successful wind industry. Policies that governments have implemented to support turbine manufacturers include (1) policies that limit competition from products manufactured outside the country (e.g., local content requirements and import duties) and (2) programs to encourage the development of industry (e.g., funding for research and development, tax incentives, and subsidies for the purchase of locally made turbines).[149] In addition, a large, stable home market is often important in the early stages of industry development and governments usually play an important role in the creation of this market through policies such as feed-in tariffs,[150] renewable portfolio standards, tax credits, loans and subsidies, and utility or government power purchase agreements.[151]

The importance of these factors[152] is illustrated in the following profiles of the wind turbine manufacturing industries in three of the countries which are the most significant producers of wind turbines, Denmark, Germany, and Spain (table 12).[153] The profiles focus on OEMs, but each of these countries is also a major source of components.

[149] Lewis and Wiser, "Fostering," 12–26.

[150] A feed-in tariff generally sets a price for renewable energy over a certain number of years and guarantees that renewable energy will have access to the grid.

[151] Lewis and Wiser, "Fostering," 7–11, 17–18.

[152] For EU countries, the discussion in this and the following section will focus on national policies. EU members recently agreed on individual targets for renewable energy generation, but until recently most of the policies that supported the development of renewable energy industries were national policies.

[153] Countries chosen for discussion were non-U.S. countries with either at least 15 percent of global exports (Germany and Denmark) or with a company that had at least ten percent of the market in 2008 (Danish OEM Vestas and Spanish OEM Gamesa). In total these three countries accounted for 73 percent of global exports of wind-powered generating sets in 2008. GTIS, Global Trade Atlas (accessed various dates).

TABLE 12 Global exports and employment of the wind industries in Denmark, Germany, and Spain

	Exports					
	2003		*2008*			
	Exports (USD)	*% of Global Exports*	*Exports (USD)*	*% of Global Exports*	*Percent Change*	**Direct Employment**
Denmark	965,937,124	79.5	1,243,393,519	23.4	29	23,500
Germany	164,019,083	13.5	2,004,311,102	37.7	1,122	38,000
Spain	45,811,192	3.8	469,680,570	8.8	925	17,769

Source: Global Trade Atlas (accessed March 8, 2009); EWEA, *Wind at Work*, 7; Spanish Wind Energy Association (AEE), *Wind Power 2008, Sector's Yearbook: Analysis and Data*, 57.

Notes: Export data are exports of wind-powered generating sets. Direct employment typically includes a range of activities such as manufacturing, operations and maintenance, and R&D, but there may be some variation in the definition of direct employment for the employment figures above.

Denmark

Wind turbine manufacturers in Denmark benefited from both active government support and their early entrance into the wind market. Danish manufacturers began entering the wind turbine industry in the 1970s, often transitioning from other industries and benefiting from the availability of workers in declining industries, including agriculture and shipbuilding. Danish companies initially entered the growing wind energy market in California, but this market collapsed in the 1980s and companies came to depend more on their home market. Denmark's government supported the development of the domestic market through a variety of policies including a feed-in tariff and subsidies for the installation of wind turbines.[154] Denmark's wind market was one of the largest in the world and Denmark is still eighth in cumulative installed capacity, but only 77 MW was added in 2008 due to the saturation of the onshore market. However, there is potential for future market growth due to strong offshore wind potential. Denmark currently generates 20 percent of its electricity from wind and cumulative installed capacity at the end of 2008 was 3,180 MW.[155]

Local manufacturing was supported through government R&D funding, and locally made turbines were favored for use in wind farms through policies such as providing financing for wind farms that used domestic turbines and developing stringent standards and certification requirements that benefited local producers.[156] Denmark developed several large companies such as Vestas, NEG Micon, and Bonus, but through mergers and acquisitions the number and the ownership of companies has changed. Vestas and NEG Micon merged and now operate under the Vestas name and Bonus was acquired by Siemens in 2004. Indian manufacturer Suzlon established its international headquarters in Denmark in part to take advantage of available skilled labor.[157] Blade manufacturer LM

[154] EWEA, *Wind at Work: Wind Energy and Job Creation in the EU*, January 2009, 23; Lewis and Wiser, "A Review of International Experience," 26–30; and Vestergaard, Brandstrup, and Goddard, "Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States," November 2004, 6–9.

[155] IEA, *IEA Wind Energy 2007 Annual Report*, July 2008, 95–96; GWEC, "US and China in Race to the Top of Global Wind Industry," February 2, 2009.

[156] Lewis and Wiser, "A Review of International Experience," 26–30; Kjaergaard and Kristensen, "Any Way the Wind Blows," 12; and Vestergaard, Brandstrup, and Goddard, 5–7.

[157] Lewis and Wiser, "Fostering," 4–5.

Glasfiber is headquartered in Denmark. Direct employment in the Danish wind industry was about 23,500 in 2007.[158]

Danish manufacturer Vestas had 17.8 percent of the global market in 2008. German manufacturer Siemens, which maintained a significant manufacturing presence in Denmark following its acquisition of Bonus, held 6.2 percent of the global market.[159] LM Glasfiber is the largest global independent producer of blades, with 25 percent of the global market.[160] Total turnover[161] of the wind industry in Denmark increased from $3.0 billion in 2003 to $7.8 billion in 2007.[162] Denmark's exports of wind-powered generating sets increased from $966 million in 2003 to $1.2 billion in 2008.[163] Denmark's exports peaked at $1.7 billion in 2007.[164]

Germany

The German wind turbine manufacturing industry developed as a result of a combination of policies that supported the development of wind turbine technology and created a market for wind turbine manufacturers.[165] Germany's wind turbine manufacturing industry is one of the largest in the world with major producers such as Enercon, Fuhrlander, Nordex, REpower, and Siemens.[166] Foreign OEMs, including GE and Vestas, also have manufacturing plants in Germany.

With slowing German demand and an increase in the size of the global market, German exports are rising.[167] In 2007, total value added for German manufacturers (including OEMs and suppliers) was $8.4 billion ($6.1 billion Euros), 83 percent of which was exported.[168] Germany's exports of wind-powered generating sets increased from $164 million in 2003 to $2 billion in 2008.[169] Enercon had 9 percent of the global market in 2008, Siemens 6.2 percent, Nordex 3.4 percent, and REpower 3.0 percent.[170] Total direct employment in the wind energy sector in Germany is 38,000.[171]

[158] EWEA, *Wind at Work*, 7.

[159] BTM Consult, *International Wind Energy Development: World Market Update 2008*, 24.

[160] Grande, "Wind Power Blades."

[161] It is not clear whether turnover in this case only includes the value of turbines produced or whether it includes components and/or services.

[162] Danish Wind Industry Association, "Vindmølleindustriens Branchestatistik 08."

[163] GTIS, Global Trade Atlas (accessed various dates).

[164] Ibid.

[165] For a discussion of the factors that contributed to the growth in the wind industry in Germany, see Johnson and Jacobson, "The Emergence of a Growth Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries"; Lewis and Wiser, "A Review of International Experience," 30–33.

[166] Suzlon Energy is the majority owner of REpower. Bureau van Dijk, Orbis Companies Database (accessed May 24, 2009).

[167] While the German market is slowing, it is still one of the largest in the world. The German market will be discussed in the next section.

[168] German Wind Energy Association, "Wind Energy 'Made in Germany' is an Export Hit," October 21, 2008.

[169] GTIS, Global Trade Atlas (accessed January 27, 2009).

[170] BTM Consult, *International Wind Energy Development: World Market Update 2008*, 24.

[171] EWEA, *Wind at Work*, 7.

Spain

Spain has a substantial wind energy manufacturing industry, including several OEMs with varying degrees of domestic and international presence. These OEMs benefit from a feed-in tariff and provincial government regulations requiring local manufacturing.[172] The largest OEM is Gamesa, which had 10.8 percent of the global market in 2008.[173] Gamesa was originally formed as a joint venture with Vestas, but split from Vestas due to strategic differences and the desire to sell turbines outside of the domestic market. Following its split with Vestas, Gamesa acquired Spanish competitor Made.[174] The other major Spanish global supplier is Acciona, which had 4.1 percent of the global market in 2008.[175] The third largest manufacturer is Ecotecnia, which had 0.8 percent of the global market.[176] There are a number of other domestic companies with small shares of the Spanish wind energy market.

The top two global manufacturers of wind turbines (Vestas and GE) have manufacturing facilities in Spain, as does the leading independent manufacturer of blades (LM Glasfiber). In all, Spain has at least 18 factories that manufacture or assemble nacelles and at least a dozen factories producing blades.[177] Direct employment in the wind energy industry in Spain in 2007 was about 17,769, including more than 5,000 manufacturing jobs. Indirect employment, including component suppliers, was an estimated 27,187.[178]

Spain's domestic market has grown,[179] but manufacturers are also becoming increasingly export oriented.[180] Spain's exports of wind-powered generating sets increased from $45.8 million in 2003 to $469.7 million in 2008.[181] Spanish companies are actively investing in overseas production, particularly in growing markets such as China and the United States. Acciona established nacelle assembly plants in China and the United States, and Gamesa has invested in the production of blades, nacelles, and towers in the United States and blades and nacelles in China.[182]

FOREIGN MARKET PROFILES

Europe continues to lead the world in annual global installed capacity, but a growing percentage of installations are in Asia and North America. The five largest markets in 2008 were the United States, China, India, Germany, and Spain (table 13). These five countries were also the five largest markets in 2007, though Spain fell from second to

[172] Ibid., 25; Lewis, "A Comparison of Wind Power Industry Development Strategies in Spain, India, and China," July 19, 2007, 9–10.
[173] BTM Consult, *International Wind Energy Development: World Market Update 2008,* 24.
[174] Lewis, "A Comparison," 11–12.
[175] BTM Consult, *International Wind Energy Development: World Market Update 2008,* 24.
[176] Ibid., 24.
[177] Spanish Wind Energy Association (AEE), *Wind Power 2008, Sector's Yearbook: Analysis and Data*, 58.
[178] Direct employment is defined as employment in operation and maintenance of wind farms, research and development, manufacturing, and assembly. AEE, 57.
[179] Spain's market will be discussed in the next section.
[180] AEE, 57.
[181] GTIS, Global Trade Atlas (accessed January 27, 2009).
[182] Acciona Windpower Web site. http://www.acciona-energia.es (accessed January 27, 2009); Gamesa Web site. http://www.gamesa.es (accessed January 27, 2009).

fifth place. Primarily as a result of the growth of the market in China and India, Asia and the Pacific's market share increased from 25 percent in 2006 to 34 percent in 2008 (figure 18). The North American market share increased from 21 to 33 percent. Europe's market share decreased from 51 percent to 33 percent. Estimates by the Global Wind Energy Council (GWEC) show stability or growth in annual wind turbine installations in all regions, but indicate a further shift in market share toward the Asia-Pacific. The GWEC estimates that Asia will account for 47 percent of all wind turbine installations by 2012, compared to 26 percent for North America and 23 percent for Europe.[183]

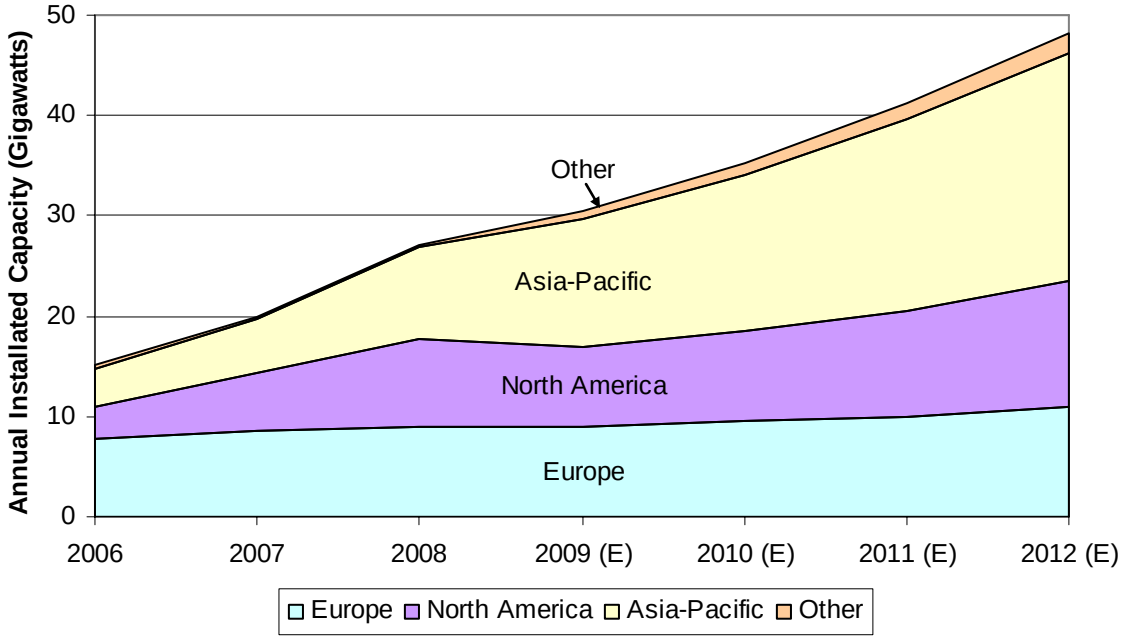
TABLE 13 Top 10 countries in annual installed capacity in 2008, MW

		2007	2008			2007	2008
1.	United States	5,244	8,358	6.	Italy	603	1,010
2.	China	3,449	6,300	7.	France	888	950
3.	India	1,730	1,800	8.	UK	427	836
4.	Germany	1,667	1,665	9.	Portugal	434	712
5.	Spain	3,522	1,609	10.	Canada	386	526

Source: GWEC, *Global Wind 2008 Report*, 10, 13.

Note: GWEC data on annual installations may vary slightly from other estimates.

FIGURE 18 Annual wind turbine installations, 2006–08, and GWEC forecasts through 2012



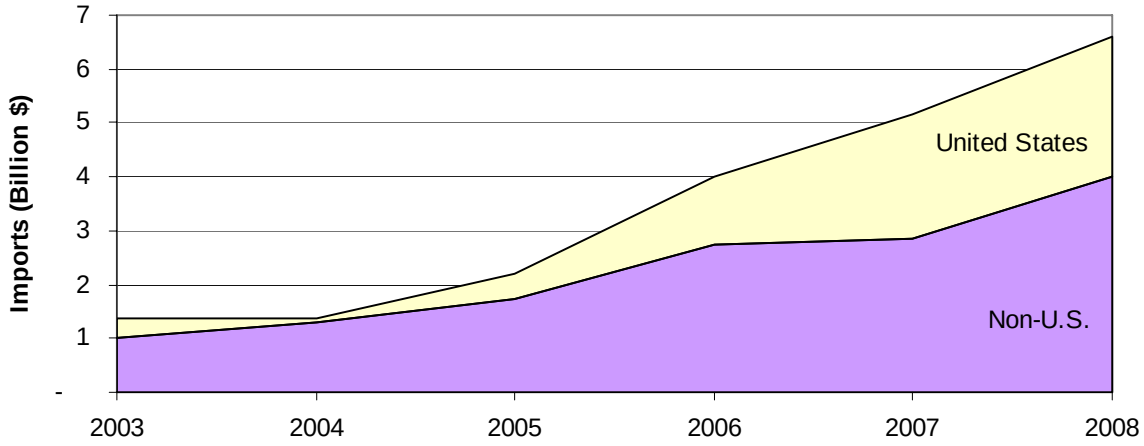
Source: GWEC, *Global Wind 2006 Report*, 9; GWEC, *Global Wind 2007 Report*, 8; and GWEC, *Global Wind 2008 Report*, 13.

Note: E: Estimated.

[183] GWEC, *Global Wind 2006 Report*, 8; GWEC, *Global Wind 2008 Report*, 10, 13, 17.

The global market for wind turbines has rapidly increased and global imports of wind-powered generating sets increased from $1.4 billion in 2003 to $6.6 billion in 2008.[184] The United States is now the largest market for wind turbines and accounted for a significant percentage of the global increase in imports of wind-powered generating sets from 2003 to 2008 (figure 19).[185]

FIGURE 19 Global imports of wind-powered generating sets, 2003–08



Source: GTIS, Global Trade Atlas (accessed various dates).

Though the United States continues to be the largest importer of wind-powered generating sets, import growth in other countries was strong. Non-U.S. imports of wind-powered generating sets increased by almost 300 percent from 2003 to 2008. The largest non-U.S. importers in 2008 were Germany, Canada, the United Kingdom, Turkey, and Spain (table 14).[186] Of the 15 largest importers, eight were located in Europe, four in the Asia-Pacific, and three in the Americas. With the exception of Germany, imports by each of the top fifteen importers increased from 2003 to 2008.[187]

[184] GTIS, Global Trade Atlas (accessed various dates).

[185] Ibid.

[186] Germany's wind turbine installations in 2008 were significantly less than the peak in 2002, but the overall size of the market remains large and Germany ranked fourth in total wind turbine installations in 2008. Ender, "Wind Energy Use in Germany-Status 31.12.2008," February 2009, 44.

[187] GTIS, Global Trade Atlas (accessed various dates).

TABLE 14 Top 15 importers of wind-powered generating sets, U.S. dollars, 2003–08

		Imports		Percent Change 2003–08	Rank: 2008 Wind Turbine Installations
		2003	*2008*		
1	United States	355,641,053	2,585,636,227	627	1
2	Germany	632,539,838	563,464,674	-11	4
3	Canada	29,694,267	539,654,533	1,717	10
4	United Kingdom	86,586	426,017,776	491,917	8
5	Turkey	731,751	283,650,236	38,663	14
6	Spain	11,430,742	275,967,022	2,314	5
7	Australia	10,300,625	216,691,118	2,004	12
8	Italy	4,042,710	191,069,500	4,626	6
9	China	31,297,102	189,281,571	505	2
10	Japan	98,477,229	174,826,254	78	13
11	France	500,677	139,371,658	27,737	7
12	Portugal	40,310,019	130,001,882	223	9
13	Netherlands	67,897,794	126,861,737	87	11
14	Brazil	1,996,946	121,720,898	5,995	22
15	South Korea	6,485,870	102,169,320	1,475	26
	All others	91,297,229	529,604,925	480	
	Total	1,382,730,438	6,595,989,331	377	

Source: GTIS, Global Trade Atlas (accessed various dates); GWEC, *Global Wind 2008 Report*, 13; EWEA, "Wind Now Leads EU Power Sector."

Note: U.S. import data may vary slightly from official Department of Commerce statistics.

Four of the five countries with the most wind turbine installations in 2008, the United States, China, Germany, and Spain, were also among the top ten importers of wind-powered generating sets in 2008. India ranked third in installations, but was 34th in wind turbine imports.[188] A recent survey of wind turbine manufacturers by the Germany Wind Energy Institute asked companies to rank the most important current and future markets for wind turbines. Manufacturers ranked Germany as the most important current wind turbine market and the second most important future market and China as the fourth most important current market, but the most important future market. Spain ranked sixth and eighth, respectively.[189] The next section will profile the market for wind turbines and related components in China, Germany, and Spain as well as in Canada and emerging markets in the Americas.[190]

China

China is one of the fastest growing wind markets in the world, with annual wind energy installations increasing by more than 6,000 percent, from 98 MW in 2003 to 6,300 MW

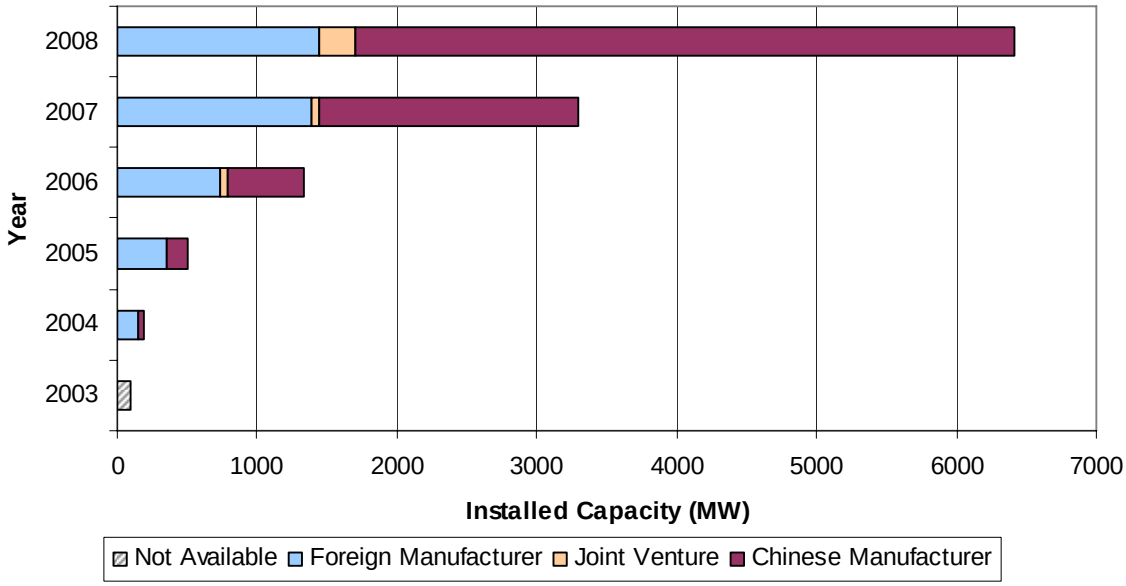
[188] The Indian market is currently dominated by domestic OEM Suzlon (69 percent of the market in 2008), Vestas (13 percent), which manufactures in India, and domestic OEM RRB Energy (9.6 percent). Domestic manufacturers benefit from tariffs that favor the import of components over completed nacelles. GTIS, Global Trade Atlas (accessed various dates); BTM Consult, *International Wind Energy Development: World Market Update 2008,* 97. For more on policies in India, see Lewis, "A Comparison," 6.

[189] The U.S. was ranked as the second most important current market and the third most important future market. HUSUM WindEnergy.

[190] Countries chosen for profiles were those in both the top five in wind turbine installations in 2008 and top 10 in wind turbine imports in 2008. In addition, the North and South American markets were selected for analysis because they are potential emerging markets that offer export opportunities for U.S. manufacturers.

in 2008 (figure 20).[191] The market for wind energy has grown due to China's need to meet its vast and expanding energy needs and the role of the government in supporting the development of the wind market. All wind projects of 50 MW or more are auctioned to project developers by the National Development and Reform Commission, while smaller projects are approved by provincial governments.[192] The government has set goals for wind installations, which have been adjusted several times as previous goals were exceeded. The latest goal is to install 10 GW of wind capacity by 2010 (a goal that was exceeded in 2008).[193] The government has also established a requirement that power producers generate 3 percent of the electricity from renewable sources (excluding hydroelectric) by 2010 and 8 percent by 2020.[194] While the Chinese government has helped spur the development of wind energy, challenges remain, including the need to modernize the electric grid, build transmission lines, and address policies related to the price of electricity.[195]

FIGURE 20 Annual installed wind capacity in China, by type of producer, 2003–08



Sources: BTM Consult, *International Wind Energy Development: World Market Update 2008*, 91; GWEC, *Global Wind 2007 Report*, 51.

The Chinese government has implemented a number of policies to encourage the development of local manufacturing to supply the wind energy market. The government has imposed local content requirements, requiring that turbines use 70 percent locally made products, and adjusted import duties to encourage the import of components rather

[191] GWEC, *Global Wind 2007 Report*, 8, 51; GWEC, "US and China in Race."

[192] EWEA, "Global Markets," 37; GWEC, *Global Wind 2008 Report*, 50; and Lewis, "Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India," November 2007, 218. For more on wind concession projects, see Li, et al., *China Wind Power Report 2007*.

[193] "Wind Energy Takes off in China," June 13, 2008; Yu, "A Gust of Support for Wind Power in China," March 20, 2008.

[194] EWEA, "Global Markets," 28.

[195] Low prices established by the government limit the profitability of wind farms and some have noted that these wind projects are only profitable due to the ability to take advantage of the Clean Development Mechanism under the Kyoto Protocol. "Wind Energy Takes off in China"; Yu; and EWEA, "Global Markets," 37.

than finished nacelles.[196] The government also encouraged local manufacturing through support for R&D and policies to promote technology transfers.[197]

Competition in the Chinese market has intensified as local companies enter the wind turbine manufacturing industry and major international OEMs enter the market. Foreign companies (e.g., GE, Gamesa, Suzlon, and Vestas) are entering the market primarily through the establishment of subsidiaries and manufacturing facilities within China. Other firms established joint ventures (e.g., Acciona, Nordex, and REpower) and a few firms licensed technology to Chinese companies.[198]

There are at least 40 Chinese OEMs, which have a growing share of the domestic market. Their market share increased from 25 percent in 2004 to 74 percent in 2008.[199] The leading OEMs in the market in 2008 were Chinese companies Sinovel, Goldwind, and Dongfang with 22, 18, and 16 percent of the market, respectively. Due to their large domestic market share, Sinovel, Goldwind, and Dongfang were seventh, ninth, and eleventh, respectively, in global market share. The combined domestic market share of other Chinese manufacturers was 18 percent. Among foreign manufacturers, Vestas was the leading supplier in 2008 with 9 percent of the Chinese market followed by Gamesa with 8 percent, GE and Suzlon with 3 percent, and Nordex and Acciona with 2 percent.[200] Global suppliers, such as blade suppliers LM Glasfiber and TPI Composites, have established manufacturing facilities in China to supply OEMs.[201]

Germany

Government policy in Germany in the 1990s spurred the creation of one of the largest global wind energy markets. In 1991 the German government implemented a feed-in tariff that specified a minimum price for renewable energy and guaranteed access to the grid for renewable energy generation. The tariff applies for 5 to 20 years, depending on the quality of the wind at the site, and declines by a small percentage each year. Combined with regulations to ease siting, national and EU renewable energy goals, and other policies, the feed-in tariff led to the rapid growth of the wind energy market in Germany.[202] Cumulative installed capacity grew from 334 MW in 1993 to 23,895 MW in 2008, and wind energy accounted for 6.4 percent of electricity consumption in 2007.[203]

Germany continues to have one of the largest global wind energy markets, but the market has slowed and is shifting to larger onshore and offshore turbines. Annual installations in

[196] Industry official, interview by Commission staff, Washington, DC, September 24, 2008; EWEA, "Global Markets," 33; and Lewis, "A Review of the Potential," 3.

[197] Lewis and Wiser, "A Review of International," 54–57.

[198] EWEA, "Global Markets," 28; GWEC, *Global Wind 2007 Report*, 51.

[199] GWEC, *Global Wind 2007 Report*, 51; BTM Consult, *International Wind Energy Development: World Market Update 2008*, 91.

[200] BTM Consult, *International Wind Energy Development: World Market Update 2008*, 24, 91

[201] TPI Composites, "TPI Composites and GE Energy Reach Agreement."; LM Glasfiber Web site. http://www.lmglasfiber.com (accessed May 24, 2009).

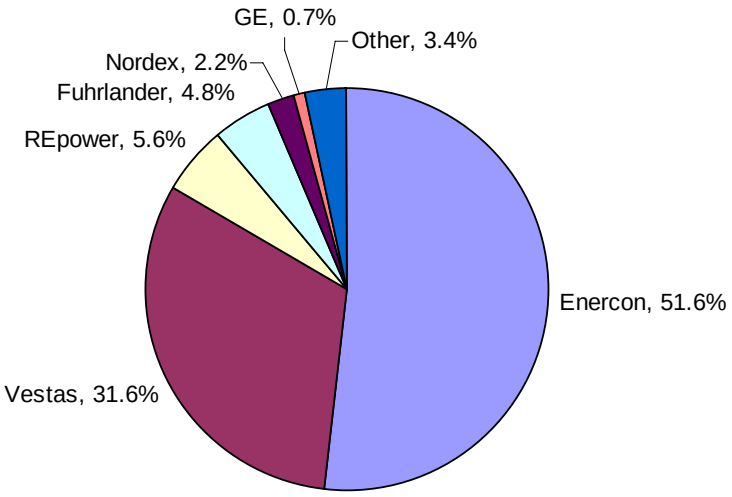
[202] German Wind Energy Association, "Wind Energy," March 2008; GWEC, *Global Wind 2007 Report*, 34; and IEA, *IEA Wind*, 126–127.

[203] Keuper, "Wind Energy Use in Germany-Status 31.12.1993," February 1994, 5; Ender, "Wind Energy Use in Germany-Status 31.12.2007," February 2008, 34; German Federal Ministry for the Environment, "Deployment of Renewable Energy Sources in Germany in 2007, Graphics and Tables," December 15, 2008; and Ender, "Wind Energy Use in Germany-Status 31.12.2008," 54.

2008 were 1,665 MW, significant but lower than the peak of over 3,000 MW in 2002.[204] Despite the decrease in annual installations, the German market is likely to remain strong due to feed-in tariffs, renewable energy goals, and significant potential wind resources. There are opportunities for expanding onshore installations, developing offshore wind, and repowering existing wind turbines, though neither of the last two accounted for a major portion of installed capacity in 2007.[205]

The German market is dominated by Enercon and Vestas, which accounted for a combined 65 percent of all wind turbines installed in Germany from 1982 through 2008 and a combined 83 percent of all turbines installed in 2008 (figure 21). GE has a manufacturing presence in Germany and a declining, though traditionally strong, market share in Germany. GE accounted for 9 percent of wind turbines installed in Germany from 1982 to 2008, but less than 1 percent in 2008.[206] That is likely to change since GE recently completed upgrading its plant in Germany to produce GE's new 2.5 MW turbine and already has at least one order in Germany.[207]

FIGURE 21 Wind turbine installations in Germany, by OEM, 2008



Source: Ender, "Wind Energy Use in Germany–Status 31.12.2008," February 2009, 54.

Note: Numbers may not add to 100 percent due to rounding.

Spain

Spain established a feed-in tariff for wind energy in 1997 and targets for renewable energy generation, both of which contributed to wind energy growth. This system differs from the system employed in Germany in that the wind project developer can choose

[204] Ender, "Wind Energy Use in Germany-Status 31.12.2007," 34; IEA, *IEA Wind*, 125–126.

[205] GWEC, *Global Wind 2007 Report*, 34–35; "Germany Plans 30 More Windfarms," *Business Week*, July 7, 2008.

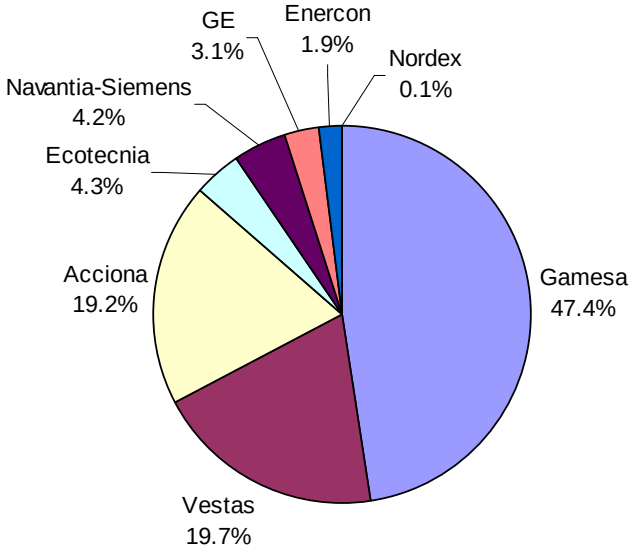
[206] Historical statistics for GE include turbines installed prior to GE's purchase of Enron Wind. Ender, "Wind Energy Use in Germany-Status 31.12.2007," 44; Ender, "Wind Energy Use in Germany-Status 31.12.2008," 54.

[207] GE Web site. http://www.ge.com (accessed February 3, 2009).

between a set feed-in tariff and a price for electricity that is a certain amount above the market price.[208] Annual installed wind capacity in Spain increased from 419 MW in 1998 to 3,522 MW in 2007, but fell to 1,609 MW in 2008. Spain ranks third in the world in cumulative installed wind capacity.[209]

Spanish companies and Vestas have the largest shares of the market in Spain. Gamesa accounted for 57 percent of all cumulative turbine installations through the end of 2007 and 47 percent of turbines installed in 2007 (figure 22).[210] Vestas accounted for 15 percent of all cumulative turbine installations in Spain through the end of 2007 and 20 percent of turbines installed in 2007. Newer market entrant Acciona has a lower historical market share, but accounted for over 19 percent of wind turbine installations in 2007. Spanish company Ecotecnia was fourth in 2007 with 4 percent of the market. Navantia-Siemens accounted for 4 percent of turbine installations, GE 3.1 percent, and Enercon 1.9 percent.[211] OEMs or suppliers often must have local production facilities in order to meet the local content requirements established by regional governments.[212]

FIGURE 22 Wind turbine installations in Spain, by OEM, 2007



Source: AEE, *Wind Power 2008*, 16-17.

Note: Numbers may not add to 100 percent due to rounding.

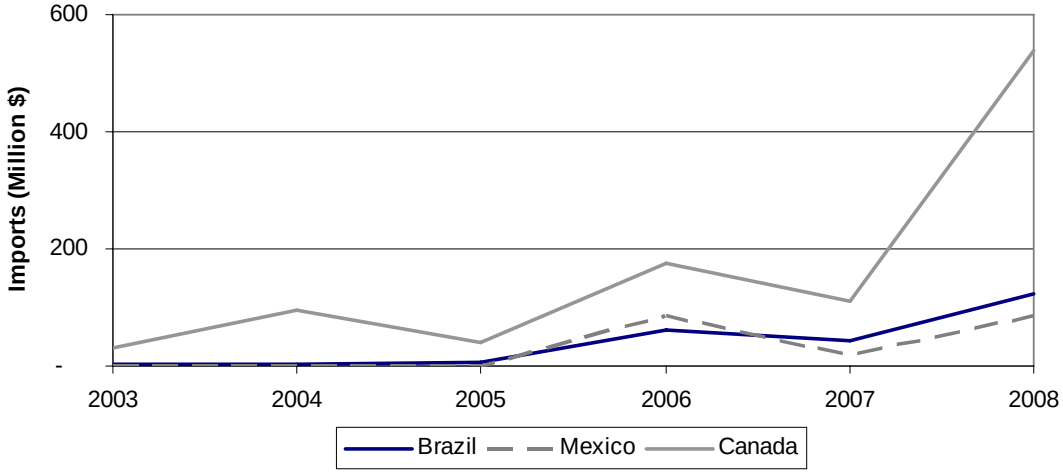
North and South America

The growth in wind installations in Canada, Mexico, and South America has been sporadic, but these markets are growing and there are export opportunities for U.S. producers. Imports of wind turbines by Brazil, Canada, and Mexico increased from $32 million in 2003 to $747 million in 2008, with Canada accounting for 71 percent of

[208] GWEC, *Global Wind 2007 Report*, 58–59; IEA, *IEA Wind*, 217–218, 223–225.
[209] AEE, 10; GWEC, *Global Wind 2007 Report*, 8; GWEC, *Global Wind 2008 Report*, 9.
[210] This includes turbines produced by OEM Made, which was acquired by Gamesa in 2003.
[211] AEE, 17.
[212] Lewis, "A Comparison," 9.

this increase (figure 23).[213] Other countries may also be potential wind markets—as noted earlier, CTC/DeWind exported 10 wind turbines to Chile in late 2008/early 2009.

FIGURE 23 Imports of wind-powered generating sets, Brazil, Canada, and Mexico, 2003–08



Source: GTIS, Global Trade Atlas (accessed various dates).

Canada was tenth in the world in wind turbine installations in 2008 and third in wind turbine imports. Annual wind turbine installations increased from 86 MW in 2003 to 526 MW in 2008. Installations in 2009 are expected to rise to 650 MW despite the financial crisis.[214] In 2008, the leading wind turbine suppliers were Siemens (33 percent), Vestas (31 percent), GE (30 percent), and Acciona (5 percent).[215] GE is not currently exporting wind turbines from the United States to Canada, but Acciona, as noted earlier, plans to build some turbines for wind projects in Canada in the United States.

Canadian government policies will likely lead to further wind turbine installations—many provinces have established renewable energy goals (ranging between 500 MW and 4,600 MW) and the federal government provides an incentive for renewable energy generation.[216] In Canada, wind farms are generally developed as a result of requests for proposals by provincial utilities. While this can lead to large contracts, one government, Quebec, has local content requirements for its contracts that reduce the ability of companies outside Canada to compete for these contracts.[217] Despite some challenges, such as the need to upgrade transmission infrastructure, there is excellent potential for wind energy generation in Canada due to good wind resources and the ability to sell this electricity into both the Canadian and American markets.[218]

Brazil and Mexico both ranked in the top 20 in wind turbine imports in 2008.[219] 94 MW were installed in Brazil in 2008 and, while there were no reported installations in Mexico, 143 MW was built in Oaxaca in 2008 and expected to come online in 2009.[220] Markets in

[213] GTIS, Global Trade Atlas (accessed various dates).
[214] Ibid.; GWEC, *Global Wind 2008 Report*, 13, 22–23.
[215] BTM Consult, *International Wind Energy Development: World Market Update 2008*, 89.
[216] GWEC, *Global Wind 2008 Report*, 22–23; "A Market Ready for the Next Big Step," October 2008, 4–5.
[217] "A Market Ready for the Next Big Step," 5–6.
[218] Hornung, "Canada is Uniquely Position to Think Big," 3.
[219] GTIS, Global Trade Atlas (accessed various dates).
[220] GWEC, *Global Wind 2008 Report*, 13, 43.

Brazil and Mexico are currently small in comparison to China, Europe, and the United States, but both countries have excellent wind resources and there is significant potential for market growth.[221]

[221] Ibid., 20–21, 42–43; U.S. Commercial Service, "Emerging Market: Renewable Energy," 2009, 53–54.

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