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U.S. Utility-Scale Wind Turbine Nacelle Production and Trade

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Abstract

This paper examines the evolution of U.S. wind turbine nacelle manufacturing and trade from 2012 to 2020. The results of this analysis indicate that the U.S. wind turbine nacelle manufacturing industry contracted starting in mid-2012, with ten nacelle plants closing during 2012–20. The three largest suppliers, however, maintained nacelle plants and by 2020 U.S. production capacity had rebounded to close to (by number of turbines) or above (by megawatts) 2012 levels. This production supplies most of the domestic market, but the reduction in the number of firms did lead to more reliance on imports in some years. In 2020, amid high demand, U.S. imports significantly increased as some firms did not have enough U.S. production capacity to meet demand and firms without U.S. production gained sales. The share of the market accounted for by imports in 2020 exceeded 30 percent on a megawatt basis and was about 25 percent on a value basis. Further, there is little available capacity to supply export markets and U.S. exports have sharply dropped from their 2014 peak.

U.S. International Trade Commission

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Introduction

The U.S. wind turbine nacelle[1] manufacturing industry in the fifteen-year period from 2006–2020 is marked by two distinct periods. The period from 2006 to mid-2012 was a period of rapid growth and diversification in the manufacturing industry, with substantial new investments in U.S. nacelle manufacturing production. The period from mid-2012 to 2020 was a period of plant closures and consolidation due to a number of factors, including overcapacity, an initial drop in demand, and a decreasing need to use U.S. plants to serve export markets. This paper will examine the evolution of U.S. nacelle manufacturing from 2012 to 2020, including trends in U.S. production and trade. The results of this analysis indicate that there was a significant reduction in the number of firms supplying the U.S. market, though production capacity rebounded in the second half of the time period. This production supplies most of the domestic market, but the reduction in the number of firms did lead to more reliance on imports in some years. Further, there is little available capacity to supply export markets and U.S. exports have sharply dropped from their 2014 peak.

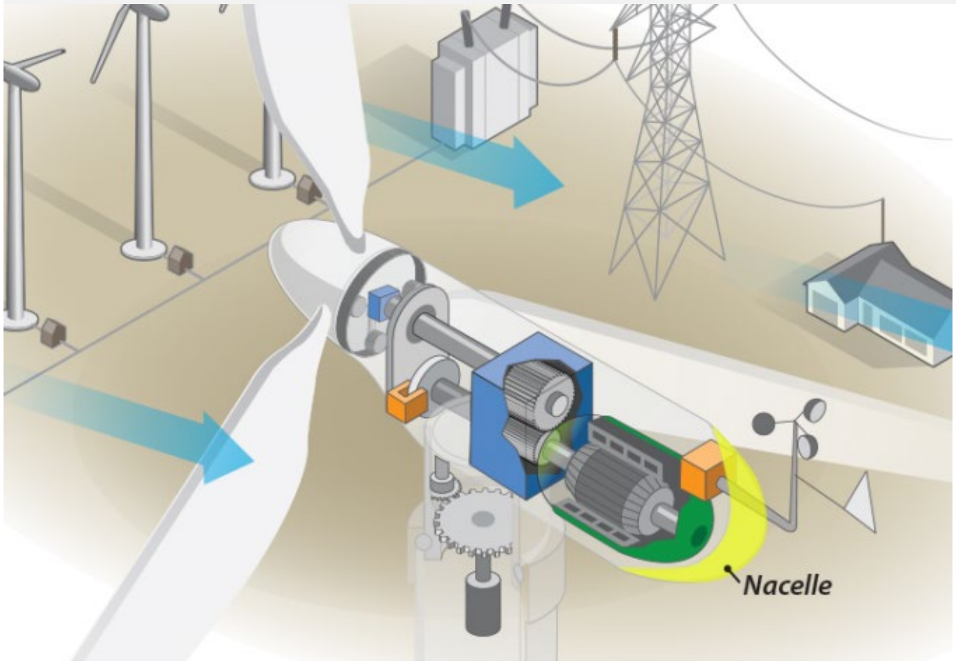
The first section of this paper will provide background information on wind turbine nacelles and the next section will discuss the market and production data used in this paper. The third section will examine market trends, including the size of the market and turbine prices. The paper will then examine the U.S. manufacturing industry, which will be followed by a discussion of U.S. imports, the share of the market accounted for by domestic production and imports, and U.S. exports. Finally, the paper will conclude with a brief summary of the findings and a discussion of additional research topics.

Wind Turbine Nacelles

Wind turbine nacelles are the major power generation component of wind turbines and house the gearbox, generator, shafts, and other parts (figure 1).[2] This paper will cover nacelles for utility-scale wind turbines, which are defined here as turbines with an output of more than 100 kilowatts (kW).[3] These turbines are typically used in large wind projects rather than in small-scale residential and commercial applications. The size of wind turbines has significantly increased over time, as companies have sought to reduce costs and increase output.[4] The average nacelle installed in the United States increased from 1.95 megawatts (MW) in 2012 to 2.75 MW in 2020.[5] Wind turbine original equipment manufacturers (OEMs)—which are the firms that design and sell the wind turbines such as General Electric (GE), Siemens Gamesa, and Vestas—typically produce nacelles in-house.[6]

[1] The nacelle is the major power generation component of a wind turbine and houses the gearbox, generator, shafts, and other parts.
[2] This paper will not cover the supply chain for wind turbine nacelles, which will be addressed in separate research. David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 2.
[3] The term "nacelle" will be used to refer to data and information that is specific to nacelles, while the broader term "turbine" will be used to refer to the entire turbine, including the nacelle, blades, hub, etc. The term "wind-powered generating set," which includes the nacelle and other wind turbine parts imported with the nacelle, will be used in the trade section of the paper. David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 1.
[4] Wiser and Bolinger, *2018 Wind Technologies Market Report*, August 2019, viii.
[5] Wiser et al., *Land-Based Wind Market Report*, August 2021.
[6] David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 1.

Figure 1 Wind turbine nacelle



Source: DOE, EERE, “Wind Gallery,” n.d. (accessed July 21, 2021).

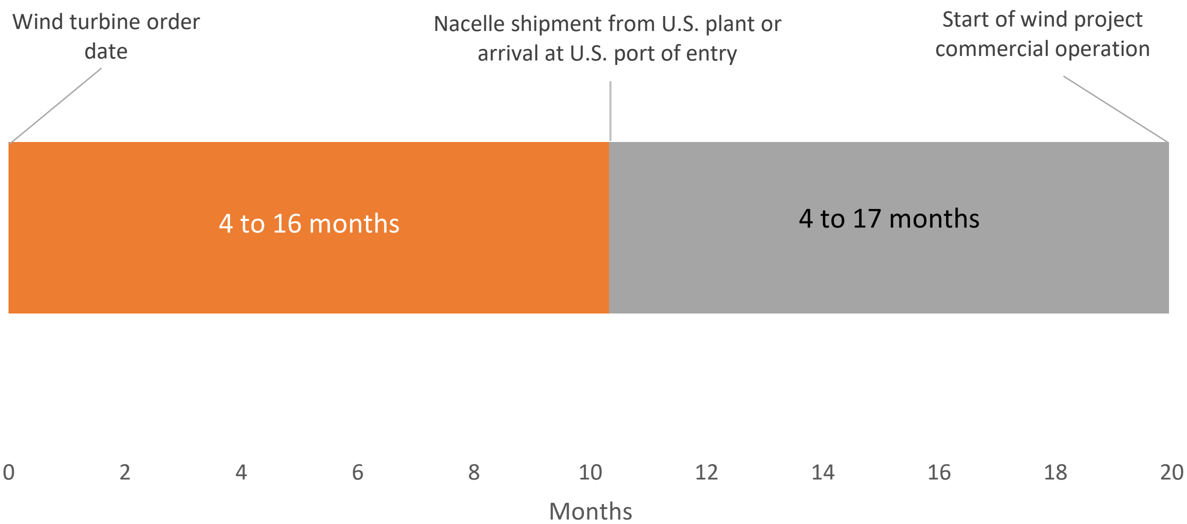
Data Used in this Paper

Apparent U.S. Consumption

Most measurements of the wind turbine market are based on when wind projects are “installed,” which is generally the start of commercial operation. This definition is applicable for understanding electricity markets but can misrepresent the amount of manufacturing and trade activity in any given year due to the lag between when a turbine is shipped and when it starts commercial operation. In the U.S. market, wind turbines are typically ordered an average of 10.3 months before the first nacelles are shipped from a U.S. factory or, if imported, land at the first port of entry (figure 2). The project then starts commercial operation, on average, 9.6 months after the nacelle is shipped from the U.S. factory or arrives at the first port of entry.[7]

[7] A number of factors contribute to this lag, including the time needed to ship the nacelle to the site, erect all of the wind turbines used in the project, finish construction of the rest of the wind project, and go through testing and commissioning. Based on data compiled by USITC staff.

Figure 2 Timeline from turbine order to wind project commercial operation



Source: The order to shipment timeline is based on 11 U.S. projects with start of commercial operation dates from 2016 to 2021, while the shipment to start of commercial operation timeline is based on 27 projects.
Notes: Bar size is based on the average length of time across all projects in the sample. Where a small share of turbines for a project were ordered earlier to meet deadlines for the receipt of tax credits and the bulk of turbines were ordered later, the order date use here is based on when the majority of turbines were ordered.

This paper, therefore, measures the size of the market based on estimates of apparent consumption (in the number of nacelles, MW, and dollar value), which is the amount of domestically produced nacelles shipped to U.S. projects plus imported nacelles. These estimates are derived by USITC staff from a range of public data sources, including reports, news articles, shipping manifest data, and U.S. Energy Information Administration (EIA) data. The value of apparent U.S. consumption of nacelles is estimated using the volume of apparent consumption in MW and an average nacelle price per MW derived from trade data.[8] The value of apparent consumption of complete turbines uses the volume of apparent consumption and the average wind turbine price per MW from BloombergNEF. The exception to using apparent consumption data will be wind turbine OEM market share data, which is only available based on installations.

U.S. Imports

U.S. import data are not specific to nacelles. As will be discussed below, broader Harmonized System (HS) subheadings and Harmonized Tariff Schedule of the United States (HTS) statistical reporting numbers will be used to track trade over time. For the purpose of calculating the share of the market supplied by imports in 2020, however, U.S. imports of nacelles are estimated. The volume of U.S. imports is estimated using transaction level U.S. import and foreign export data from shipping

[8] An alternative calculation was done to check these unit values. The average wind turbine price per MW from the BloombergNEF wind turbine price index was multiplied by the share of wind turbine costs accounted for by the nacelle according to published estimates. This alternative calculation resulted in an estimated nacelle cost that was within 1 percent of the cost estimate using trade data. BloombergNEF, *2H 2020 Wind Turbine Price Index*, July 3, 2020.

manifests. The value of U.S. nacelle imports is estimated using official U.S. import statistics narrowed as specifically as possible to U.S. nacelle imports.[9]

U.S. Shipments (Excluding Exports)

There is no readily available data source on U.S. nacelle production or shipments. For the purposes of the share of the market accounted for by domestic production, shipments are calculated by taking the difference between the size of the market and imports of nacelles. This calculation was checked using estimated imports and domestic production of various components used in wind turbine nacelle assembly. This estimated production, while varying by component analyzed, is generally similar to the level of shipments calculated using import and market size data.

U.S. Market

Wind Turbine Demand

Apparent U.S. consumption of wind turbines declined from about 9 gigawatts (GW) in 2012 to about 3 GW in 2013, then gradually rebounded to almost 14 GW in 2020 (figure 3). The value of the market followed a similar trend. However, when the market rebounded after 2013 the market value did not grow as much as the market volume due to the decline in turbine prices.[10] The significant decline in the market in 2013 was due to the expiration of the most significant federal tax incentive for wind, the production tax credit (PTC), which required wind projects to be placed in service by the end of 2012. The PTC was renewed in January 2013, but this was too late for many new projects to come online in that year. However, starting with the 2013 renewal, projects only had to start construction by the date the tax credit expired, which has led to less drastic market swings during subsequent periods of policy uncertainty.[11]

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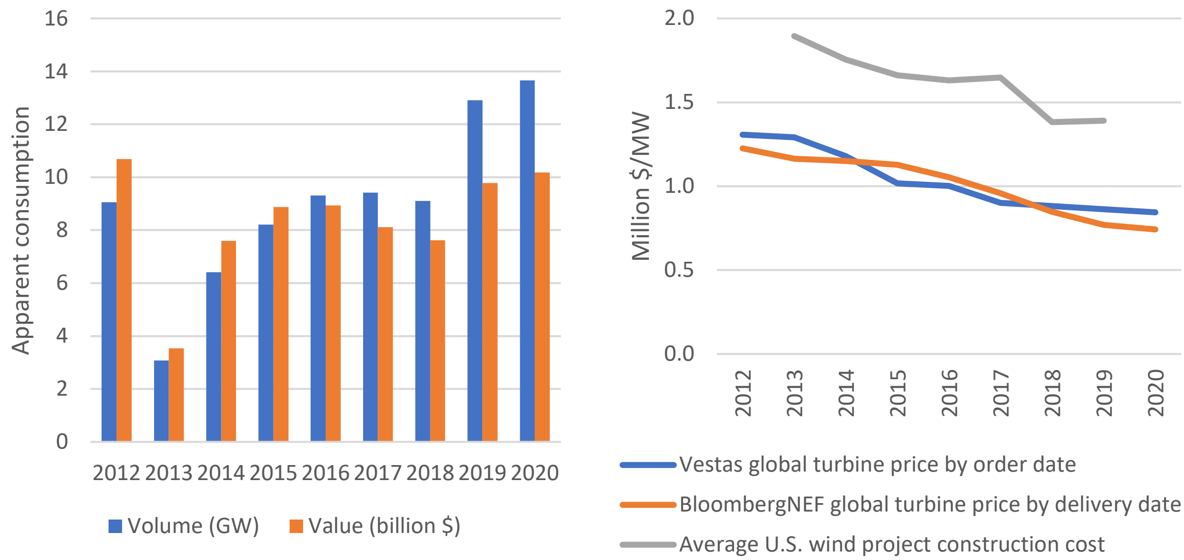
[9] The share of the market, by value, is only calculated in 2020, when a new statistical reporting number was added to the HTS, as will be discussed below.

[10] Based on the estimated market volume and wind turbine prices from BloombergNEF, *2H 2020 Wind Turbine Price Index*, July 3, 2020. The value of the market is for the entire wind turbine.

[11] The PTC is a tax credit per kilowatt hour of electricity generated. Wind projects starting construction in 2021 are eligible for a tax credit worth 60 percent of the inflation adjusted value of the PTC. There are a number of other factors that have driven the growth of the market over time, such as other federal policies (e.g., the investment tax credit and accelerated depreciation), state polices (e.g., renewable portfolio standards and state tax incentives), declining wind turbine prices, and customer preferences for renewable electricity. However, the PTC has historically been the most significant factor in annual fluctuations in installation volumes. Wiser and Bolinger, *2018 Wind Technologies Market Report*, August 2019, 49–50, 59–60, 70–73; NC Clean Energy Technology Center, DSIRE, “Renewable Electricity,” January 27, 2021; Navigant Research, *World Market Update 2013*, March 2014, 92; David and Fravel, “U.S. Wind Turbine Export Opportunities,” July 2012, 5–6.

Figure 3 Apparent U.S. consumption, wind turbines, 2012–20 (left) and wind turbine prices, 2012–20



Source: USITC staff estimate of the volume of apparent consumption; EIA, Form EIA-860 (accessed July 2, 2021); BloombergNEF, *2H 2020 Wind Turbine Price Index*, July 3, 2020; EIA, "Construction Cost Data for Electric Generators Installed," 2016–21; Vestas, *Annual Report*, 2013–21.

OEMs Supplying the U.S. Market

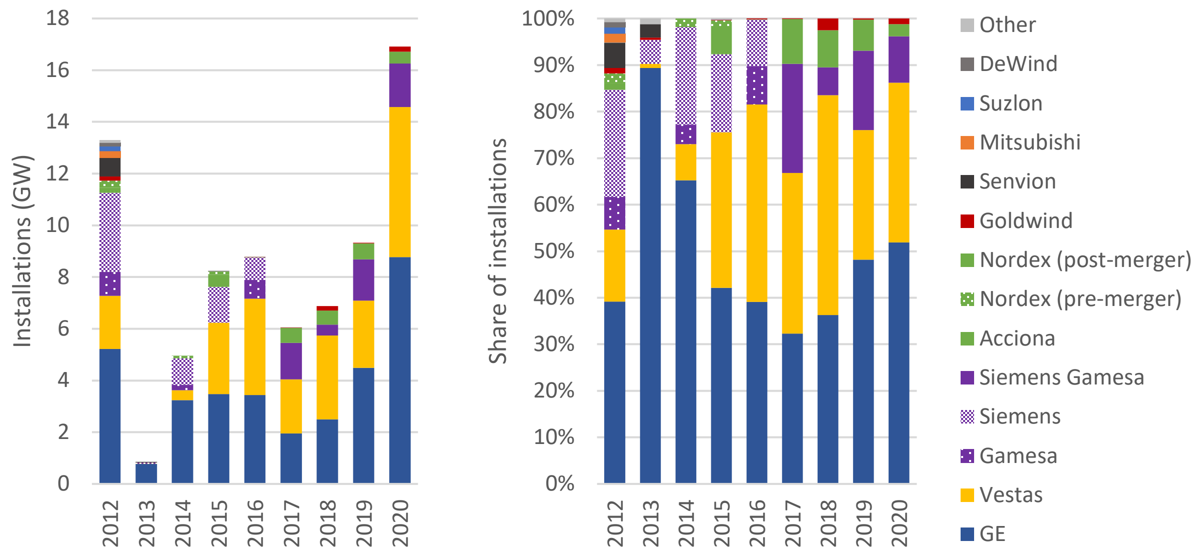
There was a significant reduction in competition in the U.S. market during 2012–20, with the number of OEMs supplying turbines (by date of installation) declining from 20 in 2012 to 5 in 2020 (figure 4).[12] U.S. installations since 2017 have principally been dominated by two firms, GE (headquartered in the United States) and Vestas (Denmark).[13] Siemens Gamesa (Spain) was the third largest supplier in most years, with Nordex (Germany) and Goldwind (China) accounting for the remaining installations.[14]

[12] EIA, Form EIA-860 (accessed July 2, 2021); ACP, *ACP Market Report: Fourth Quarter 2020*, 2021, 21.

[13] GE and Vestas are likely to remain large suppliers to the U.S. market in the near term. They reportedly were the selected supplier for 49 percent and 33 percent, respectively, of onshore wind projects under construction or in advanced development as of the end of 2020 for which a wind turbine OEM had been disclosed. EIA, Form EIA-860 (accessed July 2, 2021); ACP, *ACP Market Report: Fourth Quarter 2020*, 2021, 21.

[14] ACP, *ACP Market Report: Fourth Quarter 2020*, 2021, 21.

Figure 4 U.S. wind turbine OEM market shares, by MW installed, 2012–20



Sources: EIA, Form EIA-860 (accessed July 2, 2021); Goldwind, "China - Xinjiang Goldwind to Acquire," February 2, 2008.
Notes: Vensys installations are included under Goldwind, which has been the majority owner since 2008.

The reduction in the number of firms supplying the U.S. market reflects the consolidation of the global industry and the competitive advantages of large suppliers in a smaller market where all firms had significant available capacity. The number of OEMs globally declined from more than 70 in 2014 to 33 in 2019 and four firms—Vestas (34 percent of installations outside of China), GE (28 percent), Siemens Gamesa (11 percent) and Nordex (7 percent)—accounted for 80 percent of installations outside of China in 2020. This consolidation reflected mergers and acquisitions, bankruptcies, and industry exits. For example, GE acquired Alstom in 2015, Acciona Windpower and Nordex merged in 2016, and Siemens Wind Power and Gamesa merged in 2017. Other firms that supplied the U.S. market in 2012 either exited wind turbine manufacturing (e.g., Clipper Windpower) or went bankrupt or were liquidated (e.g., DeWind and Senvion).[15] In addition, with the slowing of the U.S. market during the first part of this

[15] The consolidation in the wind industry was driven by a number of factors, including overcapacity in the market, pricing pressures, and downturns in demand in traditional markets. Firms viewed mergers and acquisitions as a way to increase competitiveness through combining complementary capabilities, technologies, and geographic footprints; raising their market share; lowering costs through economies of scale; and increasing their ability to support innovation. Consolidation resulted both from mergers and acquisitions and industry exits, with many firms that entered the industry in response to the rapid growth in demand exiting manufacturing after failing to achieve significant sales and/or profits and some older firms going bankrupt. GWEC Market Intelligence, Market Data and Statistics (accessed June 22, 2021); BloombergNEF, Wind Trade and Manufacturing, February 2021, 7; BloombergNEF, 2H 2020 Wind Turbine Price Index, July 3, 2020; Acciona, "ACCIONA Windpower and Nordex," April 4, 2016; Siemens, "Siemens and Gamesa," June 17, 2016; Radowitz, "Siemens' Merger," January 26, 2017; Dong-chan, "Shipbuilders to Liquidate," May 19, 2006; Lacal-Arantegui, "Globalization in the Wind Energy," 2019, 620–622; Joint Research Centre, Wind Energy, 2019, 37; Tacke, "The Opportunities and Challenges," April 24, 2017; Nordex, "Nordex and Acciona Windpower," October 4, 2015; Schneider, "Why the Consolidation," December 2, 2020; Navigant Research, Supply Chain Assessment 2014–18, Q4 2014, 10; GWEC, "Wind Turbine Sizes," May 27, 2020; Weston, "'We Won't Be the Last' – Senvion CEO," December 19, 2019; Nikkei Asia, "Hitachi to Pull Out," January 25, 2019; GE, "GE Completes Acquisition," November 3, 2015; Siemens, "Merger of Siemens," April 3, 2017; Money, "Regulators: Address Safety Issues," June 23, 2021; Platinum Equity Website, "Clipper Windpower," August 2013; Vestas, "First Quarter 2021," May 2021, 6.

period, most sales went to the firms that were traditionally the largest suppliers and had advantages such as in name recognition, reputation for quality and, in some instances, pricing.[16]

U.S. Wind Turbine Nacelle Manufacturing Industry

There were three OEMs, GE (Pensacola, FL), Siemens Gamesa (Hutchinson, KS), and Vestas (Brighton, CO), with active U.S. nacelle assembly plants for onshore turbines in 2020, down from 11 OEMs manufacturing at 13 plants in March 2012.[17] GE is the largest producer (production capacity of more than 100 nacelles per week), followed by Vestas (capacity of 1,400 nacelles annually), and Siemens Gamesa (capacity of more than 500 nacelles annually).[18] In addition, Nordex has a plant (owned by Acciona prior to the merger) that has been idle in Newton, IA since 2014.[19] GE is planning to open a nacelle assembly plant in New Jersey for offshore wind turbines, and a smaller firm, Carter Wind Energy, announced plans in 2021 to build a plant for 300 to 500 kW wind turbines in Oklahoma.[20]

The U.S. nacelle manufacturing contraction occurred relatively quickly starting from the second half of 2012, with the expected the PTC expiration and decline in U.S. demand.[21] For example, Clipper Windpower exited nacelle manufacturing in 2012, Nordex closed its plant in 2013, TECO-Westinghouse's production for DeWind ended in 2013, Acciona idled production in 2014, and Gamesa had only limited production capacity by the middle of 2014 (with the plant eventually closing). Alstom had idled its plant by 2015, when the merger with GE was pending.[22] Together, these plant closures represented a reduction in U.S. annual production capacity of 5 GW and about 2,500 turbines, which was more than 30

[16] EIA, Form EIA-860 (accessed July 2, 2021); Radowitz, "Playing Catch-up," May 2017, 39–41.
[17] David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; Vestas, "Manufacturing in the USA," 2021; Siemens Gamesa, "Decade of Manufacturing," November 26, 2020; GE, "GE Renewable Energy Locations" (accessed July 23, 2021); Stromsta, "A Manufacturing Renaissance," May 2016, 49.
[18] Vestas, "Manufacturing in the USA," 2021; GE, "Manufacturing Wind Turbines," March 19, 2021; Siemens Gamesa, "Decade of Manufacturing," November 26, 2020; David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; Radowitz, "Playing Catch-up," May 2017.
[19] Nordex, Annual Report 2020, March 23, 2021, 26; Ford, "Iowa Project," November 30, 2015.
[20] Additional information on the GE plant, including when it is expected to open and the production capacity, are not yet available. Orsted, "New Jersey Selects," June 30, 2021; Halsey, "Carter Wind Turbines Chooses," April 15, 2021; Carter Wind Energy Website, "Carter Wind Energy" (accessed August 31, 2021).
[21] Though 2012 was a strong year for nacelle apparent consumption, manufacturing activities slowed later in the year as products needed to be shipped in time to meet project commissioning deadlines.
[22] David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; Ford, "Iowa Project," November 30, 2015; Brantley, "Wind Energy Manufacturer," June 28, 2013; Energy Monitor Worldwide, "GRI Pledges," June 30, 2015; Platinum Equity Website, "Clipper Windpower," August 2013; Davidson, "Accusations Fly," December 28, 2012; TECO-Westinghouse, "Company Profile" (accessed July 23, 2021); DiStefano, "For Sale," February 11, 2020; Maykuth, "Slowdowns at Gamesa," January 29, 2014.

percent of 2012 U.S. production capacity.[23] GE consolidated production from three plants into its plant in Florida, though in the long term its production capacity increased both in MW and unit terms.[24]

Several factors contributed to the reduction in the number of U.S. manufacturing plants starting in 2012. First, there was significant overcapacity in the U.S. industry even with the high level of demand in 2012. Apparent U.S. consumption of wind turbines in 2012 was less than 60 percent of annual production capacity, by number of turbines, for facilities in operation as of March 2012.[25] Second, as discussed above, the market sharply contracted after 2012 due to the expiration of the PTC.[26] Third, some companies with U.S. plants went two or more years without any installations, as orders went to larger companies.[27] Fourth, though some companies compensated for the downturn in domestic demand with production for export markets, there was overcapacity in the global industry as well, making U.S. plants unnecessary as export bases.[28] Fifth, while most of the consolidation in the global industry occurred after U.S. plants closed, GE did not retain production at Alstom's idled plant in Texas after its acquisition of Alstom's wind business.[29]

The remaining U.S. manufacturers have made significant investments in their plants since 2012 and have started production of more advanced wind turbines. Siemens Gamesa, for example, produced its 2.3 MW and 2.65 MW turbine at its Hutchinson plant prior to 2018. The firm introduced production of its 3.645 MW turbine at its Hutchinson plant in 2018 and its 4.5 MW turbine in 2019. It made investments in its plant prior to both product launches, including $6 million in the year leading up to the start of production of the 4.5 MW turbine.[30] GE moved from a batch to an assembly line production process at its plant in Florida, resulting in an increase in production capacity. Further, while a majority of its U.S. production in 2012 was of nacelles less than 2 MW, its most commonly produced models for installation in 2020 were its 2.82 MW and 2.5 MW nacelles.[31] Vestas started production in Colorado in 2010 with its 1.8 MW model and the capability of producing models with an output up to 3 MW. The firm added production lines for its V136 turbine, which starts at 3.45 MW, in 2017.[32]

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[23] David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7. Where information on the size of wind turbines produced at a particular plant was not available in the "U.S. Wind Turbine Export Opportunities" paper, information on the size of turbines produced at the plant is from Wang, "2019 Wind Turbine," August 8, 2019.
[24] GE, "GE Renewable Energy Locations" (accessed July 23, 2021); David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; GE, "Manufacturing Wind Turbines," March 19, 2021.
[25] USITC staff estimate of apparent U.S. consumption; David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; Kessler, "The Boom is Back," May 2014, 19; Wang, "2019 Wind Turbine," August 8, 2019.
[26] Brantley, "Wind Energy Manufacturer," June 28, 2013; Stromsta, "A Manufacturing Renaissance," May 2016, 42, 44; Radowitz, "Playing Catch-up," May 2017, 39; Kessler, "The Boom is Back," May 2014, 18–19.
[27] EIA, Form EIA-860 (accessed July 2, 2021); Kessler, "The Boom is Back," May 2014, 18.
[28] Global production capacity outside of China exceeded non-China installations by 20 GW in 2013 and by 10 GW in 2014. Chinese manufacturers also supplied a small share of the market outside of China in 2013 and 2014, but primarily supplied the Chinese market in those years. BloombergNEF, Wind Trade and Manufacturing, February 2021, 7; GWEC Market Intelligence, Market Data and Statistics (accessed June 22, 2021); Brantley, "Wind Energy Manufacturer," June 28, 2013; David, "China Emerges," March 2021.
[29] GE, "GE Renewable Energy Locations" (accessed July 23, 2021); David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; Energy Monitor Worldwide, "GRI Pledges," June 30, 2015.
[30] Green, "Turbine Offerings," June 4, 2019; Green, "New Nacelle," January 21, 2018.
[31] ACP, ACP Market Report: Fourth Quarter 2020, 2021, 21; EIA, Form EIA-860 (accessed July 2, 2021); GE, "Manufacturing Wind Turbines," March 19, 2021.
[32] Danko, "Apple Wind Farm," December 29, 2017; Vestas, "Building in America," September 2, 2010, 7.

The investments in U.S. production and increase in turbine sizes have resulted in a recovery in U.S. production capacity. U.S. production capacity, in terms of number of turbines, in 2020 was more than 5 percent lower than in 2012, but—due to the larger turbines sizes now produced domestically—production capacity in MW has recovered to more than 10 percent above 2012 levels.[33] According to the American Clean Power Association, annual production capacity in 2020 was 15 GW.[34] In terms of U.S. shipments, GE, Siemens Gamesa, and Vestas combined shipped more than 4,000 wind turbines to domestic wind projects in 2020.[35]

The closure of U.S. plants and industry consolidation, however, had a significant impact on the U.S. market's reliance on imports as demand increased. The aggregate numbers appear to indicate a domestic industry that has excess capacity to supply U.S. demand, but the actual picture is much more complicated as some OEMs are not able to supply high demand levels solely from their U.S. plants and OEMs generally do not produce their full range of products in the United States. U.S. firms with domestic nacelle plants accounted for 96 percent of installations in 2020, but U.S. production accounted for a much lower share of the market, as will be discussed below.[36]

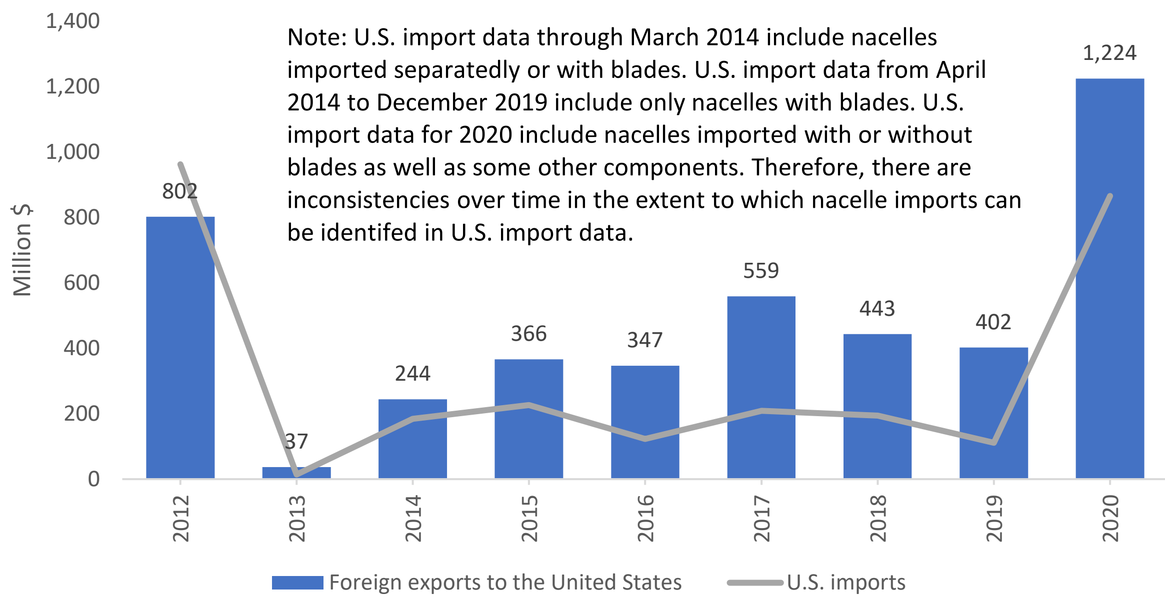
U.S. Imports

U.S. imports of nacelles substantially increased in 2020. U.S. imports of wind-powered generating sets (based on mirror export data),[37] which include nacelles as well as other products, declined from $802 million in 2012 to $37 million in 2013. Imports averaged almost $400 million annually during 2014–19, then increased to $1.2 billion in 2020 (figure 5).[38] Import growth in 2020 reflected increased shipments to the U.S. market by OEMs with no active U.S. manufacturing plants (Goldwind and Nordex).[39] In addition, some OEMs with U.S. manufacturing imported turbines due to orders exceeding domestic

[33] Wiser et al., *Wind Energy Technology*, August 2020; Vestas, "Manufacturing in the USA," 2021; GE, "Manufacturing Wind Turbines," March 19, 2021; Siemens Gamesa, "Decade of Manufacturing," November 26, 2020; David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7; Wang, "2019 Wind Turbine," August 8, 2019.
[34] Wiser et al., *Land-Based Wind Market Report*, August 2021.
[35] Based on data compiled by USITC staff.
[36] ACP, *ACP Market Report: Fourth Quarter 2020*, 2021, 21; EIA, Form EIA-860 (accessed July 2, 2021).
[37] U.S. imports of nacelles, whether or not imported with blades, were classified as wind-powered generating sets in Harmonized Tariff Schedule of the United States (HTS) subheading 8502.31.00 until April 2014. In U.S. Customs and Border Protection ruling HQ H148455, on April 4, 2014, CBP modified its previous rulings and determined that nacelles imported without blades were classified as parts of wind-powered generating sets in HTS 8503.00.95. In 2014, parts of wind-powered generating sets in HTS 8503.00.95 were included in a broader statistical reporting number and not separately disaggregated, so there is no trade data that includes nacelles imported without blades for the period from April 2014 to December 2019. On January 1, 2020, a new statistical reporting number (HTS 8503.00.9570) was added to the HTS for parts of wind-powered generating sets classified in subheading HTS 8502.31.00, which includes nacelles imported without blades. As a result of the change in classification for nacelles, there are inconsistencies over time in the extent to which nacelle imports can be identified in U.S. trade data. Therefore, this paper will primarily rely on foreign mirror trade data, though U.S. data will be shown in figures. CBP, Headquarters Ruling H148455, April 4, 2014; USITC, *Harmonized Tariff Schedule of the United States (2020) Basic Edition*, January 2020; David, "Wind Turbines," June 2009, 30.
[38] USITC DataWeb/Census (accessed June and December 2021); IHS Markit, Global Trade Atlas database (accessed June and December 2021).
[39] IHS Markit, Global Trade Atlas database (accessed June 24, 2021); Trade Data Services, Import Genius database (accessed June–July 2021).

production capacity.[40] OEMs with U.S. manufacturing also import products in order to meet delivery timelines and when there are orders for products not made in the United States.[41]

Figure 5 U.S. imports of wind powered generating sets, 2012–20



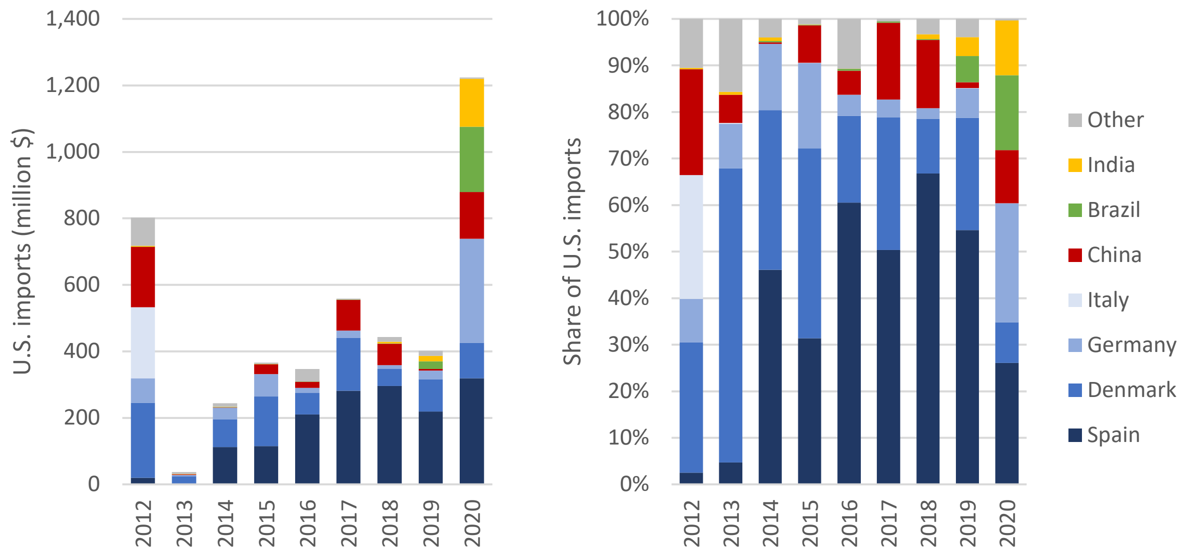
Source: USITC DataWeb/Census (accessed June and December 2021); IHS Markit, Global Trade Atlas database (accessed June and December 2021).
Notes: U.S. import data are general imports in HS 8502.31, wind-powered generating sets, and in 2020 also include HTS 8503.00.9570, parts of wind-powered generating sets classified in subheading HTS 8502.31.00. Foreign exports are based on HS 8502.31.

U.S. imports of wind-powered generating sets during 2012–20 were primarily from Europe, where the large EU-based OEMs that supply the U.S. market have nacelle production facilities (figure 6).[42] Spain was not a major exporter to the United States during 2012–13, but was subsequently the largest U.S. supplier.[43] The rise in exports to the U.S. from Spain reflects the closure of U.S. plants by Spanish OEMs Acciona and Gamesa and the recovery of their U.S. sales following the market downturn in 2013. Nordex (following its merger with Acciona) and the merged Siemens Gamesa continue to export to the United States from their plants in Spain. While Siemens Gamesa has a U.S. nacelle manufacturing plant, the firm also continues to rely on foreign production to meet a portion of U.S. demand. Nordex also imports nacelles from its plant in Germany, which accounts for a large share of the resurgence in German

[40] Based on data compiled by USITC staff.
[41] Green, "Siemens Gamesa Lands," September 2, 2020; Green, "Hutchinson Plant Lands," December 16, 2020; EIA, Form EIA-860 (accessed July 2, 2021); Green, "New Nacelle," January 21, 2018.
[42] In addition to the factors discussed here, the pattern of imports in 2020 may have been influenced by COVID-19 related plant closures, component shortages that impacted production, and logistical challenges. Also, imports from Brazil will not be covered in this discussion. While Brazil is a major wind turbine manufacturer, it was not possible to determine whether Brazil's exports to the United States were primarily nacelles or other components of wind-powered generating sets. IHS Markit, Global Trade Atlas database (accessed June 24, 2021); Brown and Wang, *Checking the Pulse*, April 28, 2020, 2–7; Vestas, "Q1 2020 Vestas Wind," May 5, 2020.
[43] IHS Markit, Global Trade Atlas database (accessed June 24, 2021).

imports in 2020.[44] U.S. imports from Europe in 2020 were primarily nacelles larger than 3 MW, including many nacelles larger than 4 MW. U.S. nacelles that are imported from Europe, therefore, are significantly larger, on average, than nacelles produced domestically.[45]

Figure 6 U.S. imports of wind-powered generating sets (based on mirror export data), 2012–20



Source: IHS Markit, Global Trade Atlas database (accessed June and December 2021).
Note: Based on foreign export data in HS 8502.31.

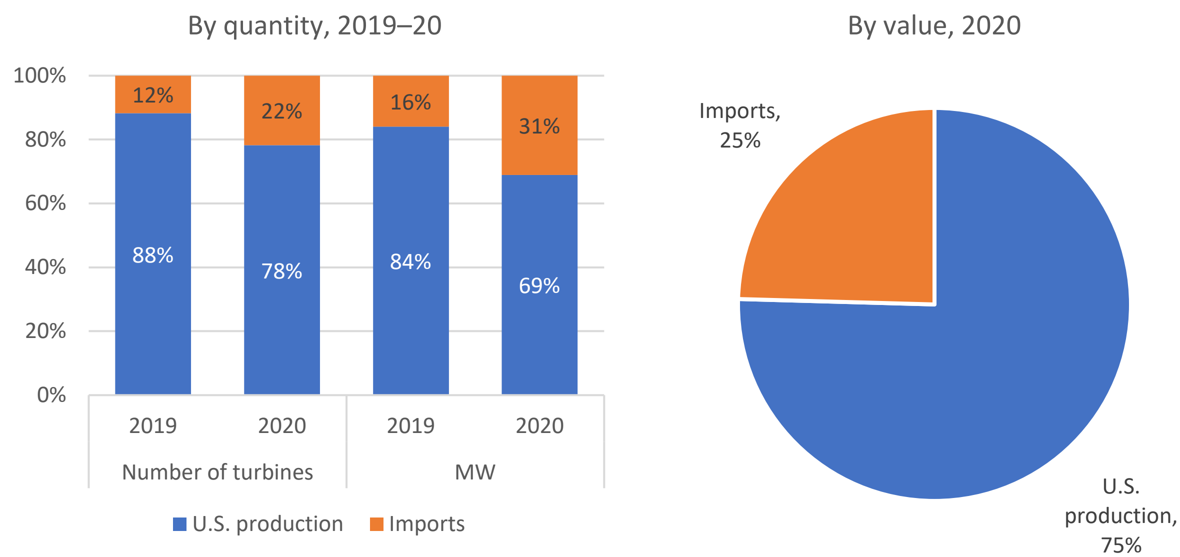
China and India were also significant sources of U.S. nacelle imports in 2020. China supplied the U.S. market at varying levels during 2012–20, with imports reflecting U.S. sales by China-headquartered Goldwind and European OEMs supplementing U.S. production with imports. Identified U.S. imports from China included a range of turbine sizes (2.1 MW to 4.5 MW) in 2020, but on average were 4.3 MW—significantly larger than the 2.75 MW average turbine installed in the U.S. market in 2020.[46] India emerged as a major source of imports in 2020, reflecting recent investments by European OEMs to expand manufacturing in India for export markets. Identified U.S. imports from India ranged 2.2 MW to 3.5 MW. The average size was 2.5 MW, smaller than the average U.S. turbine installed in 2020.[47]

[44] Green, “Siemens Gamesa Lands,” September 2, 2020; Green, “Hutchinson Plant Lands,” December 16, 2020; IHS Markit, Global Trade Atlas database (accessed June–July 2021); EIA, Form EIA-860 (accessed July 2, 2021); Trade Data Services, Import Genius database (accessed June–July 2021).
[45] Onshore wind turbines installed in Europe in 2020 were, on average, 20 percent larger than turbines installed in the United States. Trade Data Services, Import Genius database (accessed June–July 2021); Wiser et al., *Land-Based Wind Market Report*, August 2021; Wind Europe, *Wind Energy in Europe*, February 2021, 9.
[46] USITC DataWeb/Census (accessed June 24, 2021); IHS Markit, Global Trade Atlas database (accessed June 24, 2021); Trade Data Services, Import Genius database (accessed June–July 2021); Wiser et al., *Land-Based Wind Market Report*, August 2021.
[47] Upadhyay, “Foreign Firms,” July 30, 2019; Nordex, “Q1 2017 Nordex,” May 11, 2017; USITC DataWeb/Census (accessed June 24, 2021); IHS Markit, Global Trade Atlas database (accessed June 24, 2021); Trade Data Services, Import Genius database (accessed June–July 2021); Wiser et al., *Land-Based Wind Market Report*, August 2021.

Share of the Market Accounted for by Domestic Production and Imports

U.S. production supplies a majority of the domestic market, though the share of the market accounted for by imports substantially increased in 2020 (figure 7). Imports supplied an estimated 22 percent of the market by number of nacelles in 2020 and 31 percent of the market on a MW basis.[48] The smaller share accounted for by domestic production on a megawatt basis reflects the fact that imports are, on average, larger than domestically produced nacelles.[49] Imports supplied an estimated 25 percent of the market on a value basis.[50]

Figure 7 Estimated share of apparent U.S. consumption accounted for by domestic nacelle production and nacelle imports, by volume and value



Source: USITC staff estimates.
Notes: Estimated nacelle apparent consumption was $3.9 billion in 2020. See figure 3 for information on the volume of the domestic market. The U.S. import values used are based on the landed duty-paid value of imports. The share of the market, by value, is only calculated in 2020, when the new statistical reporting number was added to the HTS that includes nacelles imported separately from blades.

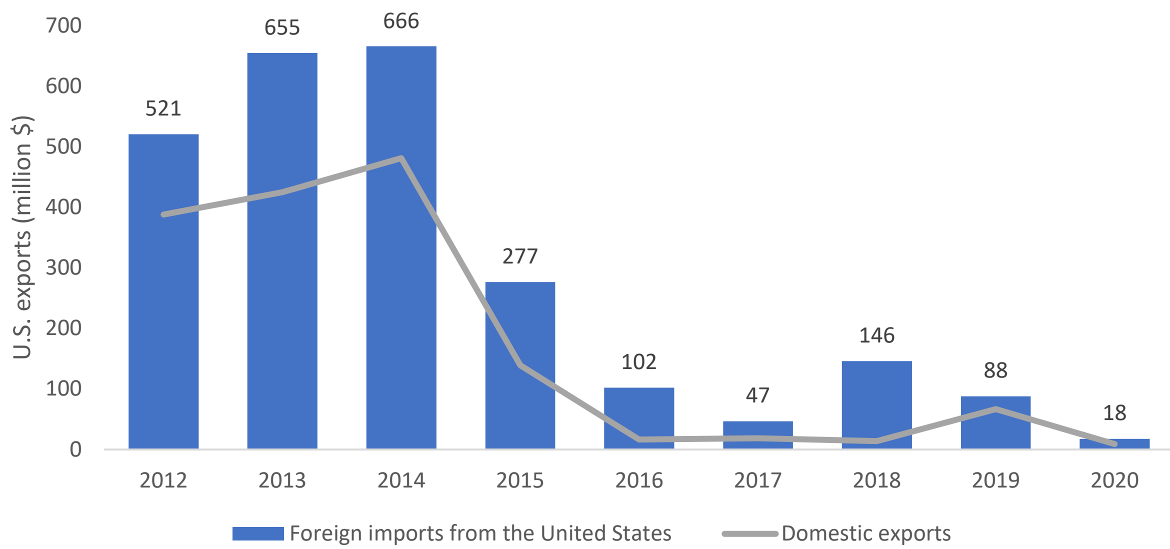
U.S. Exports

The closure of U.S. nacelle plants had a significant impact on U.S. nacelle exports, which peaked in 2014 and then significantly declined (figure 8).[51] Many European OEMs established U.S. nacelle plants with the intention of serving both the U.S. and nearby markets in Canada and Latin America, and some of the

[48] USITC staff estimates.
[49] ACP, *ACP Market Report: Fourth Quarter 2020*, 2021, 21; Trade Data Services, Import Genius database (accessed June–July 2021).
[50] USITC staff estimates.
[51] The leading export destinations during 2012–20, as measured by mirror import data, were Canada and Brazil. USITC DataWeb/Census (accessed June and December 2021); IHS Markit, Global Trade Atlas database (accessed June 24, 2021).

plants that closed were significant exporters.[52] Other factors that contributed to the decline in exports were lower prices, higher capacity utilization at the remaining domestic plants, local content requirements, and both Western OEMs and Chinese OEMs significantly increasing exports from China to these markets.[53]

Figure 8 U.S. exports of wind-powered generating sets, 2012–20



Source: USITC DataWeb/Census (accessed June and December 2021); IHS Markit, Global Trade Atlas database (accessed June 24, 2021).
Notes: These data are for HS 8502.31, wind-powered generating sets, and may include other items traded with the nacelles such as the blades. U.S. export data are domestic exports.

Conclusion

The U.S. wind turbine nacelle manufacturing industry contracted starting in mid-2012, with more than ten nacelle plants closing during 2012–20. U.S. production capacity, in terms of number of turbines, in 2020 was more than 5 percent lower than in 2012, but—due to the larger turbine sizes now produced domestically—production capacity in MW has recovered to more than 10 percent above 2012 levels. The contraction of the industry has, however, led to a reliance on imports during periods of strong demand or when firms with no U.S. production generate significant orders. Further, there is little available capacity to supply export markets and U.S. exports have sharply dropped from their 2014 peak.

The closure of U.S. nacelle plants, combined with other factors that impacted the industry such as cost pressures and turbine modularization, have also had a significant impact on the domestic supply chain for nacelle components. The evolution of the supply chain for components used in domestic nacelle manufacturing is intended to be the subject of additional research.

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[52] David, "Decline in U.S. Turbine Exports," December 2019, 1–2; Brantley, "Wind Energy Manufacturer," June 28, 2018; David and Fravel, "U.S. Wind Turbine Export Opportunities," July 2012, 7, 20, 26, 42, 38.
[53] David, "Decline in U.S. Turbine Exports," December 2019, 1–2; BloombergNEF, *2H 2020 Wind Turbine Price Index*, July 3, 2020; Vestas, *Annual Report*, 2013–21; David, "China Emerges," March 2021, 1–2; Trade Data Services, Import Genius database (accessed various dates).

Appendix A: Data Tables for Figures

Table A.1 Timeline from turbine order to wind project commercial operation, in months

Measure	Time from order to shipment/arrival at U.S. port	Time from shipment/arrival at U.S. port to start of wind project operation
Average	10.3	9.6
Range	4 to 16	4 to 17

Source: The order to shipment timeline is based on 11 U.S. projects with start of commercial operation dates from 2016 to 2021, while the shipment to start of commercial operation timeline is based on 27 projects.
Notes: Corresponds to figure 2. Where a small share of turbines for a project were ordered earlier to meet deadlines for the receipt of tax credits and the bulk of turbines were ordered later, the order date use here is based on when the majority of turbines were ordered.

Table A.2 Apparent U.S. consumption, wind turbines, 2012–20, volume in gigawatts

Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020
Volume	9.1	3.1	6.4	8.2	9.3	9.4	9.1	12.9	13.7

Source: USITC staff estimate of the volume of apparent consumption.
Note: Corresponds to figure 3.

Table A.3 Wind turbine prices, 2012–20, million $/MW

Year	Vestas global turbine price by order date	Average U.S. wind project construction cost
2012	1.31	
2013	1.29	1.90
2014	1.18	1.75
2015	1.02	1.66
2016	1.00	1.63
2017	0.90	1.65
2018	0.88	1.38
2019	0.86	1.39
2020	0.84	

Source: EIA, "Construction Cost Data for Electric Generators Installed," 2016–21; Vestas, *Annual Report*, 2013–21.
Note: Corresponds to figure 3.

Table A.4 U.S. wind turbine OEM market shares, 2012–20, by installations in MW and share of installations in percent

Company	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020
GE	MW	5,215	773	3,235	3,475	3,434	1,952	2,496	4,492	8,777
Vestas	MW	2,057	7	385	2,762	3,732	2,090	3,249	2,602	5,803
Gamesa	MW	933	0	208	0	726	0	0	0	0
Siemens	MW	3,060	45	1,039	1,384	873	0	0	0	0
Siemens Gamesa	MW	0	0	0	0	0	1,417	414	1,591	1,680
Acciona	MW	195	0	0	465	0	0	0	0	0
Nordex (pre-merger)	MW	273		90	138		0	0	0	0
Nordex (post-merger)	MW	0	0	0	0	6	583	548	617	451
Goldwind	MW	155	5	0	8	17	8	174	26	202
Senvion	MW	726	25	0	0	0	0	0	0	0
Mitsubishi	MW	252	0	0	0	0	0	0	0	0
Suzlon	MW	187	0	0	2	0	0	0	0	0
DeWind	MW	140	0	0	0	0	0	0	0	0
Other	MW	112	11	0	21	0	0	0	0	0
Total	MW	13,303	864	4,957	8,253	8,787	6,050	6,881	9,328	16,913
GE	Share	39	89	65	42	39	32	36	48	52
Vestas	Share	15	1	8	33	42	35	47	28	34
Gamesa	Share	7	0	4	0	8	0	0	0	0
Siemens	Share	23	5	21	17	10	0	0	0	0
Siemens Gamesa	Share	0	0	0	0	0	23	6	17	10
Acciona	Share	1	0	0	6	0	0	0	0	0
Nordex (pre-merger)	Share	2	0	2	2	0	0	0	0	0
Nordex (post-merger)	Share	0	0	0	0	0	10	8	7	3
Goldwind	Share	1	1	0	0	0	0	3	0	1
Senvion	Share	5	3	0	0	0	0	0	0	0
Mitsubishi	Share	2	0	0	0	0	0	0	0	0
Suzlon	Share	1	0	0	0	0	0	0	0	0
DeWind	Share	1	0	0	0	0	0	0	0	0
Other	Share	1	1	0	0	0	0	0	0	0
Total	Share	100	100	100	100	100	100	100	100	100

Sources: EIA, Form EIA-860 (accessed July 2, 2021); Goldwind, "China - Xinjiang Goldwind to Acquire," February 2, 2008.
Notes: Corresponds to figure 4. Vensys installations are included under Goldwind, which has been the majority owner since 2008.

Table A.5 U.S. imports of wind powered generating sets, 2012–20, in million dollars

Year	Foreign exports to the United States	U.S. imports
2012	802	962
2013	37	14
2014	244	184
2015	366	226
2016	347	123
2017	559	209
2018	443	194
2019	402	112
2020	1,224	865

Source: USITC DataWeb/Census (accessed June and December 2021); IHS Markit, Global Trade Atlas database (accessed June and December 2021).
Notes: Corresponds to figure 5. U.S. import data are general imports for HS 8502.31, wind-powered generating sets, and for 2020 also include HTS 8503.00.9570, parts of wind-powered generating sets classified in subheading HTS 8502.31.00. Foreign exports are based on HS 8502.31.

Table A.6 U.S. imports of wind-powered generating sets (based on mirror export data), 2012–20, value in million dollars and share in percent

Country	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020
Spain	Value	20	2	112	115	210	281	296	219	319
Denmark	Value	225	23	84	149	64	159	52	97	107
Germany	Value	75	4	35	67	16	22	10	26	313
Italy	Value	213	0	0	0	0	0	0	0	0
China	Value	182	2	1	29	18	92	65	5	140
Brazil	Value	0	0	1	1	1	1	1	23	196
India	Value	2	0	2	0	0	0	5	16	145
Other	Value	85	6	10	4	37	3	15	16	4
Total	Value	802	37	244	366	347	559	443	402	1,224
Spain	Share	2	5	46	31	61	50	67	55	26
Denmark	Share	28	63	34	41	19	28	12	24	9
Germany	Share	9	10	14	18	5	4	2	6	26
Italy	Share	27	0	0	0	0	0	0	0	0
China	Share	23	6	0	8	5	17	15	1	11
Brazil	Share	0	0	0	0	0	0	0	6	16
India	Share	0	1	1	0	0	0	1	4	12
Other	Share	11	16	4	1	11	1	3	4	0
Total	Share	100	100	100	100	100	100	100	100	100

Source: IHS Markit, Global Trade Atlas database (accessed June and December 2021).
Notes: Corresponds to figure 6. Based on foreign export data in HS 8502.31.

Table A.7 Estimated share of apparent U.S. consumption accounted for by domestic nacelle production and nacelle imports, by volume and value, in percent

Production/imports	Measure	2019	2020
U.S. production	Share of number of turbines	88	78
U.S. imports	Share of number of turbines	12	22
Total	Share of number of turbines	100	100
U.S. production	Share of MW	84	69
U.S. imports	Share of MW	16	31
Total	Share of MW	100	100
U.S. production	Share of value	Not estimated	75
U.S. imports	Share of value	Not estimated	25
Total	Share of value	Not estimated	100

Source: USITC staff estimates.
Notes: Corresponds to figure 7. Estimated nacelle apparent consumption was $3.9 billion in 2020. See figure 3 for information on the volume of the domestic market. The U.S. import values used are based on the landed duty-paid value of imports. The share of the market, by value, is only calculated in 2020, when the new statistical reporting number was added to the HTS that includes nacelles imported separately from blades.

Table A.8 U.S. exports of wind-powered generating sets, 2012–20, in million dollars

Year	Foreign imports from the United States	Domestic exports
2012	521	388
2013	655	425
2014	666	481
2015	277	139
2016	102	17
2017	47	19
2018	146	14
2019	88	67
2020	18	9

Source: USITC DataWeb/Census (accessed June and December 2021); IHS Markit, Global Trade Atlas database (accessed June 24, 2021).
Notes: Corresponds to figure 8. These data are for HS 8502.31, wind-powered generating sets, and may include other items traded with the nacelles such as the blades. U.S. export data are domestic exports.

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