2018 Wind Technologies Market Report: Summary

Ryan Wiser & Mark Bolinger, Lawrence Berkeley National Laboratory

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Purpose, Scope, and Data:

- Publicly available annual report summarizing key trends in the U.S. wind power market, with a focus on 2018
- Scope focuses on land-based wind turbines over 100 kW
- Separate DOE-funded reports on distributed and offshore wind
- Data sources include EIA, FERC, SEC, AWEA, etc. (see full report)

Report Authors:

- Primary authors: Ryan Wiser and Mark Bolinger, Berkeley Lab
- Contributions from others at Berkeley Lab, Exeter Associates, National Renewable Energy Laboratory

Funded by: U.S. DOE Wind Energy Technologies Office

Available at: http://energy.gov/windreport
Report Contents

• Installation trends
• Industry trends
• Technology trends
• Performance trends
• Cost trends
• Wind power price trends
• Policy and market drivers
• Future outlook
Key Findings

- Wind capacity additions continued at a robust pace in 2018, with significant additional new builds anticipated in near-term in part due to PTC
- Wind has been a significant source of new electric generation capacity additions in the U.S. in recent years
- Supply chain is diverse and multifaceted, with strong domestic content for nacelle assembly, towers, and blades
- Turbine scaling is significantly boosting wind project performance, while the installed cost of wind projects has declined
- Wind power sales prices and levelized cost of energy are at all-time lows, enabling economic competitiveness (with the PTC) despite low gas prices
- Growth beyond current PTC cycle remains uncertain: could be blunted by declining federal tax support, expectations for low natural gas prices and solar costs, and modest electricity demand growth
Installation Trends
Wind Power Additions Continued at a Robust Pace in 2018, with 7,588 MW of New Capacity, Bringing the Total to 96,433 MW

- $11 billion invested in wind power project additions in 2018
- Over 80% of new 2018 capacity located in Interior region
- Partial repowering trend: 1,312 MW of existing wind plants retrofitted in 2018
Wind Power Represented 21% of Electric-Generating Capacity Additions in 2018, Behind Solar and Natural Gas

Over the last decade, wind has comprised 28% of total capacity additions nationwide, and a much higher proportion in some regions of the country.
Globally, the U.S. Ranked 2nd in Annual Wind Power Capacity Additions in 2018, and in Cumulative Wind Power Capacity

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>China</td>
<td>23,000</td>
<td>211,392</td>
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<tr>
<td>United States</td>
<td>7,588</td>
<td>96,433</td>
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<tr>
<td>Germany</td>
<td>3,371</td>
<td>59,313</td>
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<tr>
<td>India</td>
<td>2,191</td>
<td>35,129</td>
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<td>Brazil</td>
<td>1,939</td>
<td>53,531</td>
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<td>United Kingdom</td>
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<td>20,964</td>
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<td>1,565</td>
<td>15,309</td>
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<td>Mexico</td>
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<td>14,707</td>
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<td>Sweden</td>
<td>720</td>
<td>12,816</td>
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<td>Canada</td>
<td>566</td>
<td>9,959</td>
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<tr>
<td>Rest of World</td>
<td>7,545</td>
<td>91,518</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>51,315</strong></td>
<td><strong>591,069</strong></td>
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</table>

- U.S. remains a distant second to China in annual and cumulative capacity
- Global wind additions in 2018 were below the 53,500 MW added in 2017 and the record level of 63,800 MW added in 2015
The United States is Lagging Other Countries in Wind Energy as a Percentage of Electricity Consumption

Wind Generation as a Proportion of Total Electricity Generation in 2018

Denmark, Ireland, Portugal, Germany, Spain, U.K., EU, Sweden, Romania, Austria, Netherlands, Brazil, Turkey, Belgium, Poland, United States, Australia, France, Canada, Italy, Mexico, India, China

Note: Figure only includes the countries with the most installed wind power capacity at the end of 2018
The Geographic Spread of Wind Power Projects Across the United States Is Broad, with the Exception of the Southeast

Note: Numbers within states represent cumulative installed wind capacity and, in brackets, annual additions in 2018.
Texas Installed the Most Wind Power Capacity in 2018; 14 States Exceed 10% Wind Energy as Percentage of In-State Generation

<table>
<thead>
<tr>
<th>State</th>
<th>Installed Capacity (MW)</th>
<th>2018 Wind Generation as a Percentage of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas</td>
<td>2,359</td>
<td>24,895</td>
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<tr>
<td>Iowa</td>
<td>1,120</td>
<td>8,421</td>
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<tr>
<td>Colorado</td>
<td>600</td>
<td>8,072</td>
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<tr>
<td>Oklahoma</td>
<td>576</td>
<td>5,840</td>
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<tr>
<td>Nebraska</td>
<td>558</td>
<td>5,653</td>
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<tr>
<td>Kansas</td>
<td>543</td>
<td>4,861</td>
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<tr>
<td>Illinois</td>
<td>529</td>
<td>3,778</td>
</tr>
<tr>
<td>California</td>
<td>330</td>
<td>3,703</td>
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<tr>
<td>Indiana</td>
<td>200</td>
<td>3,213</td>
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<tr>
<td>New York</td>
<td>158</td>
<td>3,155</td>
</tr>
<tr>
<td>North Dakota</td>
<td>148</td>
<td>3,076</td>
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<tr>
<td>Ohio</td>
<td>113</td>
<td>2,317</td>
</tr>
<tr>
<td>Montana</td>
<td>105</td>
<td>1,987</td>
</tr>
<tr>
<td>Minnesota</td>
<td>90</td>
<td>1,972</td>
</tr>
<tr>
<td>New Mexico</td>
<td>51</td>
<td>1,904</td>
</tr>
<tr>
<td>Michigan</td>
<td>44</td>
<td>1,732</td>
</tr>
<tr>
<td>South Dakota</td>
<td>41</td>
<td>1,488</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>21</td>
<td>1,369</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>2</td>
<td>1,019</td>
</tr>
<tr>
<td>Alaska</td>
<td>1</td>
<td>973</td>
</tr>
<tr>
<td>Rest of U.S.</td>
<td>0</td>
<td>7,005</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>7,588</strong></td>
<td><strong>96,433</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State</th>
<th>In-State Generation</th>
<th>In-State Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kansas</td>
<td>36.4%</td>
<td>North Dakota 53.5%</td>
</tr>
<tr>
<td>Iowa</td>
<td>33.7%</td>
<td>Kansas 47.1%</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>31.7%</td>
<td>Oklahoma 43.4%</td>
</tr>
<tr>
<td>North Dakota</td>
<td>25.8%</td>
<td>Iowa 43.2%</td>
</tr>
<tr>
<td>South Dakota</td>
<td>24.4%</td>
<td>New Mexico 25.6%</td>
</tr>
<tr>
<td>Maine</td>
<td>21.0%</td>
<td>Wyoming 24.9%</td>
</tr>
<tr>
<td>New Mexico</td>
<td>18.7%</td>
<td>South Dakota 21.7%</td>
</tr>
<tr>
<td>Minnesota</td>
<td>17.9%</td>
<td>Maine 21.0%</td>
</tr>
<tr>
<td>Colorado</td>
<td>17.3%</td>
<td>Texas 18.6%</td>
</tr>
<tr>
<td>Texas</td>
<td>15.9%</td>
<td>Colorado 17.5%</td>
</tr>
<tr>
<td>Vermont</td>
<td>15.8%</td>
<td>Minnesota 17.0%</td>
</tr>
<tr>
<td>Idaho</td>
<td>14.7%</td>
<td>Nebraska 16.9%</td>
</tr>
<tr>
<td>Nebraska</td>
<td>14.1%</td>
<td>Oregon 15.0%</td>
</tr>
<tr>
<td>Oregon</td>
<td>11.0%</td>
<td>Montana 14.9%</td>
</tr>
<tr>
<td>Wyoming</td>
<td>9.0%</td>
<td>Idaho 10.8%</td>
</tr>
<tr>
<td>Montana</td>
<td>7.9%</td>
<td>Illinois 9.1%</td>
</tr>
<tr>
<td>Illinois</td>
<td>6.8%</td>
<td>Washington 8.2%</td>
</tr>
<tr>
<td>California</td>
<td>6.5%</td>
<td>Vermont 7.1%</td>
</tr>
<tr>
<td>Washington</td>
<td>6.3%</td>
<td>Hawaii 5.8%</td>
</tr>
<tr>
<td>Indiana</td>
<td>5.0%</td>
<td>Indiana 5.6%</td>
</tr>
<tr>
<td>Rest of U.S.</td>
<td>1.1%</td>
<td>Rest of U.S. 1.5%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>6.5%</strong></td>
<td><strong>TOTAL 7.3%</strong></td>
</tr>
</tbody>
</table>

**2018 Wind Penetration by ISO:** SPP: 23.9%; ERCOT: 18.6%; MISO: 7.3%; CAISO: 7.3%; ISO-NE: 2.8%; PJM: 2.7%; NYISO: 2.5%
A Record Level of Wind Power Capacity Entered Transmission Interconnection Queues in 2018; Solar and Storage Also Growing

- Hybrid plants with storage represent 20% of solar in queue in 2018, but just 2% of wind in queue is proposed to include storage
- AWEA reports 39 GW of capacity under construction or in advanced development at end of 1Q2019

Note: Not all of this capacity will be built.
Larger Amounts of Wind Power Capacity Planned for Southwest Power Pool, Mountain & Midwest Regions; Major Growth in PJM

Note: Not all of this capacity will be built
Industry Trends
• Globally, Vestas, Goldwind, Siemens Gamesa, and GE were the top suppliers of wind turbines in 2018
• Chinese suppliers occupied 8 of the top 15 spots in the global ranking, based primarily on sales within their domestic market
The Domestic Supply Chain for Wind Equipment is Diverse

- Some manufacturers increased the size of their U.S. workforce in 2018 and/or expanded existing facilities, but expectations for significant additional supply-chain expansion have become less optimistic.
- Continued near-term expected growth, but strong competitive pressures and expected reduced demand as PTC is phased out.
- Two new manufacturing facilities announced with expected online dates in 2019; four facilities stopped serving industry.
- Many manufacturers remain; three of the largest OEMs serving U.S. market all have at least one facility.
- Wind-related jobs reached a new all-time high, at 114,000.
Domestic Manufacturing Capability for Nacelle Assembly, Towers, & Blades Reasonably Well Balanced Against Historical Demand
Turbine OEM Profitability Has Generally Declined in Most Recent Years, Following Several Years of Recovery Since Low in 2012

OEM Profit Margins

Solid line with circle markers = EBITDA
Dashed line with square markers = EBIT

Gamesa/SGRE 2008-2018
Vestas 2008-2018
Nordex 2008-2018
Goldwind 2008-2018
U.S. Is a Net Importer: Imports of Wind Equipment into the United States Are Sizable; Exports Remained Low in 2018

Notes: Figure only includes tracked trade categories; misses other wind-related imports; see full report for the assumptions used to generate this figure

- Exports of wind-powered generating sets = $13 million in 2018
- No ability to track other wind-specific exports, but total ‘tower and lattice mast’ exports equaled $29 million
Tracked Wind Equipment Imports in 2018: 44% from Asia, 35% from Europe, 20% from the Americas

Note: Tracked wind-specific equipment includes: wind-powered generating sets, towers, hubs and blades, wind generators and parts
Source Markets for Imports Have Varied Over Time, and By Type of Wind Equipment

- Majority of imports of wind-powered generating sets historically from home countries of OEMs, dominated by Europe
- Decline in imports of towers from Asia over time, in part due to tariffs, but rebound in 2018
- Majority of imports of blades & hubs from Asia (especially) China
- Mexico becoming a dominant supplier of generators and parts
Domestic Manufacturing Content is Strong for Nacelle Assembly, Towers, and Blades, but not Equipment Internal to the Nacelle

Domestic Content for 2018 Turbine Installations in the United States:

<table>
<thead>
<tr>
<th></th>
<th>Towers</th>
<th>Blades &amp; Hubs</th>
<th>Nacelle Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>75–90%</td>
<td>50–70%</td>
<td>&gt; 85%</td>
</tr>
</tbody>
</table>

- Imports occur in untracked trade categories, including many nacelle internals; nacelle internals generally have domestic content of < 20%
The Project Finance Environment Remained Strong in 2018

- Sponsors raised $6-7 billion of tax equity in 2018
- Tax reform legislation contained a number of provisions with implications for wind finance, but in general those implications have been modest
Independent Power Producers Own the Majority of Wind Assets Built in 2018

2018 Capacity by Owner Category

- **IPP:** 6,073 MW (80.0%)
- **IOU:** 1,509 MW (19.9%)
- **Other:** 4 MW (0.1%)
- **POU:** 2 MW (0.0%)
Long-Term Sales to Utilities Remained Most Common Off-Take, but Direct Retail Sales and Merchant Were Significant

- 24% of added wind capacity in 2018 are from direct retail sales; 49% of total wind capacity contracted through PPAs in 2018 involve non-utility buyers.
Technology Trends
Turbine Capacity, Rotor Diameter, and Hub Height Have All Increased Significantly Over the Long Term, and in 2018

Average Nameplate Capacity (MW)

Average Rotor Diameter (right scale)

Average Hub Height (right scale)

Commercial Operation Year


Average Nameplate Capacity (left scale)
Growth in Rotor Diameter and Nameplate Capacity Have Outpaced Growth in Hub Height over the Last Two Decades
Turbines Originally Designed for Lower Wind Speed Sites Dominate the Market

Specific Power:
- **Specific power**: turbine nameplate capacity divided by swept rotor area; lower specific power leads to higher capacity factors, as shown later.
- **IEC Class 1/2/3** represent turbines designed originally for high, medium, and low wind speed, respectively.
Wind Turbines Continued to be Deployed in Somewhat Lower Wind-Speed Sites in 2018
Low Specific Power Turbines Are Deployed in Low & High Wind Speeds; Taller Towers More Common in Great Lakes & Northeast
Wind Power Projects Planned for the Near Future Are Poised to Continue the Trend of Ever-Taller Turbines

Histogram of cumulative FAA applications through May 2019 greater than 500 feet

Total turbine heights proposed in FAA applications, over time

Median Tip Height (with 25th and 75th percentiles)
- % of Applications >500 ft (right axis)
A Large Number of Projects Continued to Employ Multiple Turbine Configurations from a Single Turbine Supplier

Note: Turbine configuration = unique combination of hub height, rotor diameter, and/or capacities
Through 2018, 23 Projects Have Been Partially Repowered, most of which Feature Larger Rotors and Lower Specific Power
Performance Trends
Capacity Factors Have Increased Significantly Over Time, by Online Date (i.e., Commercial Online Date, COD)

<table>
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<tr>
<th>Year</th>
<th>Capacity Factor</th>
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<tbody>
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<td>'98-99</td>
<td>0.9</td>
</tr>
<tr>
<td>'00-01</td>
<td>0.9</td>
</tr>
<tr>
<td>'02-03</td>
<td>1.7</td>
</tr>
<tr>
<td>'04-05</td>
<td>2.3</td>
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<tr>
<td>2006</td>
<td>1.6</td>
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<td>2007</td>
<td>5.2</td>
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<td>2008</td>
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<td>2009</td>
<td>9.7</td>
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<td>2010</td>
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<td>2015</td>
<td>8.3</td>
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<tr>
<td>2016</td>
<td>8.2</td>
</tr>
<tr>
<td>2017</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Graph showing capacity factor changes over time.
Fleet-Wide Average Capacity Factors Have Gradually Increased, Reaching 35% for the First Time in 2018
The Interior Region Features the Highest Capacity Factors, in Part Reflecting the Strength of the Wind Resource

Sample includes projects built from 2014-2017

Projects built from 1998-2017

Only projects built from 2014-2017
Time Trends Explained by Competing Influences of Lower Specific Power, Higher Hub Heights, Varying Quality Wind Resource Sites

- Weighted-Average Capacity Factor in 2018 (left scale)
- Index of the Inverse of Built Specific Power (right scale)
- Index of Built Turbine Hub Height (right scale)
- Index of Built Wind Resource Quality at 80m (right scale)

Commercial Operation Date

Index of Capacity Factor Influences (1998-99=100)
Controlling for Wind Resource Quality and Specific Power Demonstrates Impact of Turbine Evolution

- Turbine design changes are driving capacity factors higher for projects located in given wind resource regimes
Controlling for Wind Resource Quality and Commercial Operation Date Also Illustrates Impact of Turbine Evolution

Average Capacity Factor in 2018

Commercial Operation Date

- Highest Wind Resource Quality
- Higher Wind Resource Quality
- Medium Wind Resource Quality
- Lower Wind Resource Quality
• Graphic includes 9 projects totaling 2.2 GW that partially repowered their turbines in 2017, and shows the increase in capacity factor in 2018 (relative to the 4-year average from 2013-2016) as a function of the reduction in average specific power.
Wind Curtailment Varies by Region; Was Highest in MISO in 2017, but Highest-Ever in ERCOT in 2009

- In areas where curtailment has been particularly problematic in the past—principally in Texas—steps taken to address the issue have born fruit.
Yearly Variations in Average Wind Speed Also Impact Project Performance, but 2018 Was a Reasonably Normal Wind Year
Change in Performance as Projects Age Also Impacts Overall Trends; Performance Degradation Shown After Year 10

Sample includes projects with COD from 1998 to 2017

Indexed Capacity Factor (Year 2=100%)

- Median (with 10th/90th percentile error bars)
- Capacity-Weighted Average

Years post-COD: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Sample GW: 79.5 79.8 71.5 63.3 58.1 57.1 43.5 37.7 32.4 23.2 14.6 8.8 8.0 5.1 4.2 2.9 1.7 0.8 0.8
Cost Trends
Wind Turbine Prices Remained Well Below the Levels Seen a Decade Ago

- Recent turbine orders in the range of $700-900/kW
Lower Turbine Prices Have Driven Reductions in Total Installed Project Costs

- 2018 projects had average cost of $1,470/kW, down ~$1000/kW since 2009-2010
- Limited sample of under-construction projects suggest somewhat lower costs in 2019
Economies of Scale Are Apparent, Especially when Moving from Small- to Medium-Sized Projects

![Diagram showing the relationship between project size and installed project cost. The graph compares capacity-weighted average project cost to individual project cost across different project sizes and turbine sizes. The data indicates that as project sizes increase, the installed project cost decreases, reflecting economies of scale.](image-url)
Regional Differences in Average Wind Power Project Costs Are Apparent, but Sample Size Is Limited

- **Capacity-Weighted Average Project Cost**
- **Individual Project Cost**
- **Capacity-Weighted Average Cost, Total U.S.**

Sample includes projects built in 2018.

- **Interior**: 4,559 MW
- **Great Lakes**: 881 MW
- **West**: 135 MW
- **Northeast**: 101 MW

Installed Project Cost (2018 $/kW)

- Range from 0 to 5,000 $/kW
Most Projects—and All of the Low-Cost Projects—are Located in the Interior; Other Regions Have Higher Costs

Note: Only includes 2018 projects
O&M Costs Vary By Project Age and Commercial Operations Date

Note: Sample is limited; few projects in sample have complete records of O&M costs from 2000-18; O&M costs reported here DO NOT include all operating costs

• Capacity-weighted average 2000-2018 O&M costs for projects built in the 1980s equal $72/kW-year, dropping to $60/kW-year for projects built in the 1990s, to $29/kW-year for projects built in the 2000s and since 2010
O&M Costs Are Lower for More-Recent Projects, and Increase with Age for the Older Projects

Note: Sample size is limited

- O&M reported in figure does not include all operating costs: recent work by Berkeley Lab suggests all-in operating costs for the most recent wind projects in the United States of ~$40/kW-yr
Wind Power Price Trends
Sample of Wind Power Sales Prices

• Berkeley Lab collects data on historical wind power sales prices, and long-term power purchase agreement (PPA) prices
• PPA sample includes 448 contracts totaling 42,018 MW from projects built from 1998 to the present, or planned for installation in 2019 or beyond
• Prices reflect the bundled price of electricity and RECs as sold by the project owner under a PPA
  – Dataset excludes merchant plants, projects that sell renewable energy certificates (RECs) separately, and direct retail sales
  – Prices reflect receipt of state and federal incentives (e.g., the PTC or Treasury grant), as well as various local policy and market influences; as a result, prices do not reflect wind energy generation costs
Wind PPA Prices Are at Historical Lows

Levelized PPA Price (2018 $/MWh)

- Interior (27.7 GW)
- West (7.4 GW)
- Great Lakes (4.8 GW)
- Northeast (1.6 GW)
- Southeast (0.5 GW)

PPA Execution Date

- 50 MW
- 300 MW
A Smoother Look at the Time Trend Shows a Steep Decline in Pricing Since 2009; Prices Below $20/MWh in Interior Region
Recent Wind PPAs Are Priced in the Mid-Teens in Some Cases

Levelized PPA Price (2018 $/MWh)

- Interior (11.6 GW)
- West (0.5 GW)
- Great Lakes (1.7 GW)
- Northeast (0.6 GW)
- Southeast (0.2 GW)

Black line shows nationwide average

PPA Execution Date

2014 2015 2016 2017 2018
Despite Recent Low PPA Prices, Wind Faces Competition from Solar and Natural Gas

Levelized PPA and Gas Price (2018 $/MWh)

- Levelized 20-year EIA gas price projections (converted at 7.5 MMBtu/MWh)
- Utility-Scale Solar (252 PPAs totaling 15.7 GW)
- Utility-Scale Wind (310 PPAs totaling 32.4 GW)
Recent Wind Prices Are Competitive with the Expected Future Cost of Burning Fuel in Natural Gas Plants

- Price comparisons shown are far from perfect—see full report for caveats
The Economic Competitiveness of Wind Power Is Affected by Its Grid-System Value (Energy & Capacity) in Wholesale Markets

• Wholesale market value considers hourly local wholesale energy price and hourly wind output, along with capacity value where available
• Wholesale market value has declined over last decade, but increased in last couple years
• Recent wind PPAs are comparable to grid-system market value, with a number of recent PPAs coming in at a discount relative to wholesale market value estimates

- Market value estimates in 2018 at project level span a wide range, from a low of $7/MWh to a high of $72/MWh, with a median value of $22/MWh
Renewable Energy Certificate (REC) Prices in RPS Compliance Markets Remained Low in 2018

- REC prices vary by: market type (compliance vs. voluntary); geographic region; specific design of state RPS policies

![Graphs showing REC prices in different markets from 2010 to 2019]
The Levelized Cost of Wind Energy Is at an All-Time Low: Nationwide Average of $38/MWh for Projects Built in 2018

- Estimates reflect variations in installed cost, capacity factors, operational costs, cost of financing, and project life; include accelerated depreciation but exclude PTC
Policy and Market Drivers
The Federal Production Tax Credit (PTC) Remains One of the Core Motivators for Wind Power Deployment

- 5-year extension of PTC in 2015, plus guidance allowing 4 years for project completion after the start of construction
- PTC phase-out, with progressive reduction in the value of the credit for projects starting construction after 2016
- PTC phases out in 20%-per-year increments for projects starting construction in 2017 (80% PTC value), 2018 (60%), 2019 (40%)

<table>
<thead>
<tr>
<th>Legislation</th>
<th>Date Enacted</th>
<th>Start of PTC Window</th>
<th>End of PTC Window</th>
<th>Effective PTC Planning Window (considering lapses and early extensions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ticket to Work and Work Incentives Improvement Act of 1999</td>
<td>12/19/1999</td>
<td>7/1/1999</td>
<td>12/31/2001</td>
<td>24 months</td>
</tr>
<tr>
<td>American Taxpayer Relief Act of 2012</td>
<td>1/2/2013</td>
<td>1/1/2013</td>
<td>Start construction by 12/31/2013</td>
<td>12 months (in which to start construction)</td>
</tr>
<tr>
<td>Tax Increase Prevention Act of 2014</td>
<td>12/19/2014</td>
<td>1/1/2014</td>
<td>Start construction by 12/31/2014</td>
<td>2 weeks (in which to start construction)</td>
</tr>
<tr>
<td>Consolidated Appropriations Act of 2016</td>
<td>12/18/2015</td>
<td>1/1/2015</td>
<td>Start construction by 12/31/2016</td>
<td>12 months to start construction and receive 100% PTC value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Start construction by 12/31/2017</td>
<td>24 months to start construction and receive 80% PTC value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Start construction by 12/31/2018</td>
<td>36 months to start construction and receive 60% PTC value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Start construction by 12/31/2019</td>
<td>48 months to start construction and receive 40% PTC value</td>
</tr>
</tbody>
</table>
State Policies Help Direct the Location and Amount of Wind Development, but Wind Growth is Outpacing State Targets

- 29 states and D.C. have mandatory RPS programs, which can support ~5 GW/yr of renewable energy additions on average through 2030 (less for wind specifically)
System Operators Are Implementing Methods to Accommodate Increased Penetrations of Wind

Integrating wind energy into power systems is manageable, but not free of additional costs.

Transmission Barriers Remain

Notes: Because methods vary and a consistent set of operational impacts has not been included in each study, results from the different analyses of integration costs are not fully comparable.
Future Outlook
Sizable Wind Additions Anticipated for 2019–2020 Given Federal Tax Incentives; Downturn and Greater Uncertainty Beyond 2020

Historical Wind Power Capacity Additions

Forecasts (bar = average)

Analyst projections
Future Outlook, Beyond Current PTC Cycle, is Uncertain

Current Low Prices for Wind, Future Technological Advancement, and Direct Retail Sales May Support Higher Growth in Future, but Headwinds Include:

• Phase-out of federal tax incentives
• Continued low natural gas and wholesale electricity prices
• Potential decline in market value as wind penetration increases
• Modest electricity demand growth
• Limited near-term demand from state RPS policies
• Limited transmission infrastructure in some areas
• Growing competition from solar in some regions
Conclusions

• Wind capacity additions continued at a robust pace in 2018, with significant additional new builds anticipated in near-term in part due to PTC

• Wind has been a significant source of new electric generation capacity additions in the U.S. in recent years

• Supply chain is diverse and multifaceted, with strong domestic content for nacelle assembly, towers, and blades

• Turbine scaling is significantly boosting wind project performance, while the installed cost of wind projects has declined

• Wind power sales prices and levelized cost of energy are at all-time lows, enabling economic competitiveness (with the PTC) despite low gas prices

• Growth beyond current PTC cycle remains uncertain: could be blunted by declining federal tax support, expectations for low natural gas prices and solar costs, and modest electricity demand growth
For More Information

See full report for additional findings, a discussion of the sources of data used, etc.:
  – windreport.lbl.gov

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