U.S. Wind Industry Update
WindExchange Webinar
September 2016

Ryan Wiser & Mark Bolinger
Lawrence Berkeley National Laboratory
2015 Wind Technologies Market Report

Purpose, Scope, and Data:

• Publicly available annual report summarizing key trends in the U.S. wind power market, with a focus on 2015
• Scope primarily includes wind turbines over 100 kW in size
• Separate DOE-funded report on distributed wind
• Data sources include AWEA, EIA, FERC, SEC, etc. (see full report)

Report Authors:

• Primary authors: Ryan Wiser and Mark Bolinger, Berkeley Lab
• Contributions from others at Berkeley Lab, Exeter Associates, NREL

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

Available at: http://energy.gov/eere/wind
Report Contents

• Installation trends
• Industry trends
• Technology trends
• Performance trends
• Cost trends
• Wind power price trends
• Policy & market drivers
• Future outlook

Current presentation focuses on subset of this content
Installation Trends: A Quick Summary
Wind Power Additions Surged in 2015, with 8,598 MW of New Capacity Added

- $14.5 billion invested in wind power project additions in 2015
- More than $150 billion invested since beginning of the 1980s
- Cumulative wind capacity up 12%, bringing total to 74 GW
Wind Energy Technologies Office

Wind Power Represented 41% of Electric-Generating Capacity Additions in 2015

Over last decade, wind has comprised 31% of capacity additions nationwide, and a much higher proportion in some regions.
Texas Installed the Most Wind Capacity in 2015; 12 States ≥ 10% Wind Energy

- Texas had almost 3 times as much wind capacity as the next-highest state
- 24 states had > 500 MW of capacity at end of 2015 (17 > 1 GW, 11 > 2 GW)
- IA = 31% of total in-state generation from wind; SD = 26%, KS = 24%; 12 states ≥ 10%

<table>
<thead>
<tr>
<th>Installed Capacity (MW)</th>
<th>Percentage of In-State Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas</td>
<td>3,615</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>1,402</td>
</tr>
<tr>
<td>Kansas</td>
<td>799</td>
</tr>
<tr>
<td>Iowa</td>
<td>524</td>
</tr>
<tr>
<td>Colorado</td>
<td>399</td>
</tr>
<tr>
<td>Illinois</td>
<td>274</td>
</tr>
<tr>
<td>New Mexico</td>
<td>268</td>
</tr>
<tr>
<td>North Dakota</td>
<td>258</td>
</tr>
<tr>
<td>Minnesota</td>
<td>200</td>
</tr>
<tr>
<td>California</td>
<td>194</td>
</tr>
<tr>
<td>South Dakota</td>
<td>175</td>
</tr>
<tr>
<td>Maine</td>
<td>173</td>
</tr>
<tr>
<td>Indiana</td>
<td>150</td>
</tr>
<tr>
<td>Nebraska</td>
<td>80</td>
</tr>
<tr>
<td>Arizona</td>
<td>30</td>
</tr>
<tr>
<td>Maryland</td>
<td>30</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>14</td>
</tr>
<tr>
<td>Ohio</td>
<td>8</td>
</tr>
<tr>
<td>Connecticut</td>
<td>5</td>
</tr>
<tr>
<td>New York</td>
<td>1</td>
</tr>
<tr>
<td>Rest of U.S.</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>8,598</strong></td>
</tr>
</tbody>
</table>

* Based on 2015 wind and total generation by state from EIA’s Electric Power Monthly.
Interconnection Queues Demonstrate that a Substantial Amount of Wind Is Under Consideration

Wind represented 31% of capacity in sampled 34 queues; 2015 = largest amount of wind additions since 2010

But… absolute amount of wind (and coal & nuclear) in queues has declined in recent years whereas natural gas and solar capacity has increased or held steady

Not all of this capacity will be built….

- AWEA reports 15 GW of capacity under construction after 1Q2016
Larger Amounts of Wind Planned for Texas, Midwest, Southwest Power Pool, Northwest, PJM, and Mountain Region

Not all of this capacity will be built....
First Commercial Offshore Turbines To Be Commissioned in 2016 Amid Mixed Market Signals

- 30 MW Block Island project (RI) to be commissioned in 2016
- BOEM has granted multiple leases as of end of 2015; DOE funding 3 pilot deployments (NJ, ME, OH)

Legal and political headwind for high-profile projects:
- Cape Wind (MA) power purchase agreements cancelled by utilities
- Fishermen’s Atlantic City (NJ) rejected twice by state PUC
- Dominion (VA) announced delay; DOE withdrew funding offer

Pressing challenges include cost, lack of PPAs and policy incentives, regulatory complexity

23 proposed offshore projects in various stages of development, totaling > 16 GW of potential capacity
Industry Trends
GE and Vestas Captured 73% of the U.S. Market in 2014

- Recent dominance of the three-largest turbine suppliers in the U.S. market
- Globally, Goldwind and Vestas were the top suppliers, followed by GE
- Chinese suppliers occupied 5 of the top 10 spots in the global ranking, based almost entirely on sales within their domestic market
Manufacturing Supply Chain Continued to Adjust to Swings in Domestic Demand

- Upswing in near- to medium-term expected growth, but strong competitive pressures and possible reduced demand over time as the PTC is phased down
- 3 domestic manufacturing facility closures in 2015; 1 new opening
- Many manufacturers remain: over last decade, manufacturers have localized and expanded U.S. presence; “Big 3” OEMs all have at least one facility
- Wind related jobs increased from 73,000 in 2014 to 88,000 in 2015

Note: map not intended to be exhaustive
Domestic Manufacturing Capability for Nacelle Assembly, Towers, and Blades Is Reasonably Well Balanced Against Near-Term Demand Forecasts

Annual installed wind power capacity
Nacelle assembly manufacturing capacity
Tower manufacturing capacity
Blade manufacturing capacity

Past      Projected
Turbine OEM Profitability Has Generally Rebounded Over the Last Three Years

Solid line with circle markers = EBITDA
Dashed line with square markers = EBIT
Imports of Wind Equipment Are Sizable; Exports Declined in 2015

U.S. is a net importer of wind equipment

Exports of wind-powered generating sets decreased to $149 million in 2015; no ability to track other wind-specific exports, but total tower exports equalled $63 million

• Figure only includes tracked trade categories; misses other wind-related imports
• See full report for the assumptions used to generate this figure
Tracked Wind Equipment Imports in 2015: 40% Asia, 38% Europe, 22% Americas

Note: Tracked wind-specific equipment includes: wind-powered generating sets, towers, hubs and blades, wind generators and parts
Domestic Manufacturing Content Is Strong for Nacelle Assembly, Towers, and Blades, but U.S. Is Highly Reliant on Imports for Equipment Internal to the Nacelle

Imported occur in untracked trade categories, including many nacelle internals; nacelle internals generally have domestic content of < 20%

Overall estimated domestic content: ~40% in 2012 for wind turbine equipment; ~60% if considering total projects costs, including balance-of-plant
Technology Trends
Turbines Have Grown Larger Over Time; Growth in Rotor Diameter Has Outpaced Growth in Nameplate Capacity and Hub Height in Recent Years
Turbines Originally Designed for Lower Wind Speed Sites Have Rapidly Gained Market Share

Specific Power

IEC Class

Specific Power by Selected IEC Class
Turbines Originally Designed for Lower Wind Speeds Now Regularly Used in Lower & Higher Wind Sites; Taller Towers Predominate in Great Lakes and NE

By Region

By Wind Resource Quality

Estimated Wind Resource Quality at 80 Meters
Performance Trends
Sample-Wide Capacity Factors Have Increased, but Impacted by Curtailment and Inter-Year Wind Resource Variability

Note: The wind resource index is compiled from NextEra Energy Resources reports.
Wind Curtailment Has Generally Declined in Recent Years; Higher in MISO

In areas where curtailment has been particularly problematic in the past – principally in Texas – steps taken to address the issue have born fruit.

Except for BPA, data represent both forced & economic curtailment.
Impact of Technology Trends on Capacity Factors Becomes More Apparent When Parsed by Project Vintage

Sample includes 626 projects totaling 63.0 GW
Trends Explained by Competing Influence of Lower Specific Power and Higher Hub Heights vs. Build-Out of Lower Quality Wind Resource Sites through 2012

Reversal of build-out in lower wind speed sites in 2013-2015
Controlling for Wind Resource Quality and Specific Power Demonstrates Impact of Turbine Evolution

Sample includes 601 projects totaling 62.7 GW with a commercial operation date of 1998-2014

Turbine design changes are driving capacity factors higher for projects located in given wind resource regimes.
Regional Variations in Capacity Factors Reflect the Strength of the Wind Resource and Adoption of New Turbine Technology

Sample includes 34 projects built in 2014 and totaling 4,537 MW

- **West**: 2 projects, 346 MW
- **Southeast**: 1 project, 40 MW
- **Great Lakes**: 6 projects, 568 MW
- **Northeast**: 1 project, 16 MW
- **Interior**: 24 projects, 3,566 MW

Note: Very limited sample size for 2014 projects in most regions
Degradation of Project Performance as Projects Age Also Impacts Overall Trends

Sample includes projects with COD from 1998-2014

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

<table>
<thead>
<tr>
<th>Years post-COD:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample GW:</td>
<td>63.6</td>
<td>58.8</td>
<td>57.8</td>
<td>44.1</td>
<td>38.1</td>
<td>33.3</td>
<td>23.7</td>
<td>15.2</td>
<td>9.9</td>
<td>8.0</td>
<td>5.0</td>
<td>4.3</td>
<td>2.8</td>
<td>2.4</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Sample projects:</td>
<td>756</td>
<td>721</td>
<td>709</td>
<td>564</td>
<td>478</td>
<td>418</td>
<td>307</td>
<td>207</td>
<td>165</td>
<td>122</td>
<td>99</td>
<td>86</td>
<td>63</td>
<td>53</td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: See full report for caveats associated with this figure
Cost Trends
Wind Turbine Prices Remained Well Below the Levels Seen Several Years Ago

Recent turbine orders reportedly in the range of $850-1,250/kW
• 2015 projects had an average cost of $1,690/kW, down $640/kW since 2009 and 2010; limited sample of under-construction projects slated for completion in 2016 suggest no material change in costs
Economies of Scale, Especially at Lower End of Project & Turbine Size Range

![Graph showing installed project cost vs. project size and turbine size]
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.**

### Installed Project Cost (2015 $/kW)

- **NY (4 x 275 kW)**
- **CT (2 x 2.85 MW)**
- **KS (1 x 850 kW)**
- **IL (1 x 600 kW)**

### Regions
- **Interior**: 34 projects, 5,299 MW
- **West**: 2 projects, 148 MW
- **Great Lakes**: 4 projects, 158 MW
- **Northeast**: 4 projects, 168 MW
Most 2015 Projects—and All of the Low-Cost Projects—are Located in the Interior; Other Regions Have Higher Costs

Sample includes 2015 projects only (44 projects, 5,772 MW)
Wind Power Price Trends
Long-Term Sales to Utilities Remained the Most Common Off-Take Arrangement, but Direct Retail Sales Gained Ground

- 10% of added wind capacity in 2015 are from direct retail sales; 52% of total wind capacity contracted through PPAs in 2015 involve non-utility buyers
Sample of Wind Power Prices

• Berkeley Lab collects data on historical wind power sales prices, and long-term PPA prices

• PPA sample includes 387 contracts totaling 34,558 MW from projects built from 1998-2015, or planned for installation in 2016 or 2017

• Prices reflect the bundled price of electricity and RECs as sold by the project owner under a power purchase agreement
  – 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 Remain Very Low, Especially in Interior Region

- Interior (22,044 MW, 225 contracts)
- West (7,342 MW, 75 contracts)
- Great Lakes (3,705 MW, 48 contracts)
- Northeast (1,200 MW, 27 contracts)
- Southeast (268 MW, 6 contracts)
A Smoother Look at the Time Trend Shows Steep Decline in Pricing Since 2009; Especially Low Pricing in Interior Region
Relative Competitiveness of Wind Power Challenged in 2015 as a Result of Dropping Wholesale Electric Prices

- Wholesale price range reflects flat block of power across 23 pricing nodes across the U.S. (and Interior)
- Price comparison shown here is far from perfect – see full report for caveats
Recent Wind Prices Are Hard to Beat: Competitive with Expected Future Cost of Burning Fuel in Natural Gas Plants

Price comparison shown here is far from perfect – see full report for caveats
Future Outlook
Sizable Wind Additions Anticipated for 2016-20 Given PTC Extension; Downturn and Uncertainty Beyond 2020

Wind additions through 2020 consistent with deployment trajectory analyzed in DOE’s *Wind Vision* report; not so after 2020
Current Low Prices for Wind, Future Technological Advancement, New EPA Regulations, and Direct Retail Sales May Support Higher Growth in Future, but Headwinds Include…

• Phase-down of federal tax incentives
• Continued low natural gas and wholesale electricity prices
• Modest electricity demand growth
• Limited near-term demand from state RPS policies
• Inadequate transmission infrastructure in some areas
• Growing competition from solar in some regions
For More Information
For More Information...

See full report for additional findings, a discussion of the sources of data used, etc.

- http://energy.gov/eere/wind

To contact the primary authors

- Ryan Wiser, Lawrence Berkeley National Laboratory
  510-486-5474, RHWiser@lbl.gov
- Mark Bolinger, Lawrence Berkeley National Laboratory
  603-795-4937, MABolinger@lbl.gov

Berkeley Lab’s contributions to this report were funded by the Wind Energy Technologies Office, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors are solely responsible for any omissions or errors contained herein.
Want To Know More About the Possible Future Cost of Onshore & Offshore Wind?

Recently published expert survey of 163 of the world’s foremost wind experts

Documentation:
https://emp.lbl.gov/iea-wind-expert-survey

Webinar:
September 27, 11-12 ET:
https://cc.readytalk.com/r/6j3tvw8n8lto&eom