WIND POWER TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

2015 Wind Technologies Market Report: Summary

August 2016

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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:

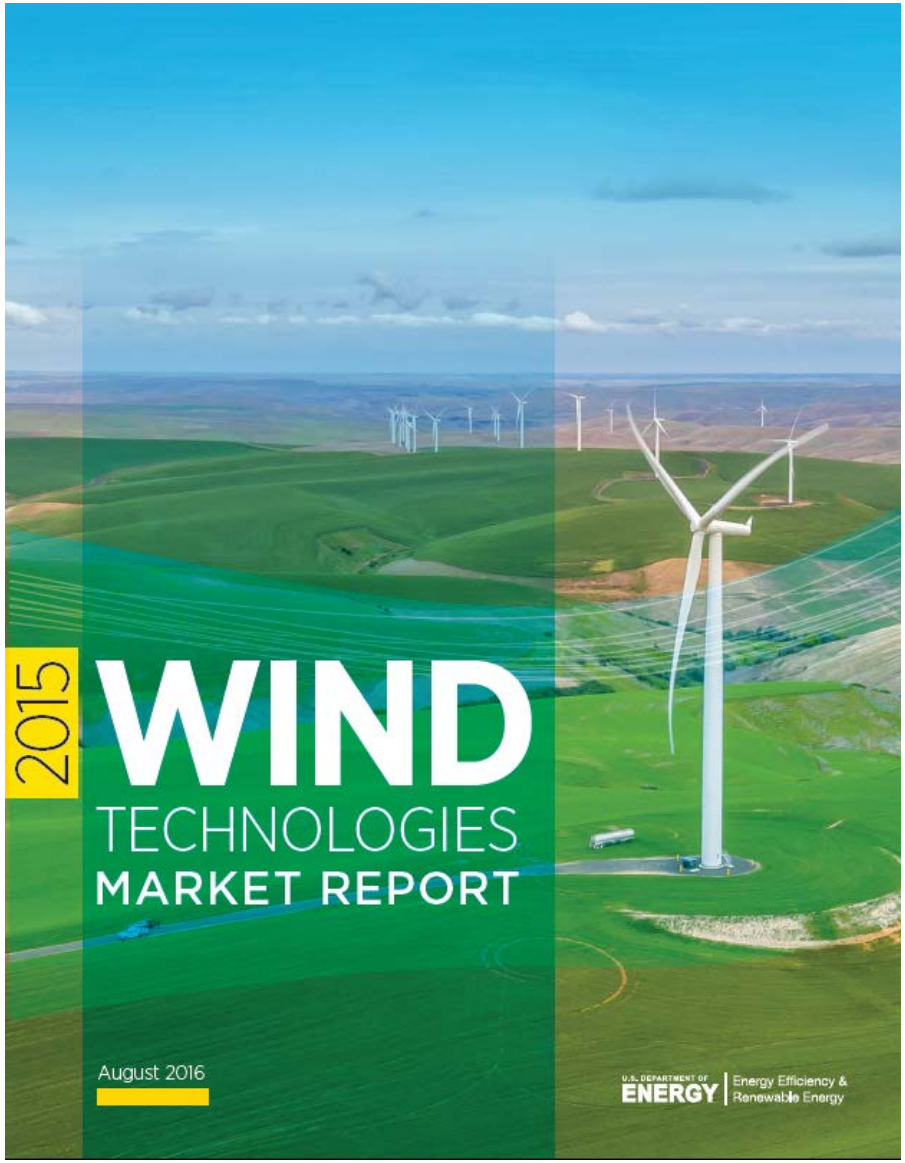
- Primary authors: Ryan Wiser and Mark Bolinger, Berkeley Lab
- Contributions from others at Berkeley Lab, Exeter Associates, NREL

Funded by: U.S. DOE Wind & Water Power 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

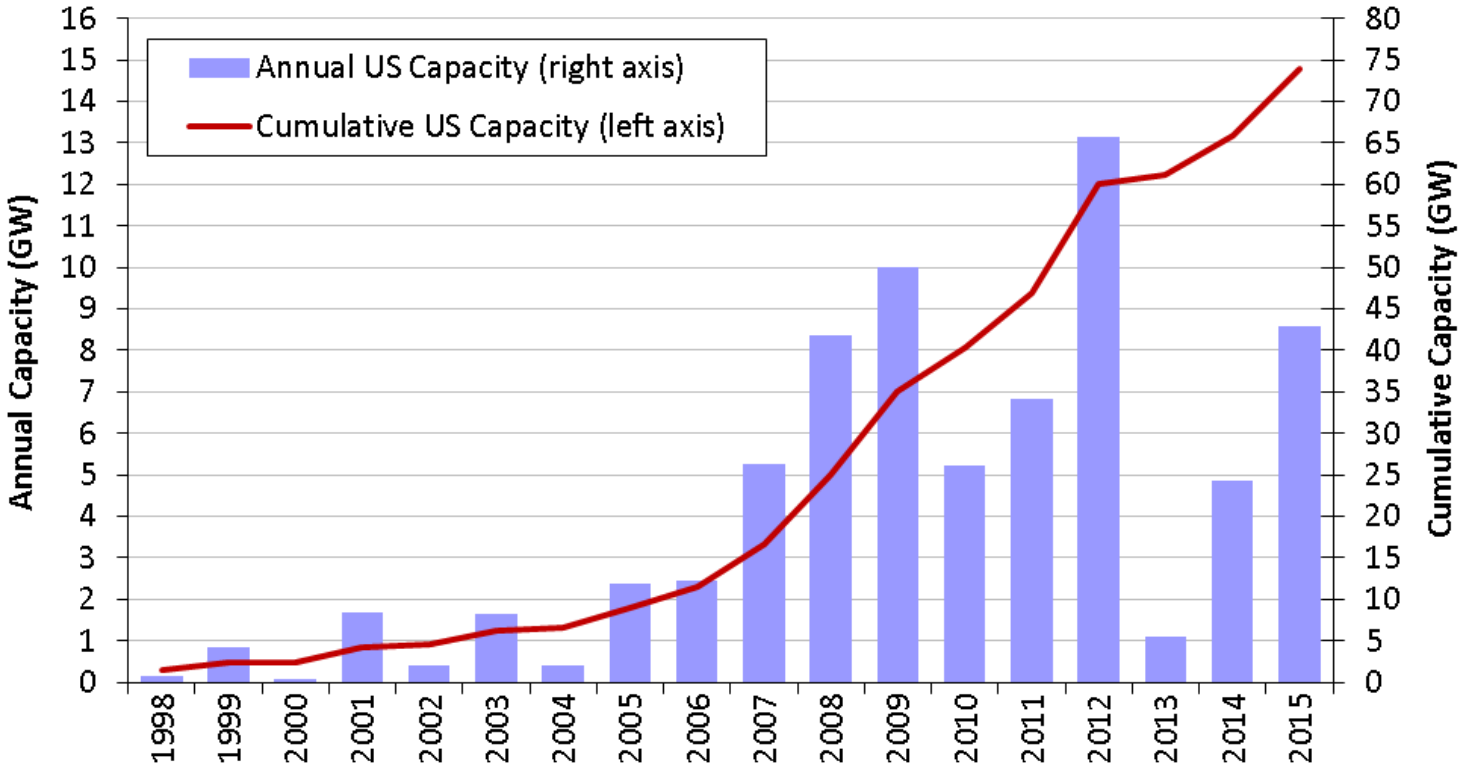


Key Findings

- Annual wind capacity additions surged in 2015, w/ significant additional new builds anticipated over next five years in part due to PTC extension
- Wind has been a significant source of new electric generation capacity additions in the U.S. in recent years
- Supply chain has been under some duress, but domestic manufacturing content for nacelle assembly, blades, and towers is strong
- Turbine scaling is significantly boosting wind project performance, while the installed cost of wind projects has declined
- Wind power sales prices remain near all-time lows, enabling economic competitiveness despite low natural gas prices
- Growth beyond current PTC cycle remains uncertain: could be blunted by declining federal tax support, expectations for low natural gas prices, and modest electricity demand growth

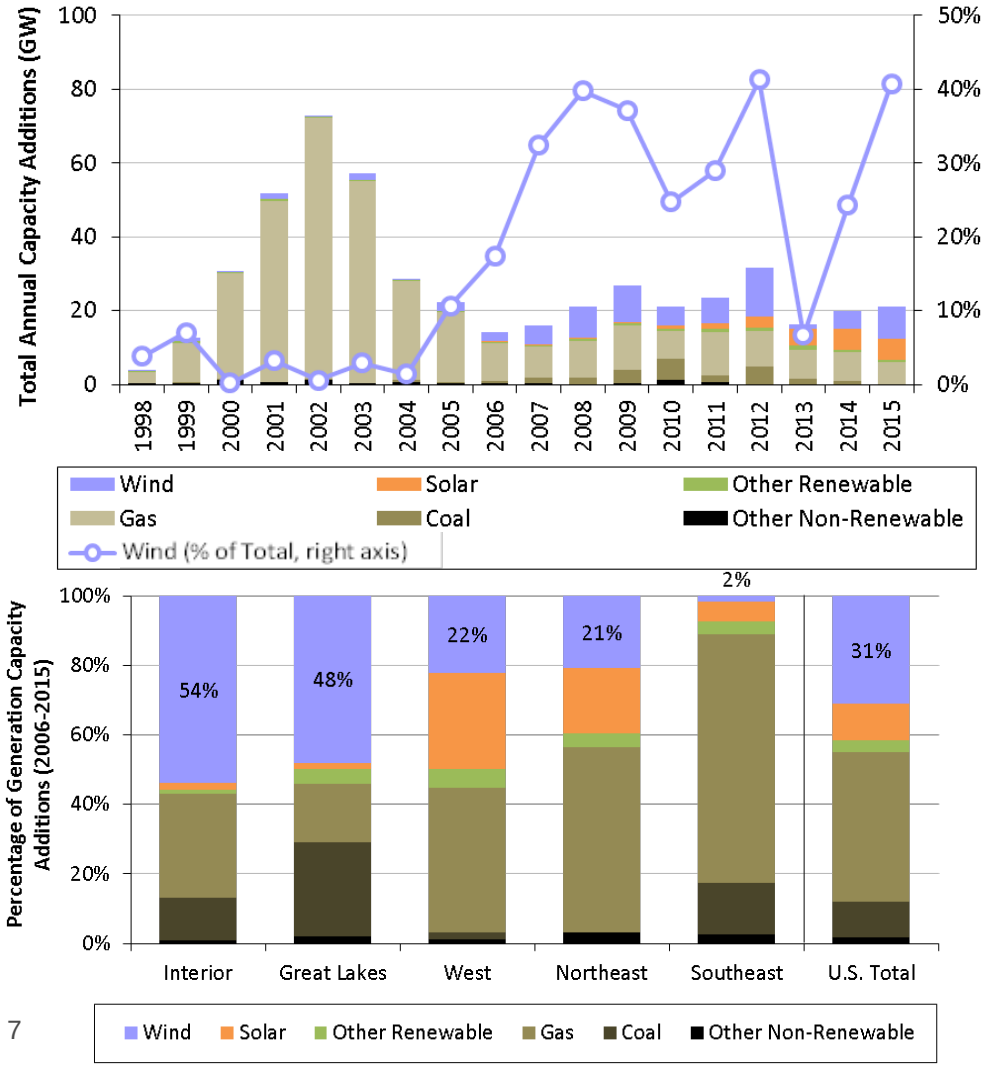
Installation Trends

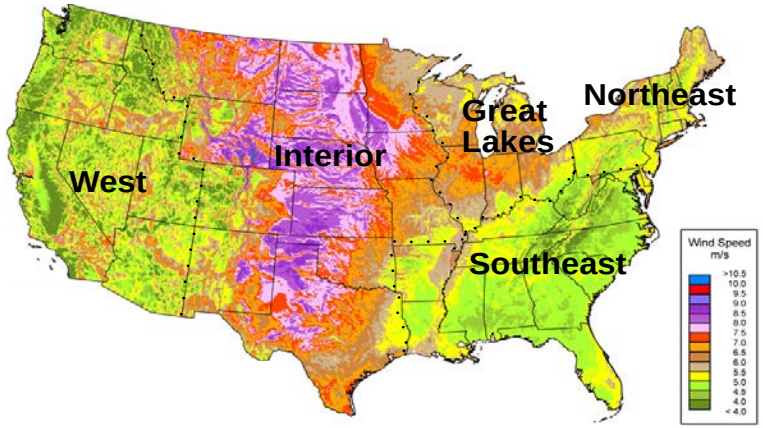
Wind Power Additions Surged in 2015, with 8,598 MW of New Capacity Added



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





Over last decade, wind has comprised 31% of capacity additions nation-wide, and a much higher proportion in some regions

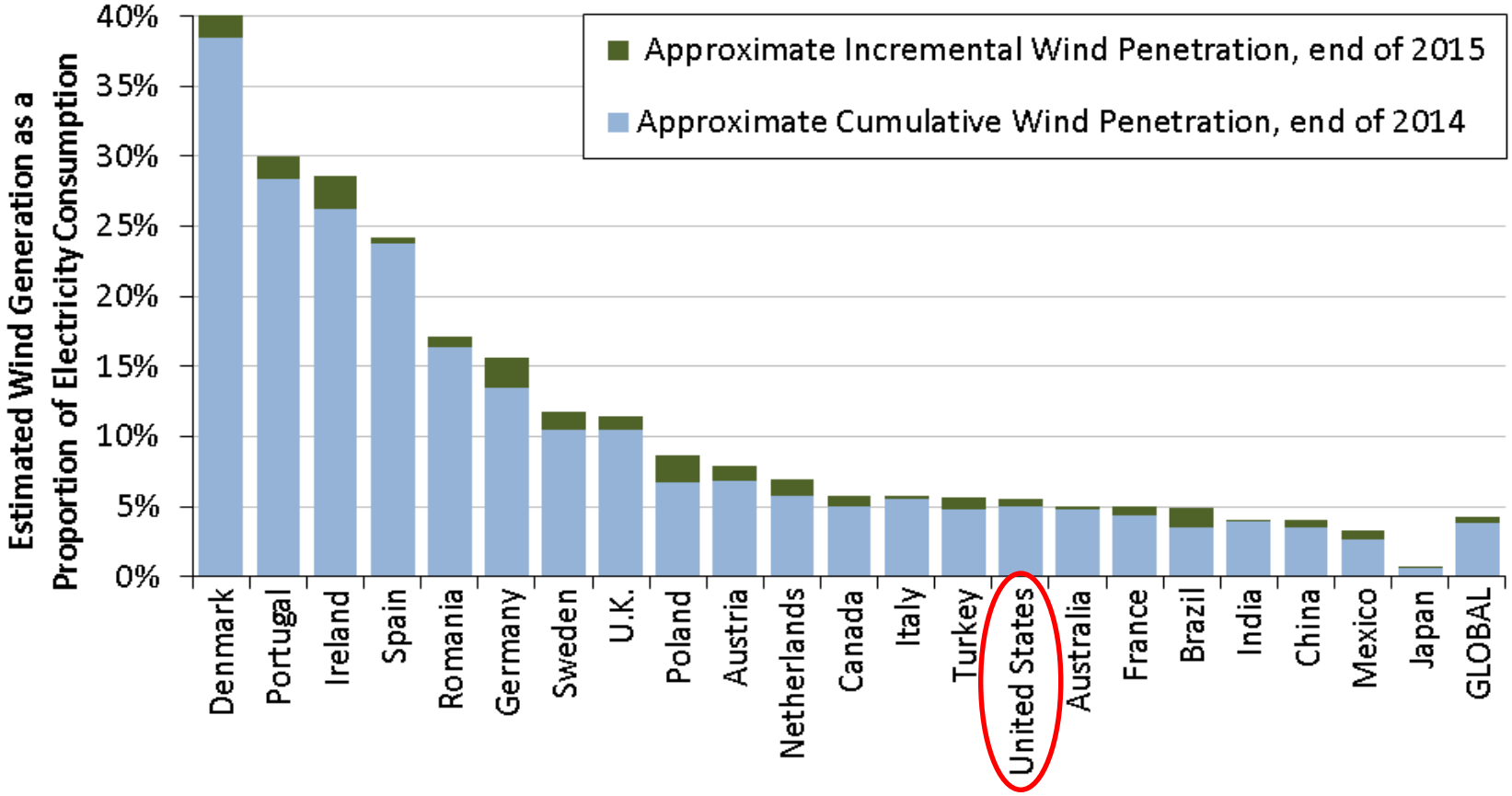
The U.S. Placed 2rd in Annual Wind Power Capacity Additions in 2015

Annual Capacity (2015, MW)		Cumulative Capacity (end of 2015, MW)	
China	30,293	China	145,053
United States	**8,598**	**United States**	**73,992**
Germany	6,013	Germany	44,986
Brazil	2,754	India	25,352
India	2,623	Spain	22,665
Canada	1,506	United Kingdom	13,388
Poland	1,266	Canada	11,190
France	1,073	France	10,243
United Kingdom	975	Brazil	9,346
Turkey	956	Italy	8,851
Rest of World	7,078	*Rest of World*	68,464
TOTAL	**63,135**	**TOTAL**	**433,530**

Source: Navigant; AWEA project database for U.S. capacity

- Global wind additions reached a new high in 2015
- U.S. remains a distant second to China in cumulative capacity
- U.S. led the world in wind energy production in 2015

U.S. Lagging Other Countries in Wind As a Percentage of Electricity Consumption



Note: Figure only includes the countries with the most installed wind power capacity at the end of 2015

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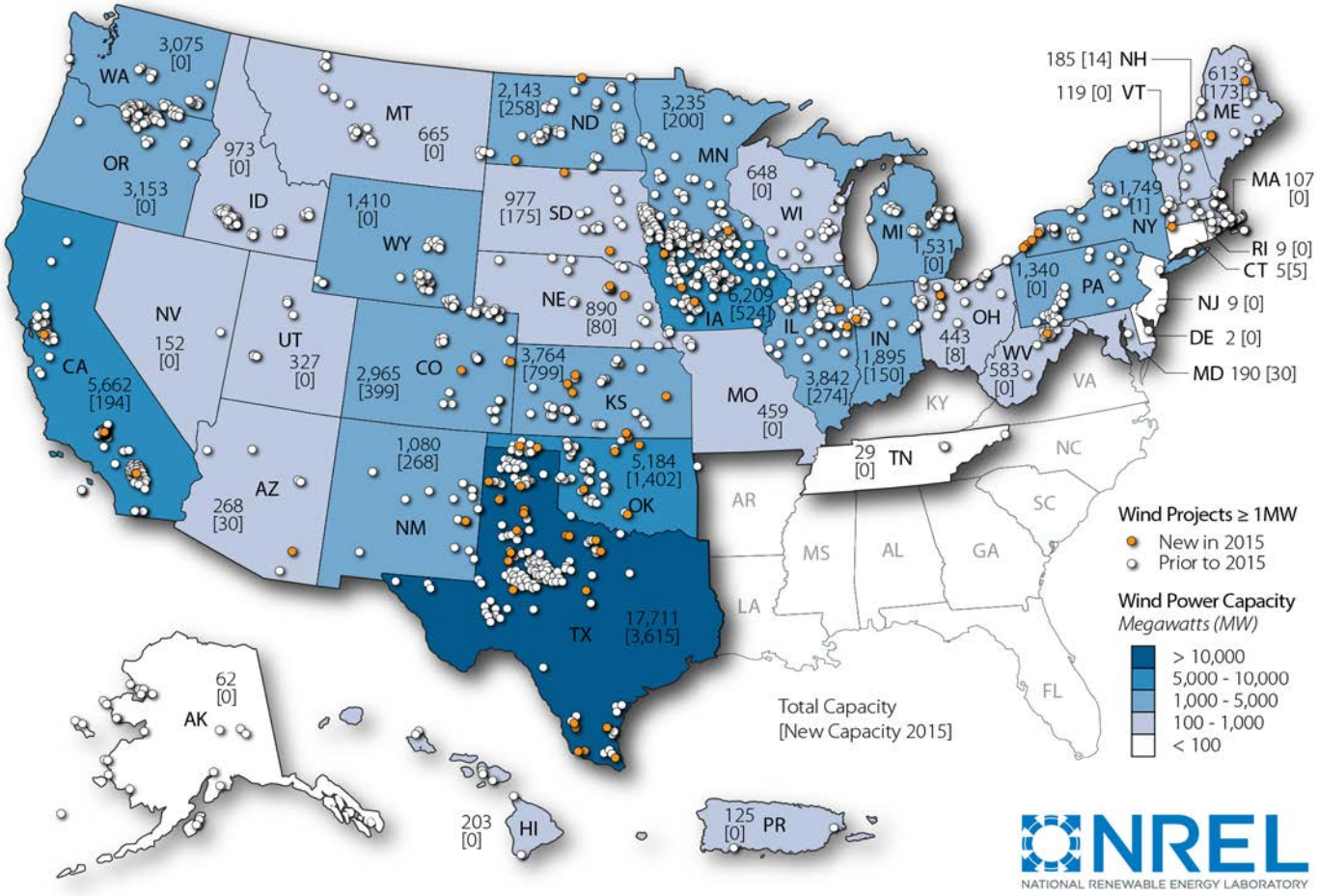
Geographic Spread of Wind Projects in the United States Is Reasonably Broad



Note: Numbers within states represent cumulative installed wind capacity and, in brackets, annual additions in 2015

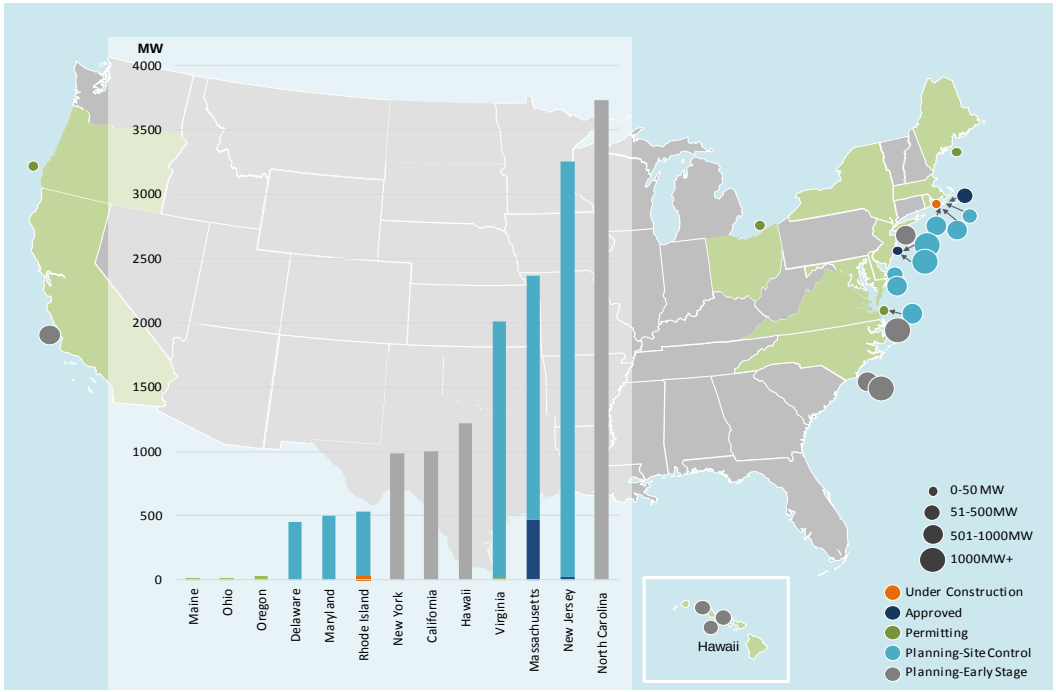
Texas Installed the Most Wind Capacity in 2015; 10 States ≥ 10% Wind Energy

Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2015)		Cumulative (end of 2015)		Actual (2015)*	
Texas	3,615	Texas	17,711	Iowa	31.3%
Oklahoma	1,402	Iowa	6,209	South Dakota	25.5%
Kansas	799	California	5,662	Kansas	23.9%
Iowa	524	Oklahoma	5,184	Oklahoma	18.4%
Colorado	399	Illinois	3,842	North Dakota	17.7%
Illinois	274	Kansas	3,764	Minnesota	17.0%
New Mexico	268	Minnesota	3,235	Idaho	16.2%
North Dakota	258	Oregon	3,153	Vermont	15.4%
Minnesota	200	Washington	3,075	Colorado	14.2%
California	194	Colorado	2,965	Oregon	11.3%
South Dakota	175	North Dakota	2,143	Maine	10.5%
Maine	173	Indiana	1,895	Texas	10.0%
Indiana	150	New York	1,749	Nebraska	8.0%
Nebraska	80	Michigan	1,531	Wyoming	7.7%
Arizona	30	Wyoming	1,410	Montana	6.6%
Maryland	30	Pennsylvania	1,340	Washington	6.5%
New Hampshire	14	New Mexico	1,080	New Mexico	6.3%
Ohio	8	South Dakota	977	California	6.2%
Connecticut	5	Idaho	973	Hawaii	6.1%
New York	1	Nebraska	890	Illinois	5.5%
Rest of U.S.	0	*Rest of U.S.*	5,203	*Rest of U.S.*	1.0%
TOTAL	**8,598**	**TOTAL**	**73,992**	**TOTAL**	**4.7%**

* Based on 2015 wind and total generation by state from EIA's *Electric Power Monthly*.

- 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%; 10 states ≥ 10%)

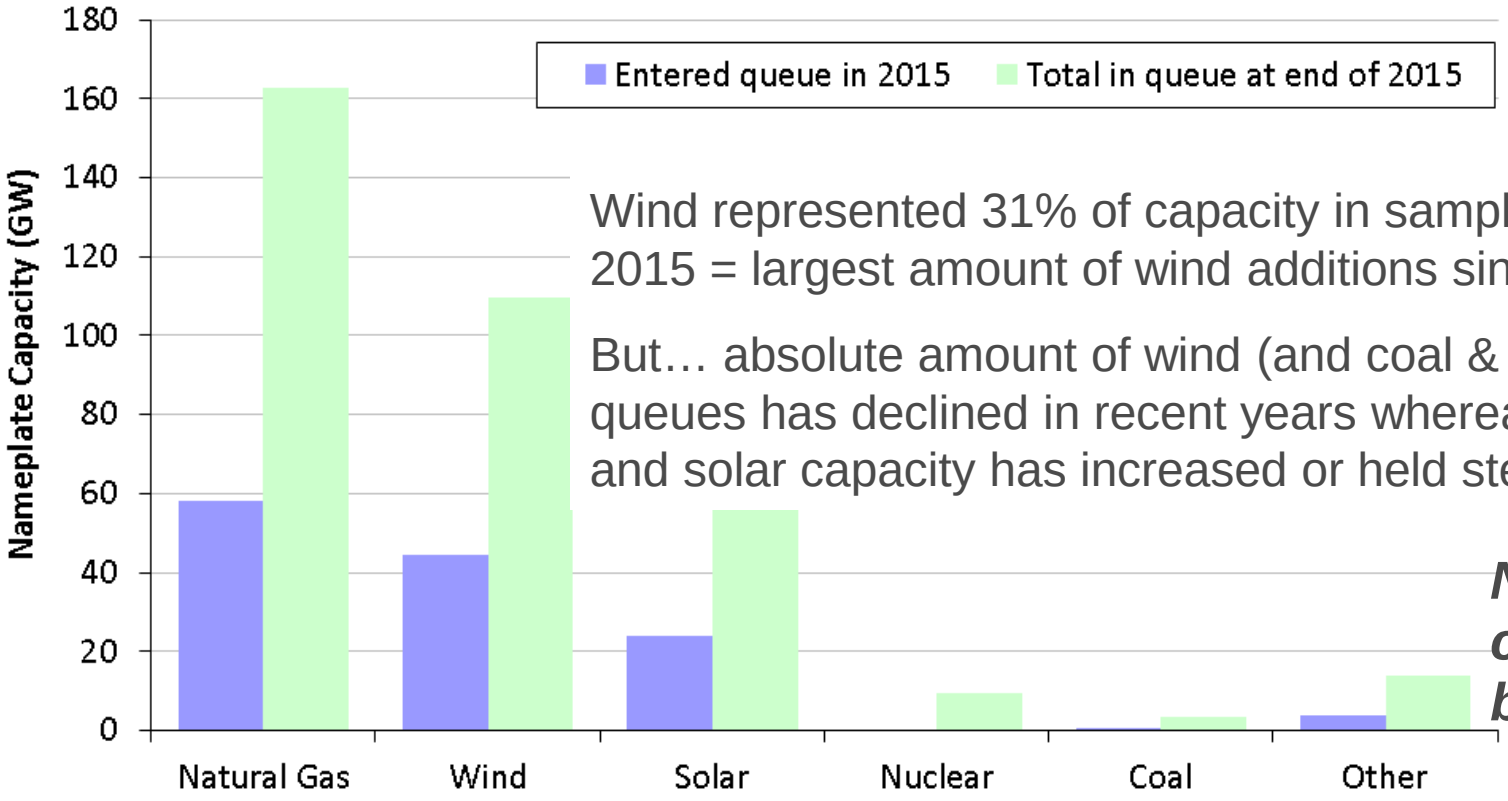
First Commercial Offshore Turbines Expected To Be Commissioned in 2016 Amid Mixed Market Signals



23 proposed offshore projects in various stages of development, totaling > 16 GW of potential capacity

- 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

Interconnection Queues Demonstrate that a Substantial Amount of Wind Is Under Consideration



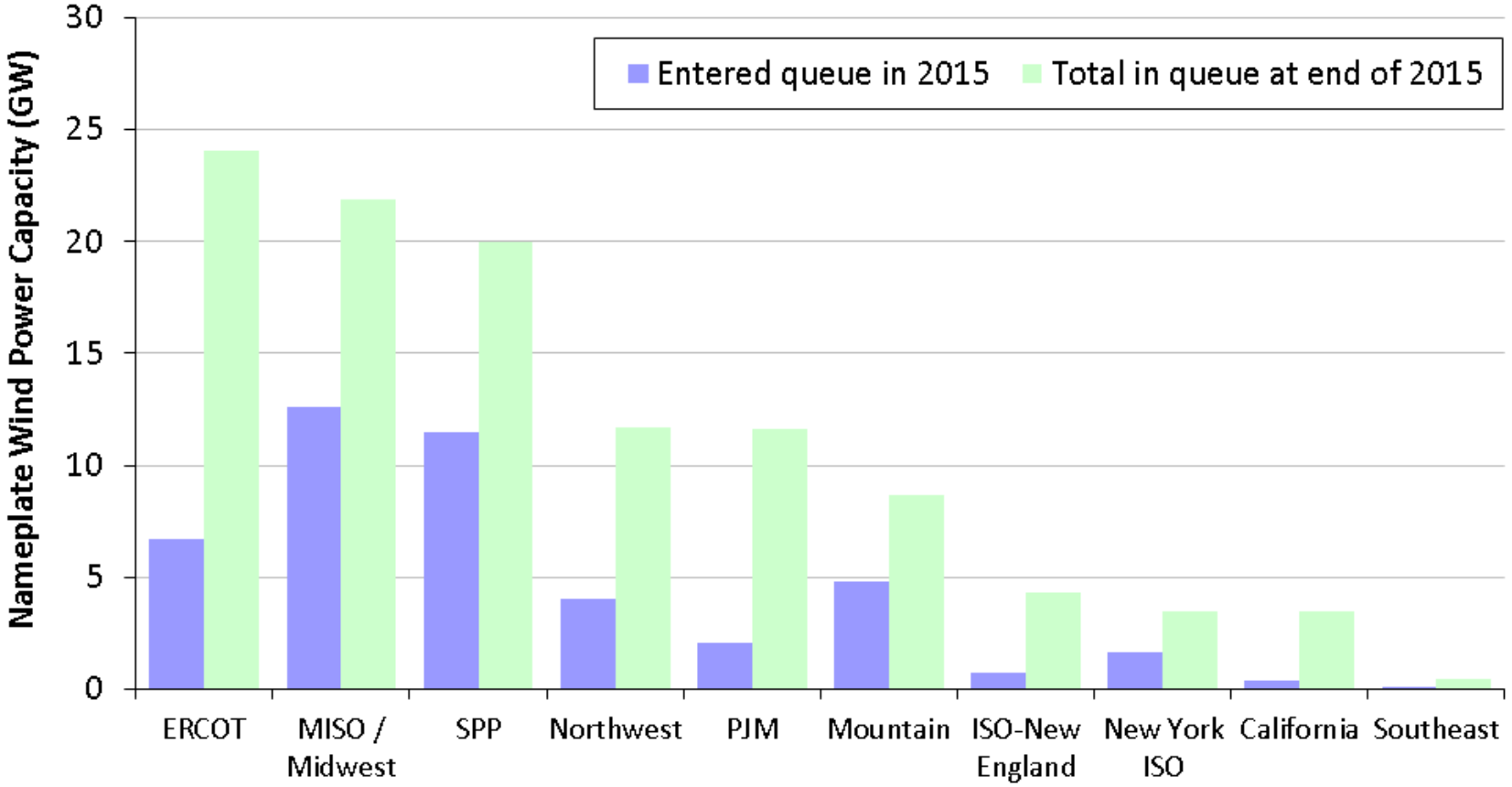
Wind represented 31% of capacity in sampled 34 queues; 2015 = largest amount of wind additions since 2010

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

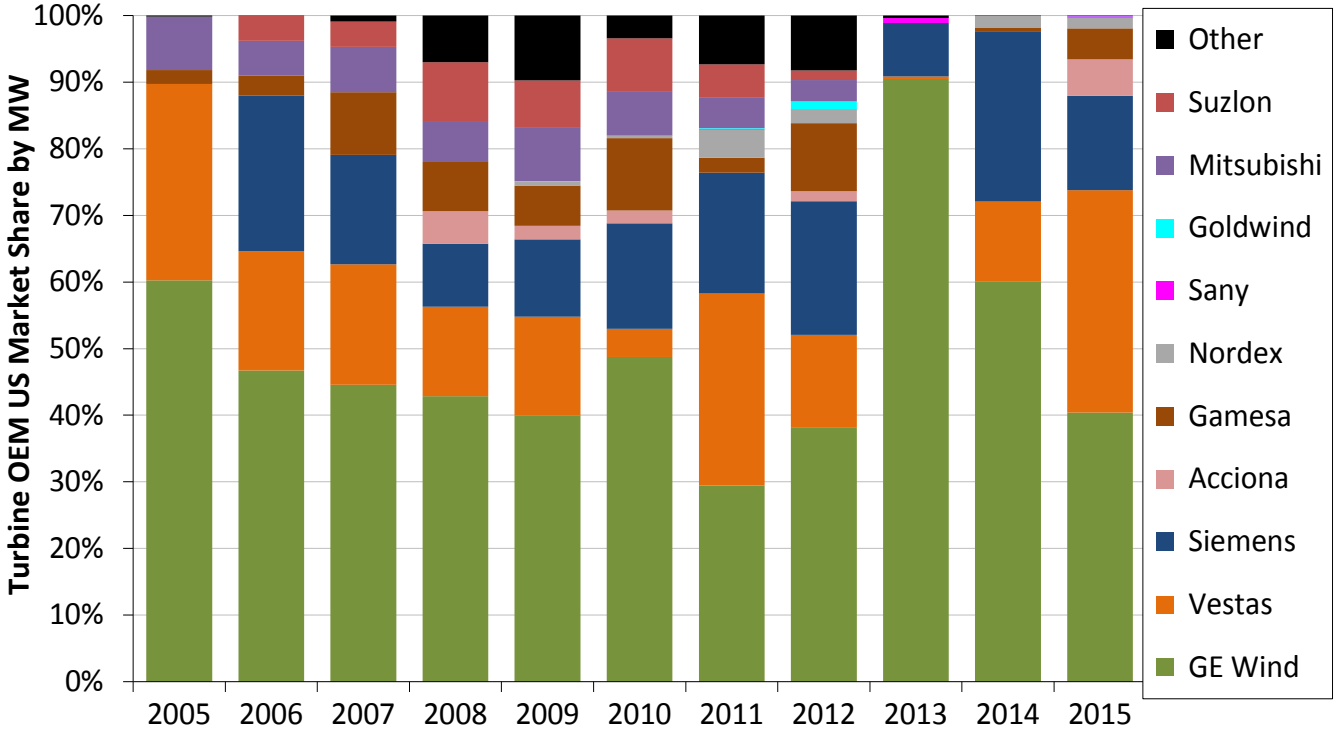
Larger Amounts of Wind Planned for Texas, Midwest, Southwest Power Pool, Northwest, PJM, and Mountain Region



Not all of this capacity will be built….

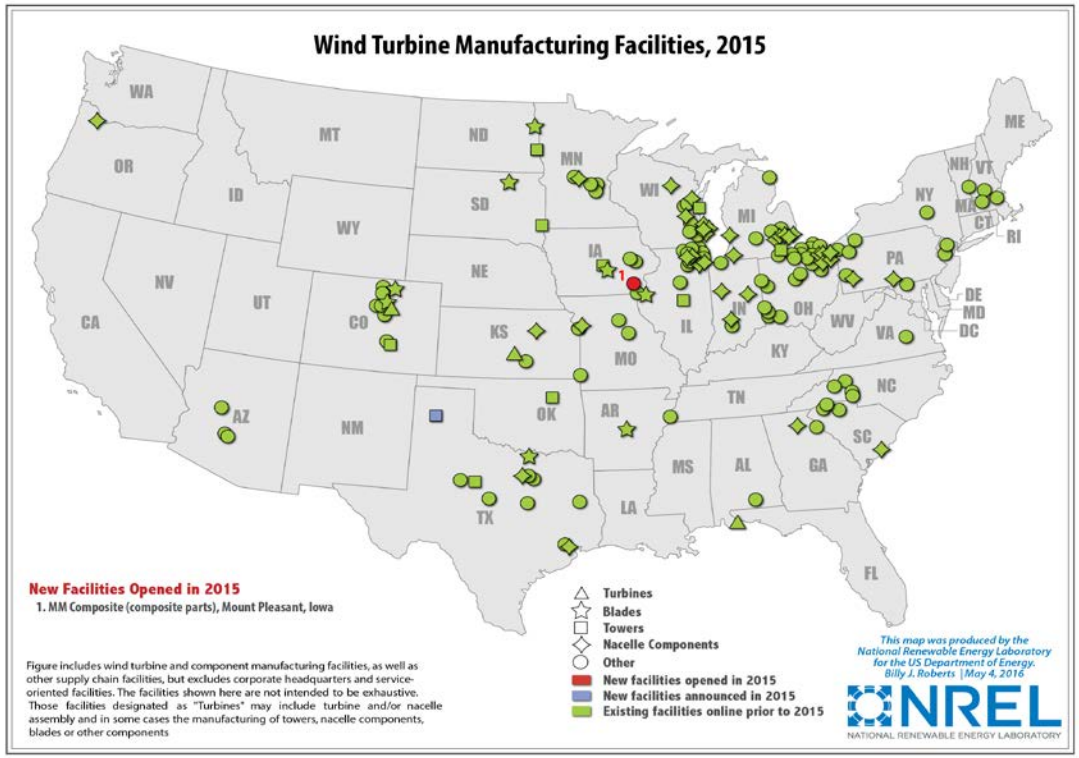
Industry Trends

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

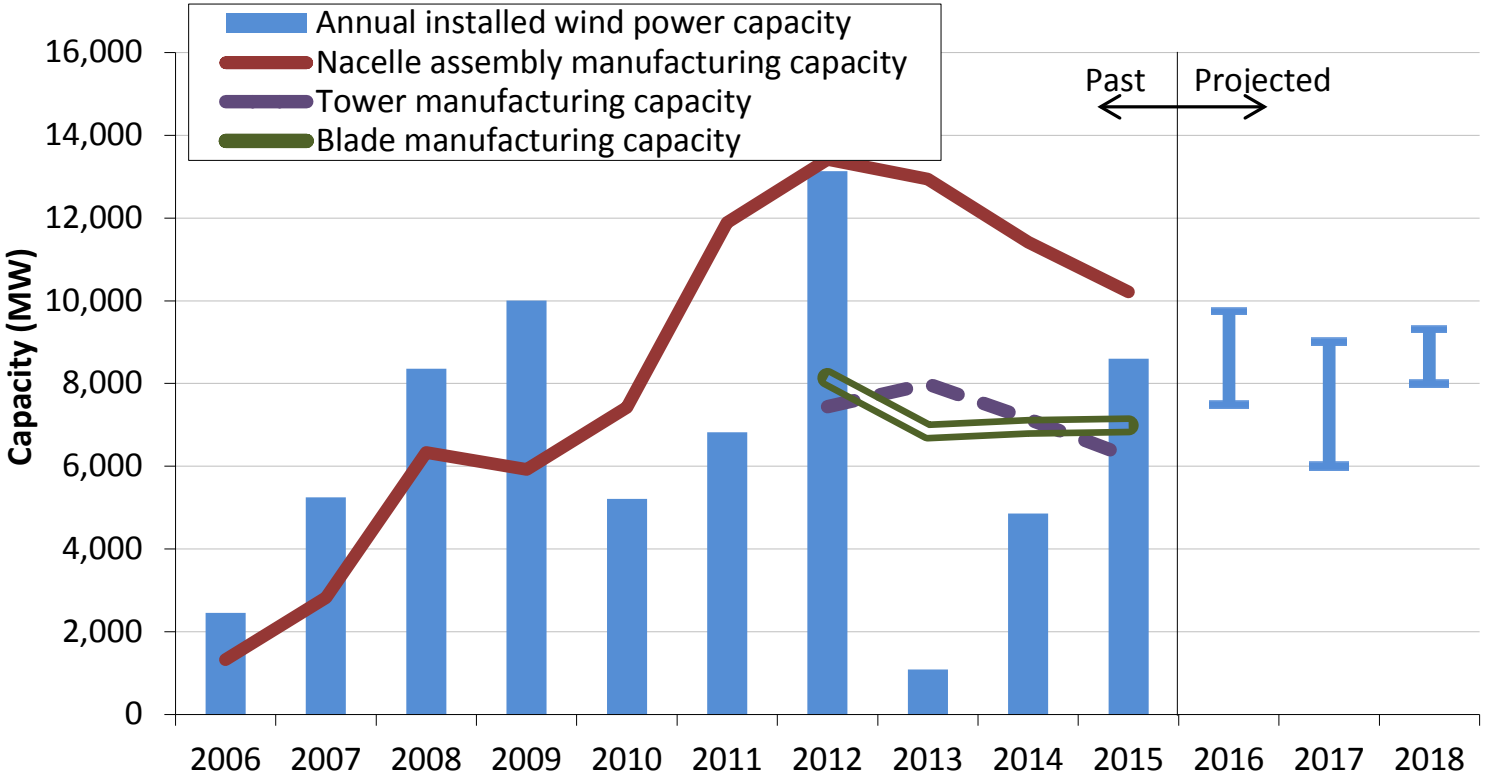
Manufacturing Supply Chain Continued to Adjust to Swings in Domestic Demand



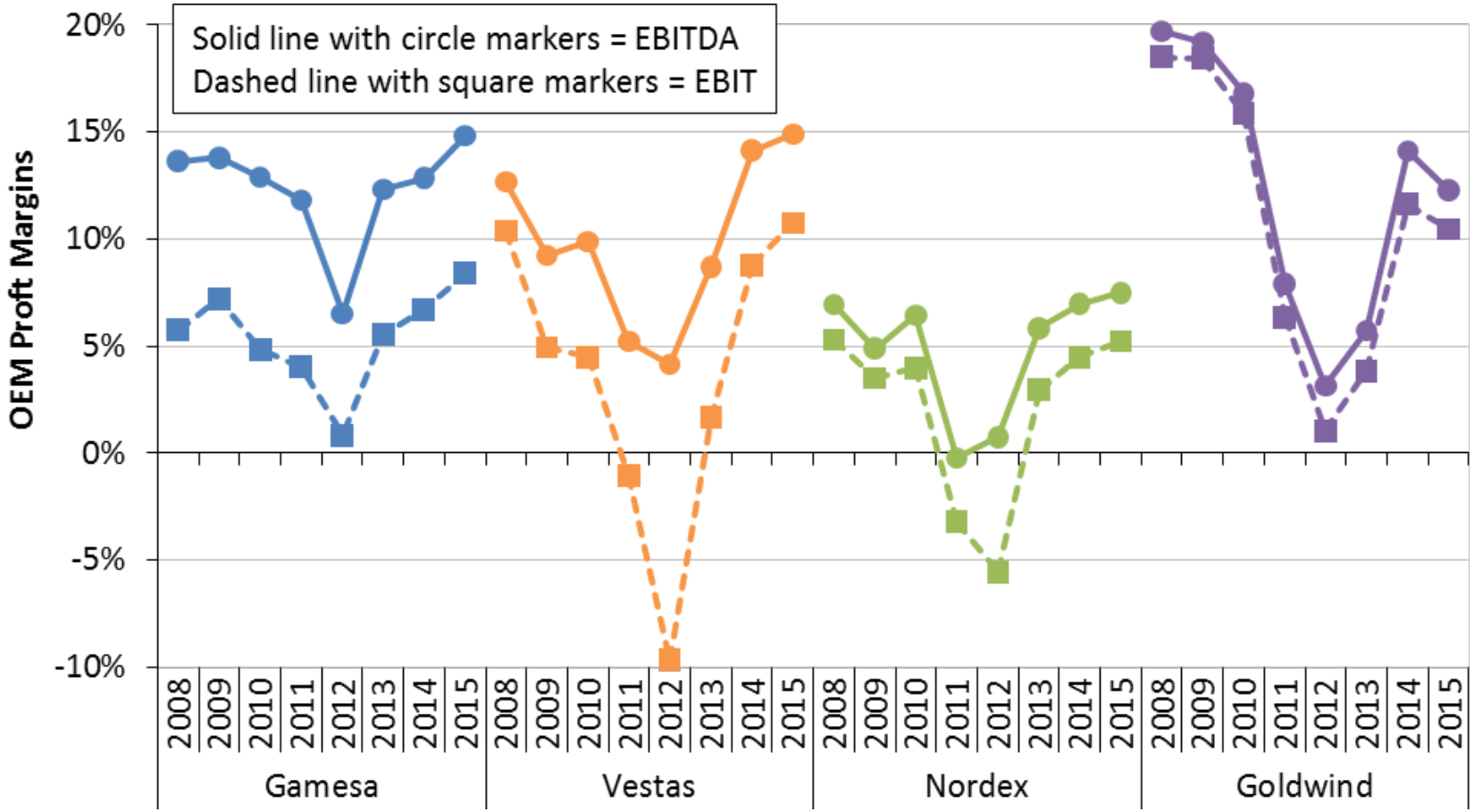
Note: map not intended to be exhaustive

- 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

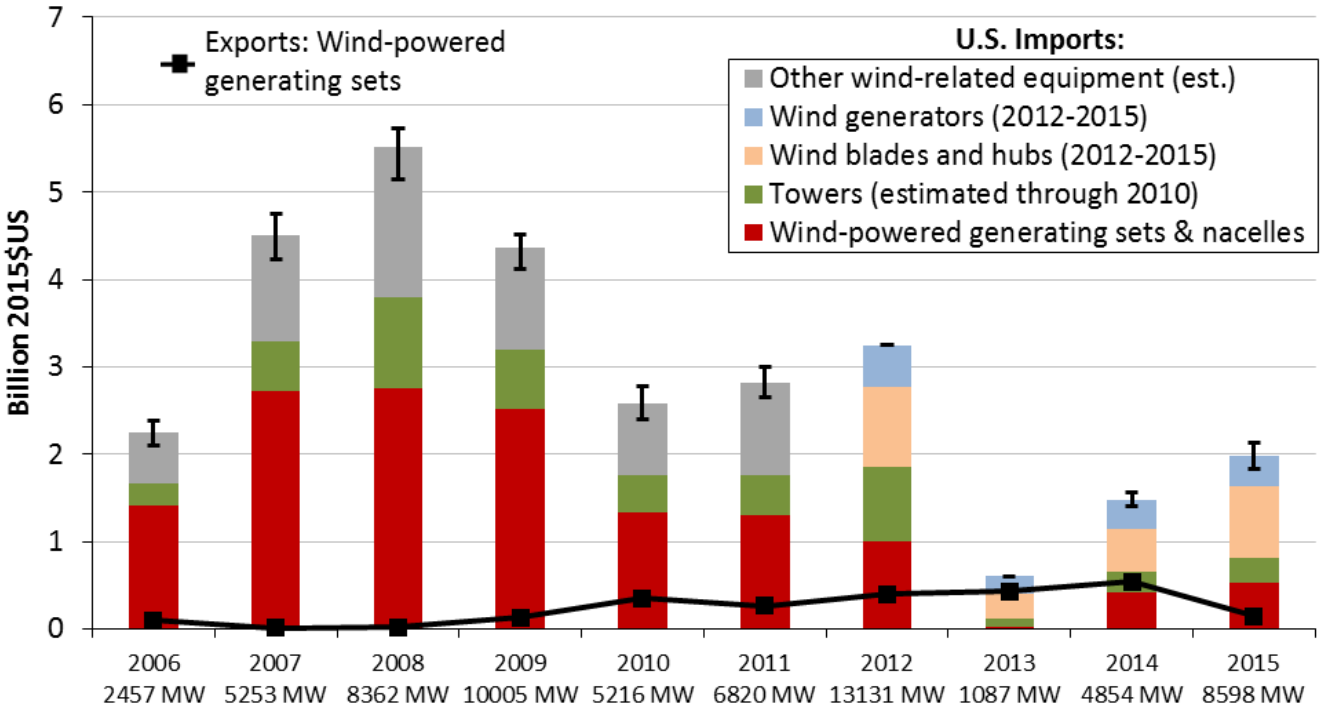
Domestic Manufacturing Capability for Nacelle Assembly, Towers, and Blades Is Reasonably Well Balanced Against Near-Term Demand Forecasts



Turbine OEM Profitability Has Generally Rebounded Over the Last Three Years



Imports of Wind Equipment Are Sizable; Exports Declined in 2015

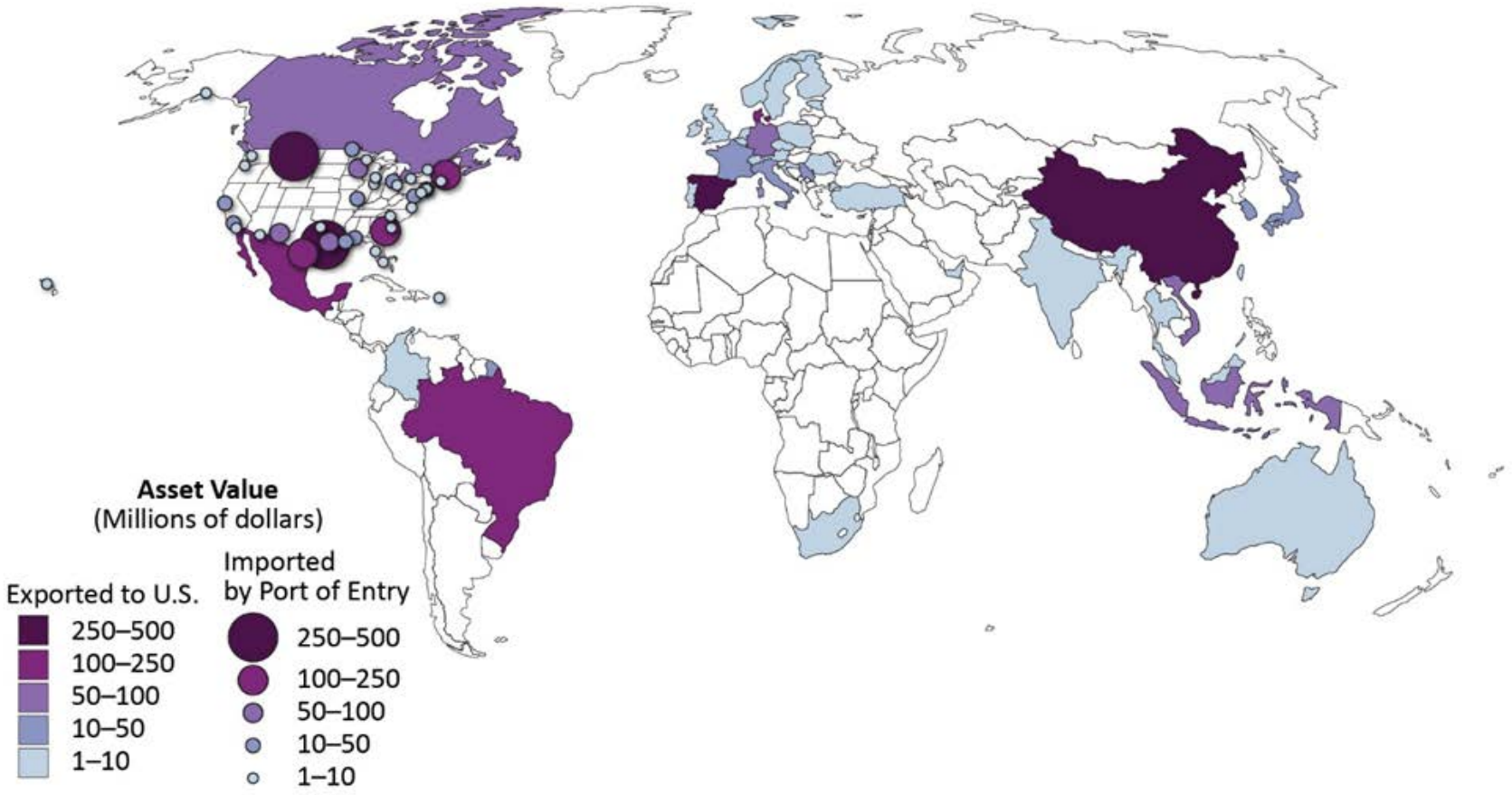


U.S. is a net importer of wind equipment

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*

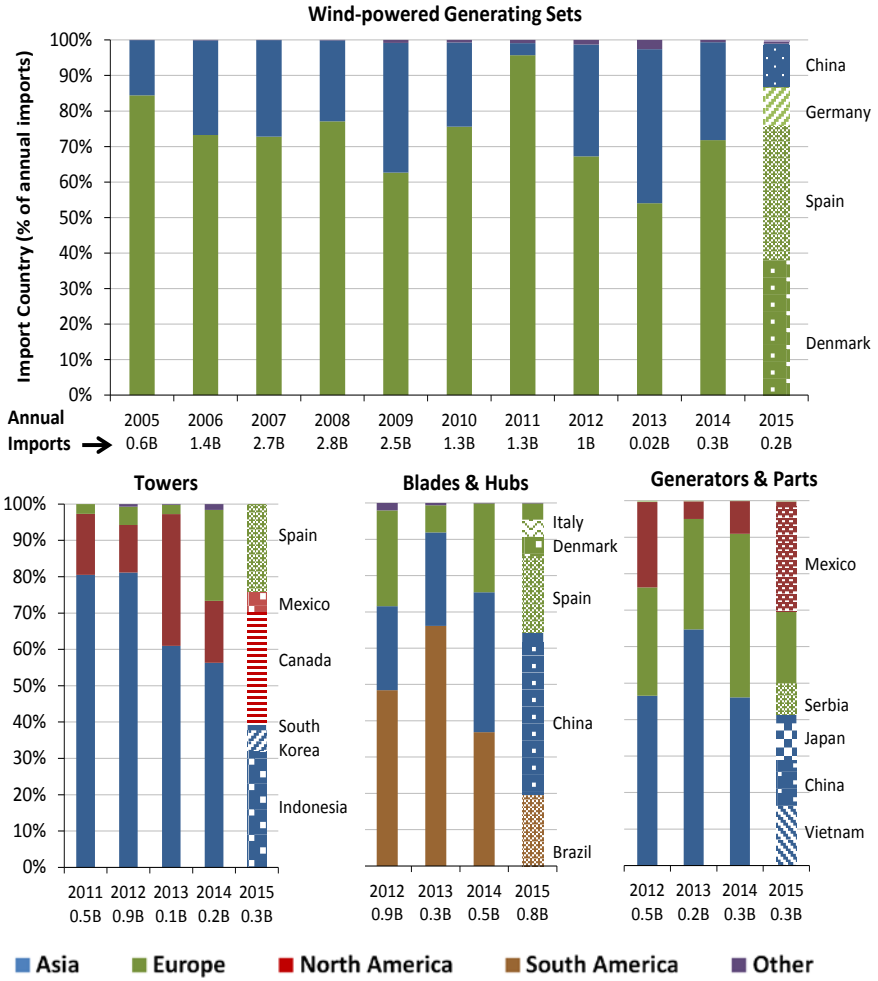
Tracked Wind Equipment Imports in 2015: 40% Asia, 38% Europe, 22% Americas



Note: Tracked wind-specific equipment includes: wind-powered generating sets, towers, hubs and blades, wind generators and parts

Source Markets for Imports Vary Over Time, and By Type of Wind Equipment

- Majority of imports of wind-powered generating sets from home countries of OEMs, dominated by Europe
- Significant imports of towers from Asia, but decline in recent years after tariff measures largely stopped imports from China and Vietnam
- Majority of imports of blades & hubs from China, Brazil, Europe
- Globally diverse sourcing strategy for generators & 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

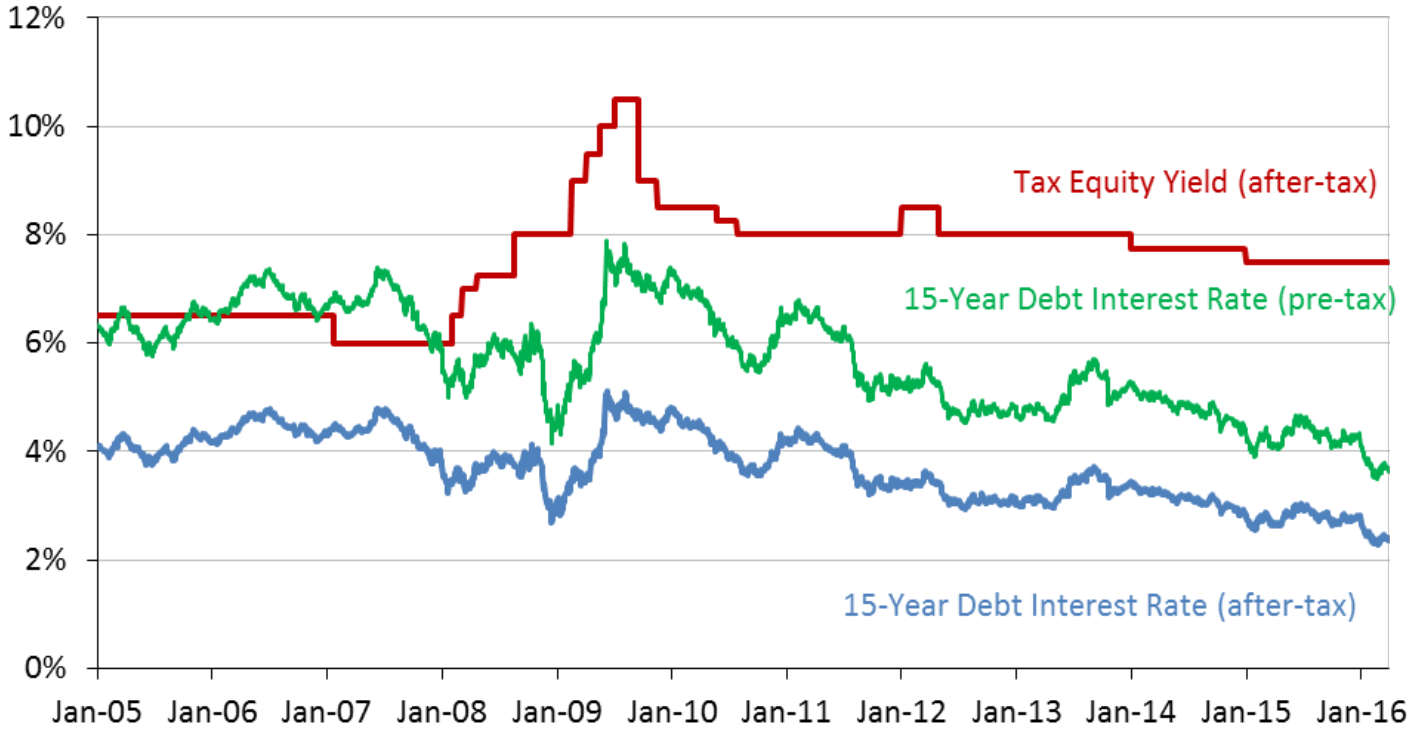
Domestic Content for 2015 Turbine Installations in the U.S.

Towers	Blades & Hubs	Nacelle Assembly
80-85%	50-70%	> 85% of nacelle assembly

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

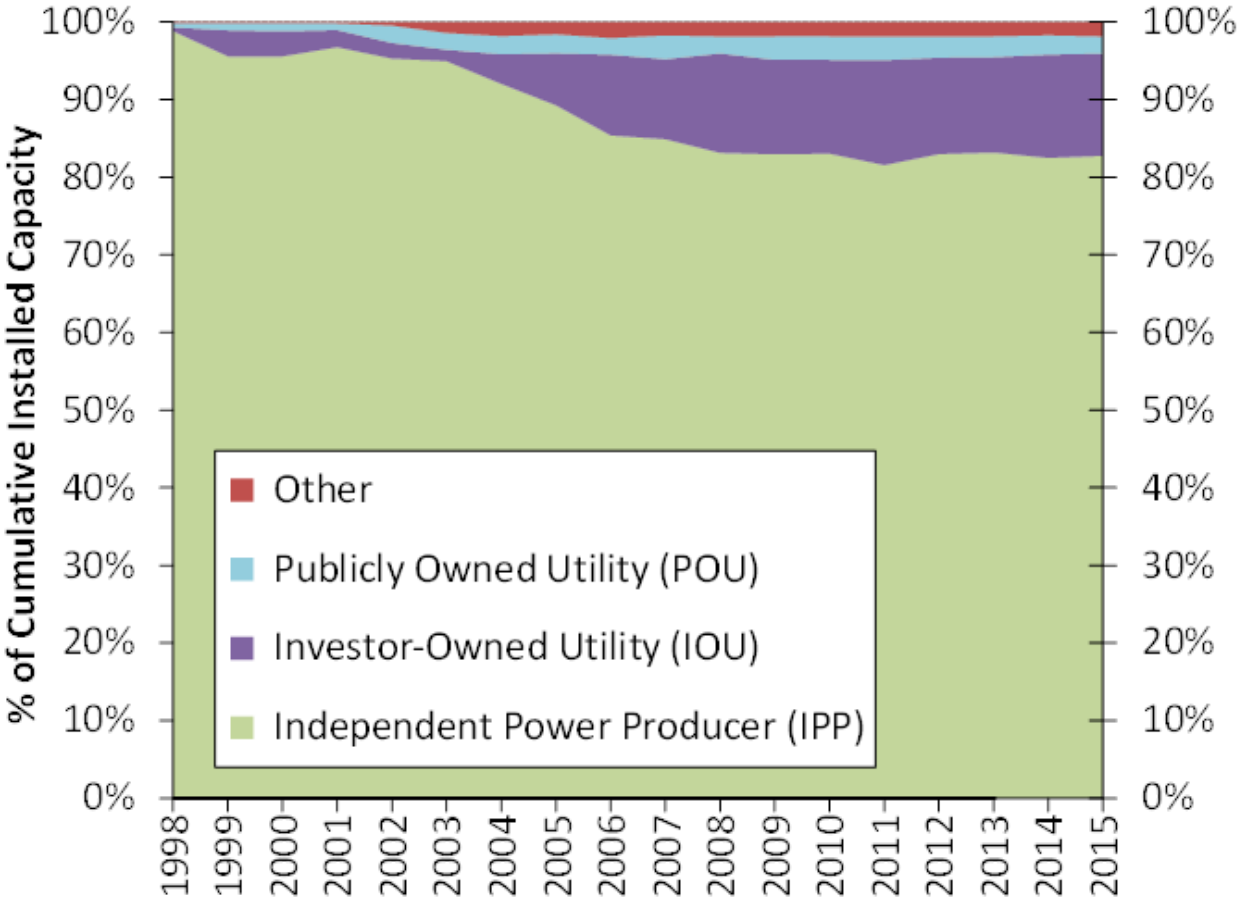
Overall estimated domestic content: ~40% in 2012 for wind turbine equipment; ~60% if considering total projects costs, including balance-of-plant

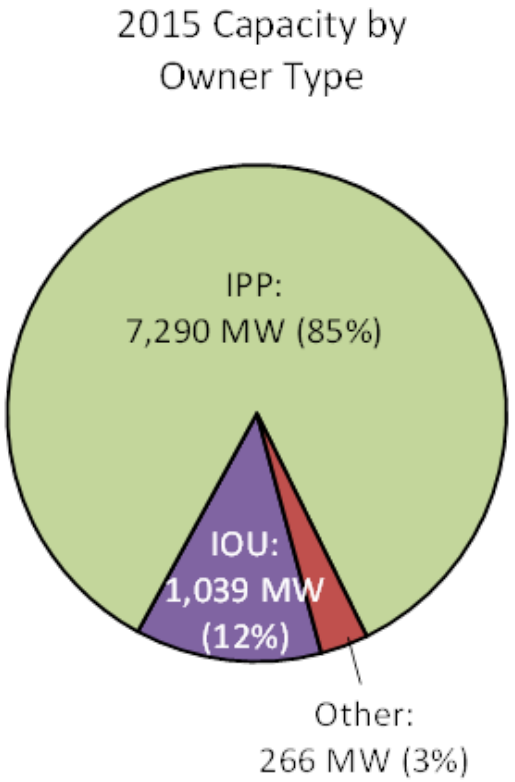
The Project Finance Environment Remained Strong in 2015



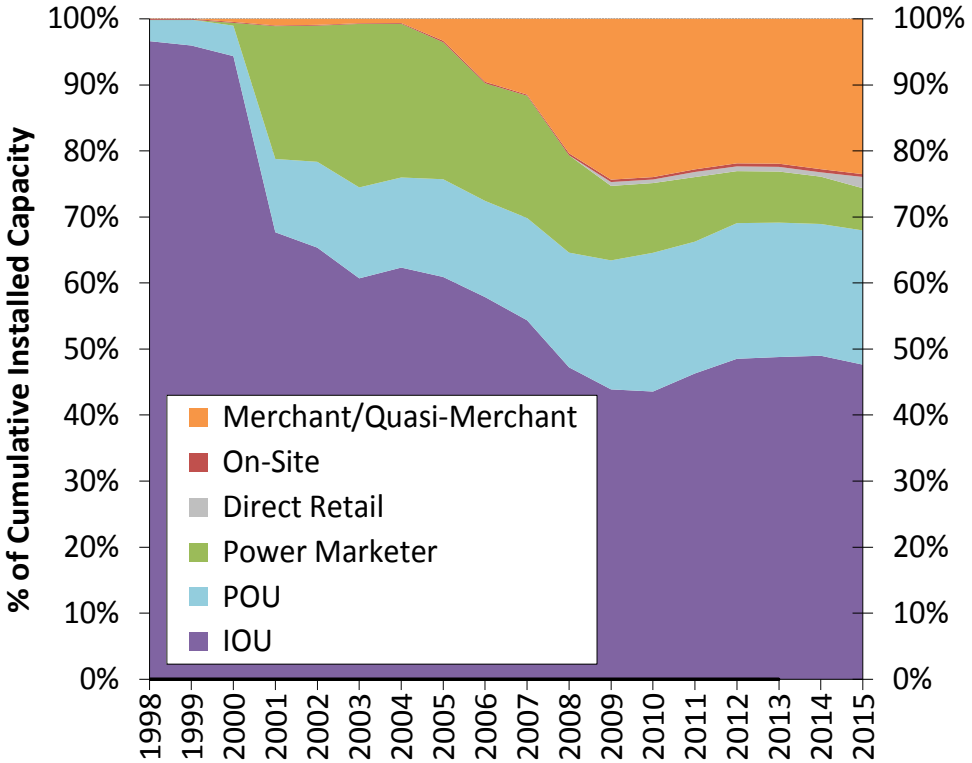
- Project sponsors raised $5.9-6.4 billion of tax equity (largest single-year amount on record) and $2.9 billion of debt in 2015
- Tax equity yields drifted slightly lower, as did debt interest rates

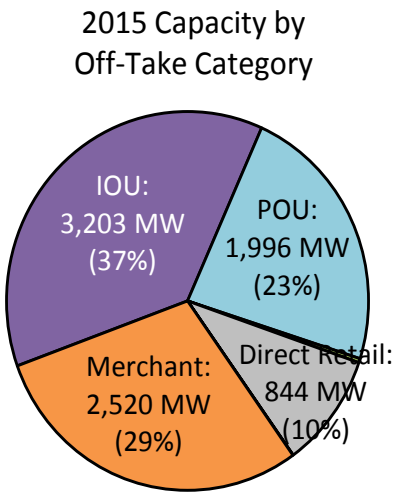
IPPs Own the Majority of Wind Assets Built in 2015





Long-Term Sales to Utilities Remained the Most Common Off-Take Arrangement, but Direct Retail Sales Gained Ground

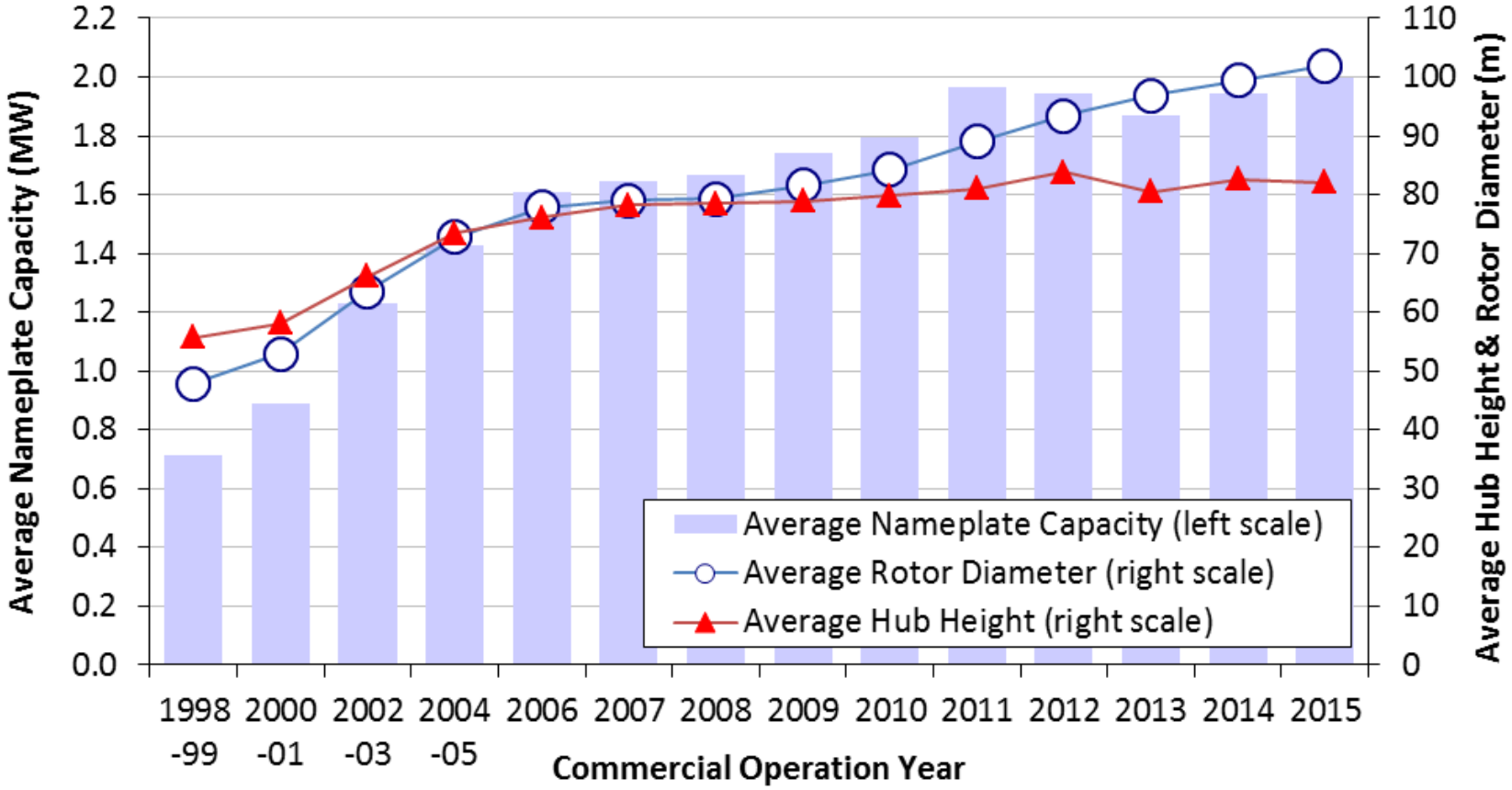




- 10% of added wind capacity in 2015 are from direct retail sales; 52% of total wind capacity contracted through PPAs in 2015 involve non-utility buyers

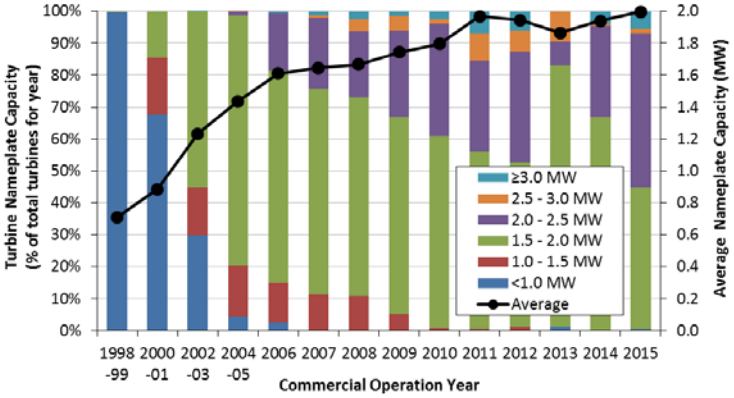
Technology Trends

Turbine Nameplate Capacity, Hub Height, and Rotor Diameter Have All Increased Significantly Over the Long Term

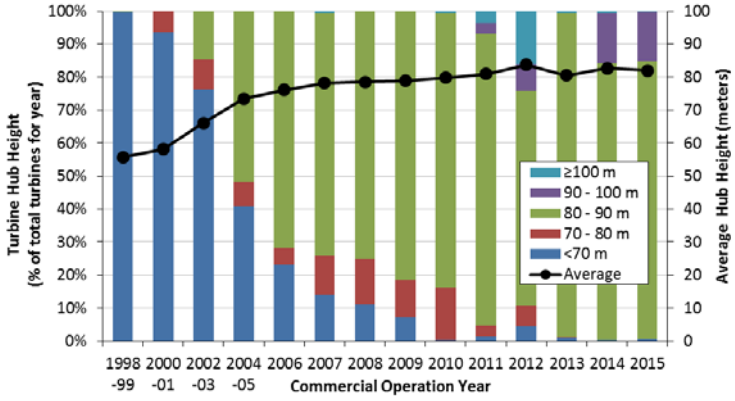


Growth in Rotor Diameter Has Outpaced Growth in Nameplate Capacity and Hub Height in Recent Years

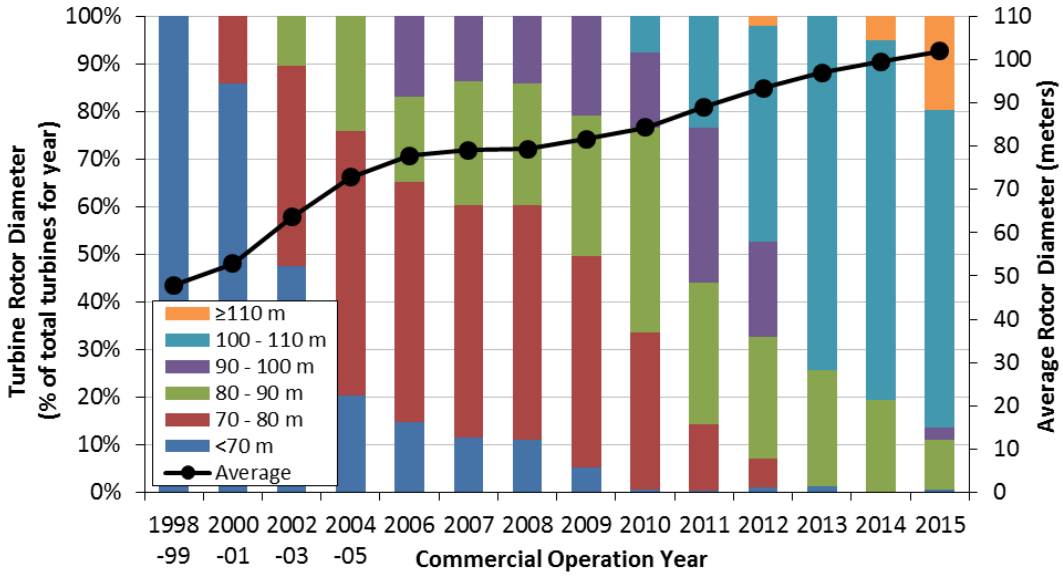
Nameplate Capacity



Hub Height

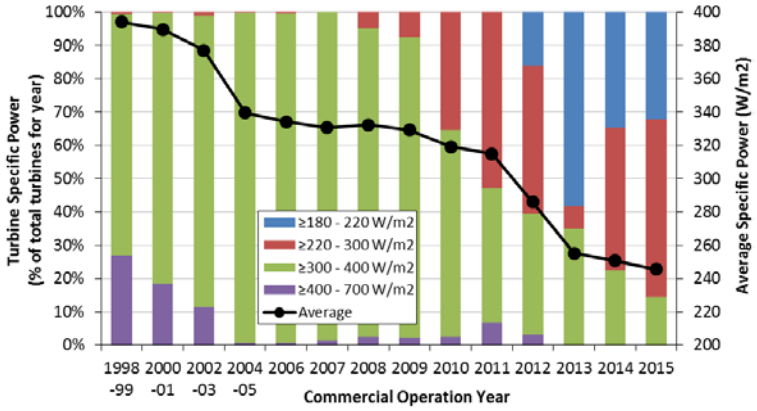


Rotor Diameter

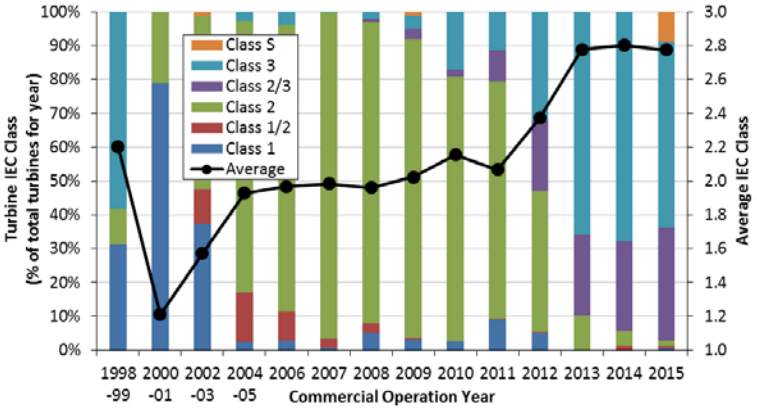


Turbines Originally Designed for Lower Wind Speed Sites Have Rapidly Gained Market Share

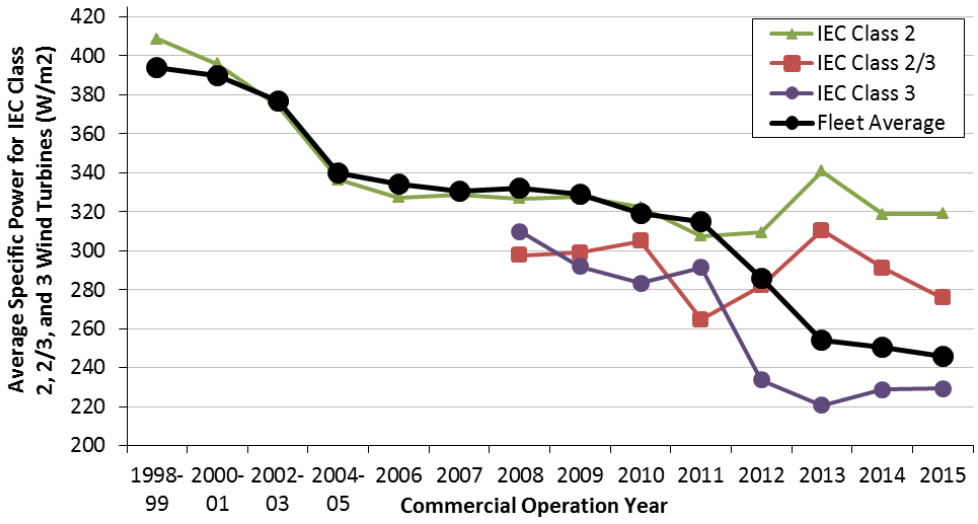
Specific Power



IEC Class

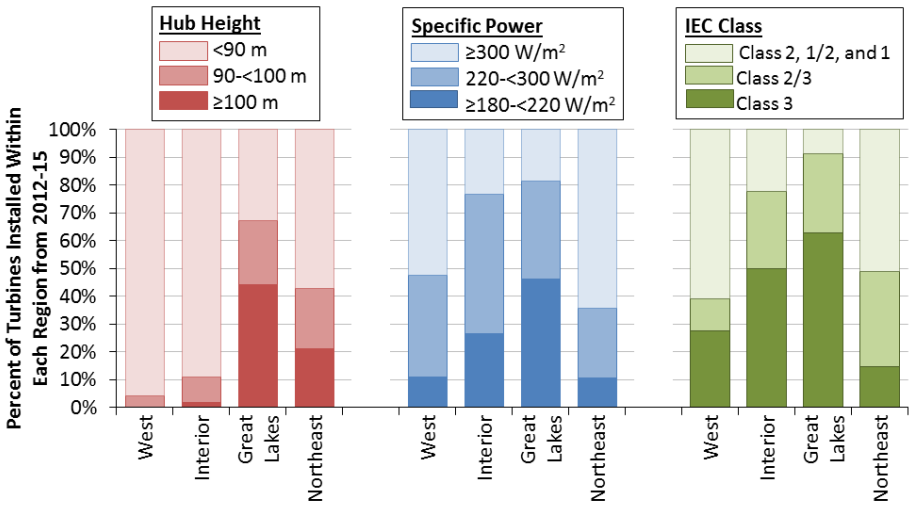


Specific Power by Selected IEC Class

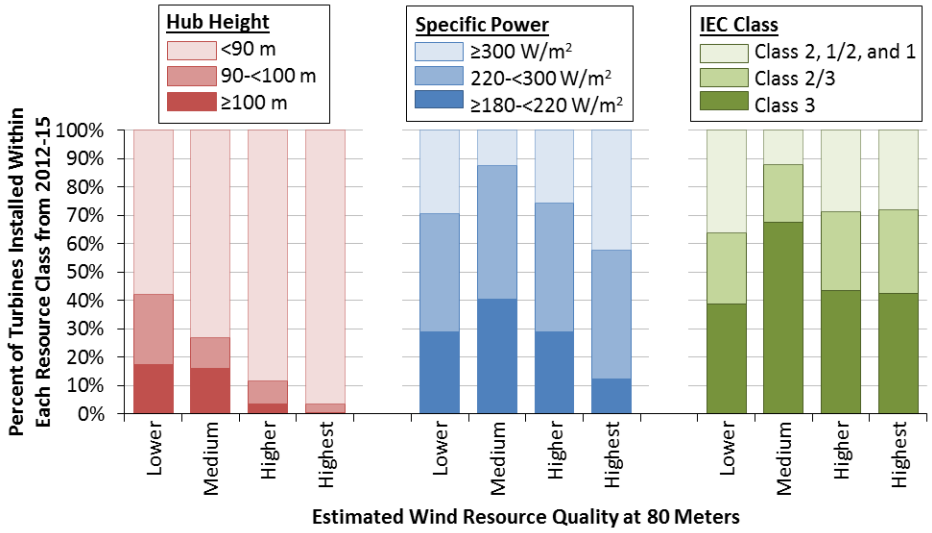


Turbines Originally Designed for Lower Wind Speeds Now Regularly Used in Lower & Higher Wind Sites; Taller Towers Predominate in Great Lakes and NE

By Region

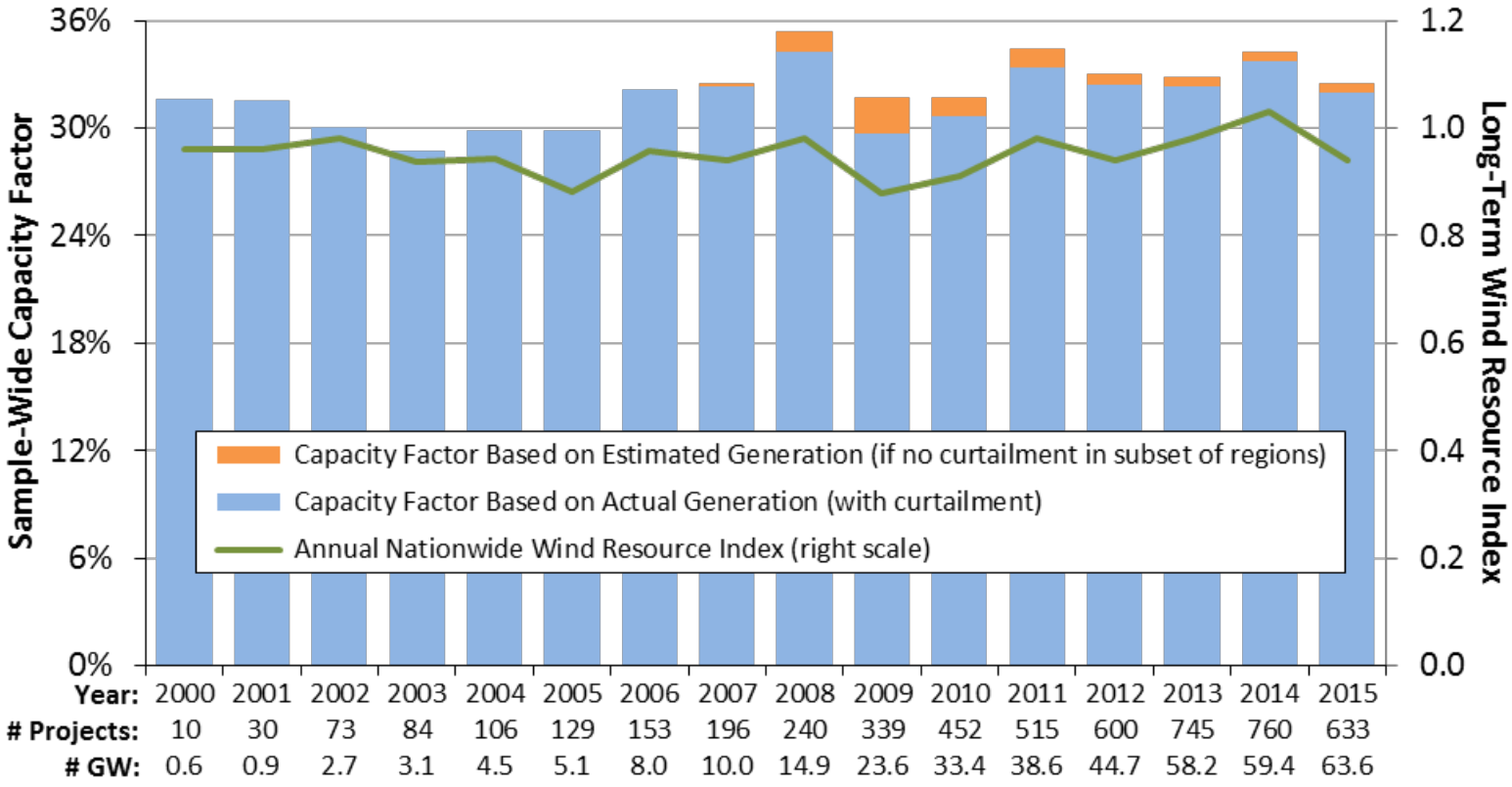


By Wind Resource Quality



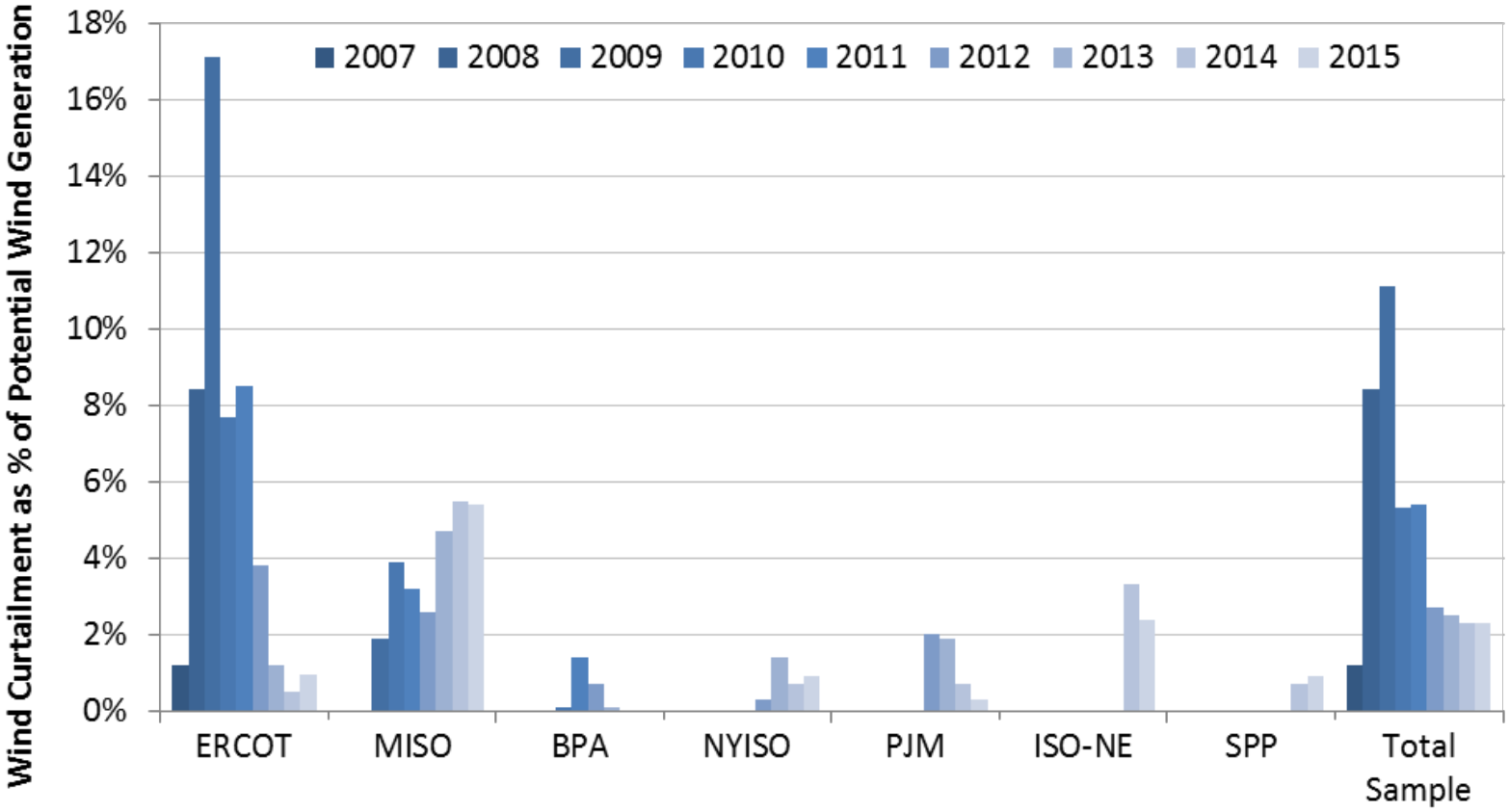
Performance Trends

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

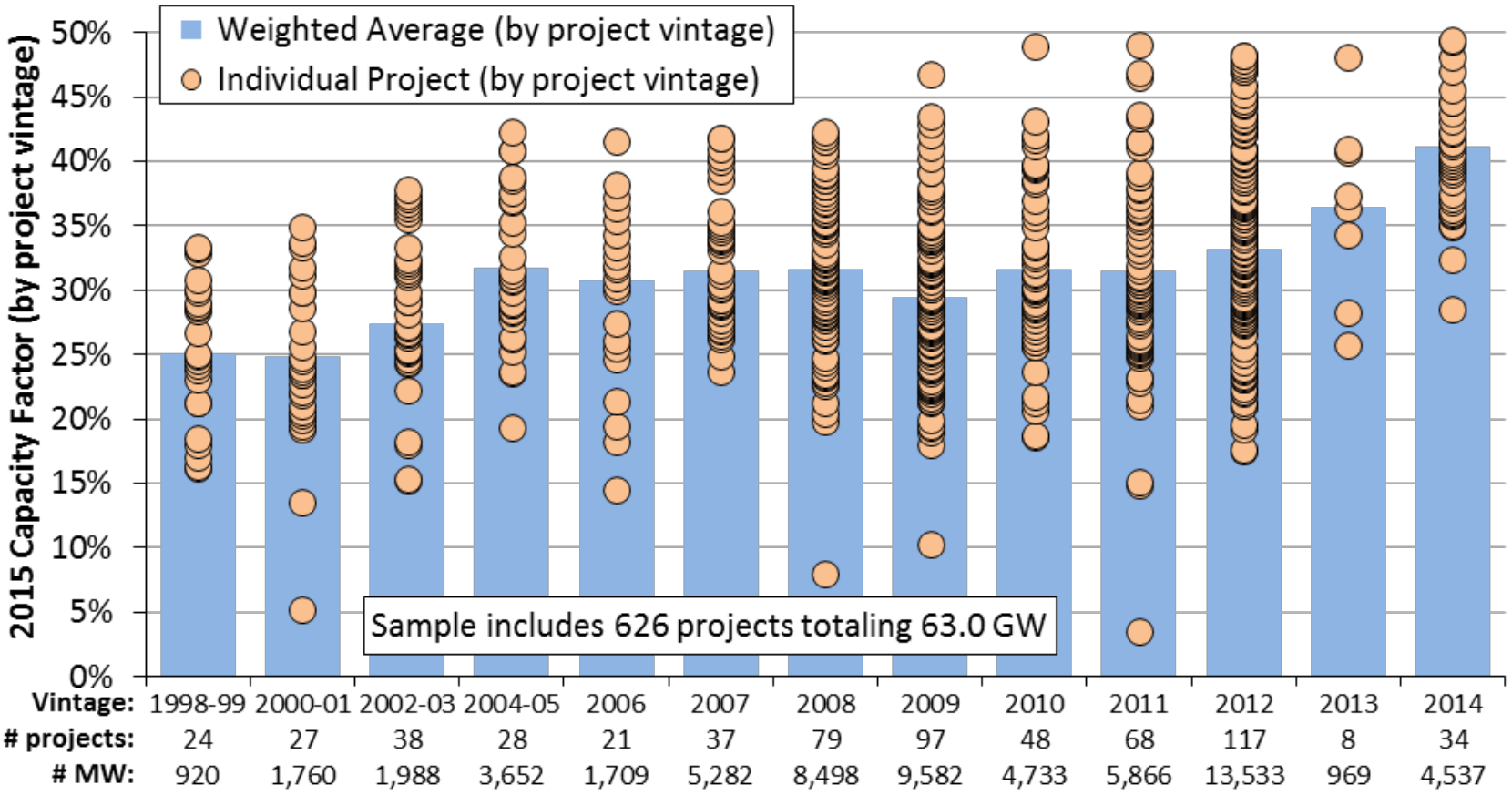
Wind Curtailment Has Generally Declined in Recent Years; Higher in MISO



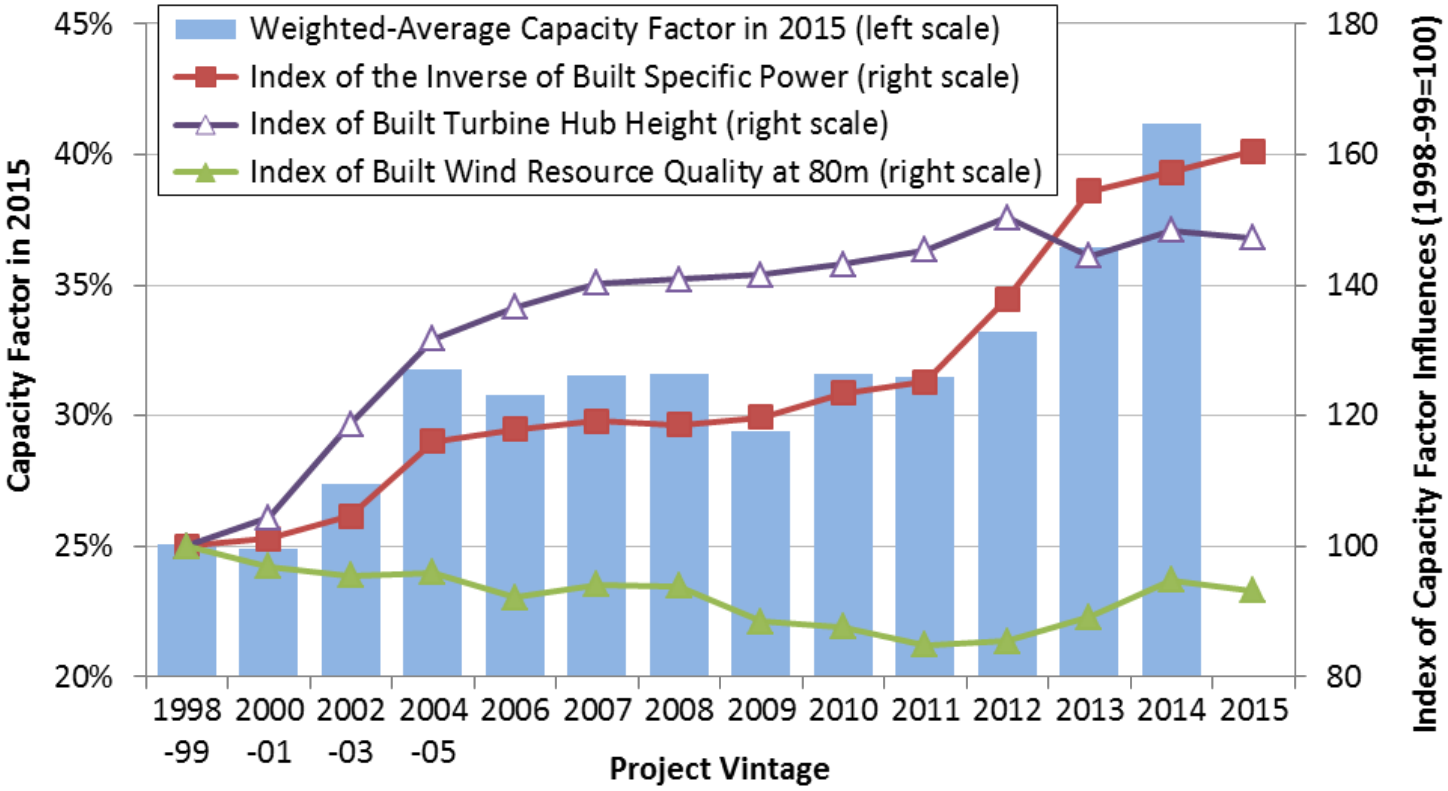
Except for BPA, data represent both forced & economic curtailment

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

Impact of Technology Trends on Capacity Factors Becomes More Apparent When Parsed by Project Vintage



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

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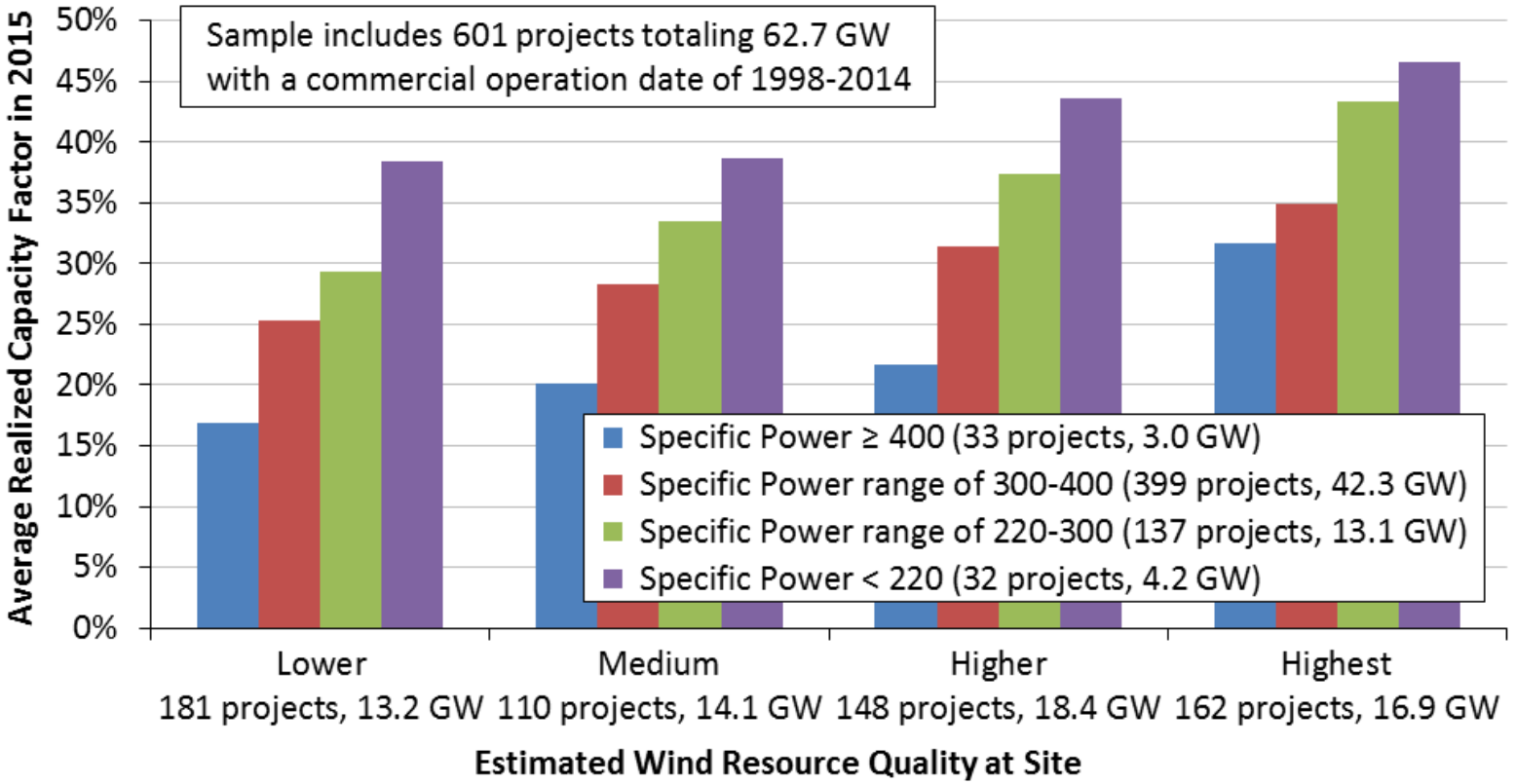
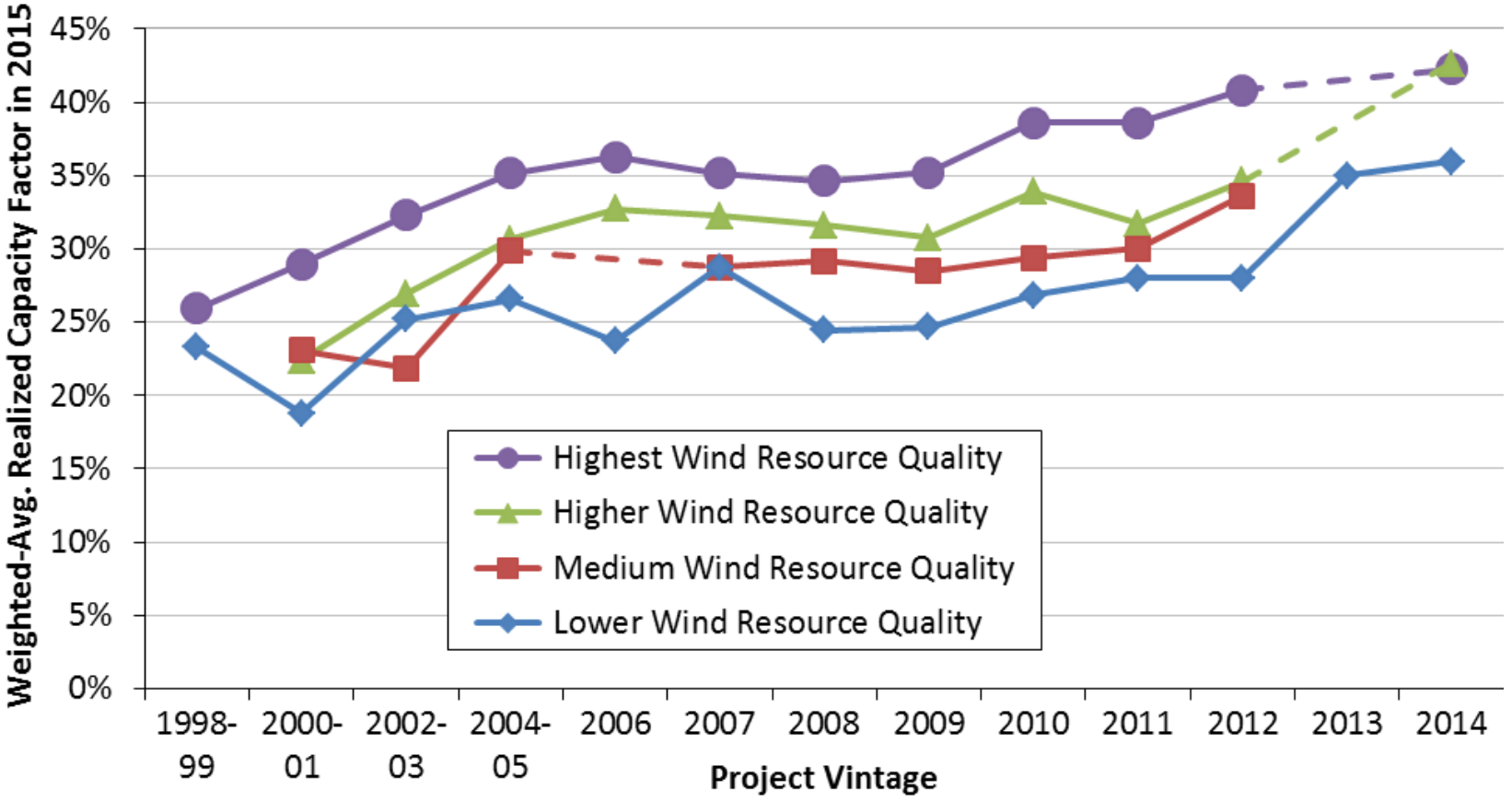
Controlling for Wind Resource Quality and Specific Power Demonstrates Impact of Turbine Evolution



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

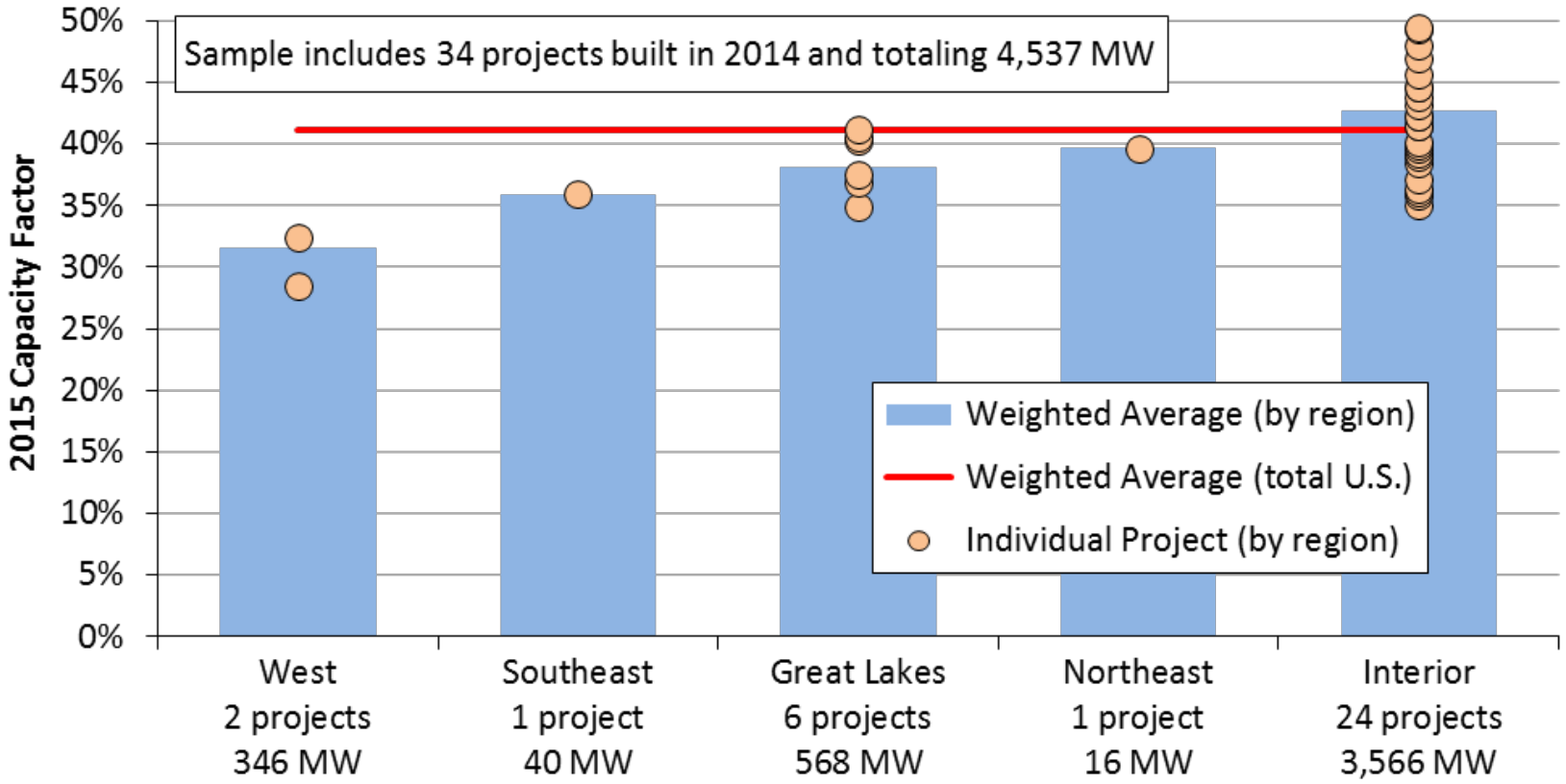


Degradation of Project Performance as Projects Age Also Impacts Overall Trends

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

Note: See full report for caveats associated with this figure

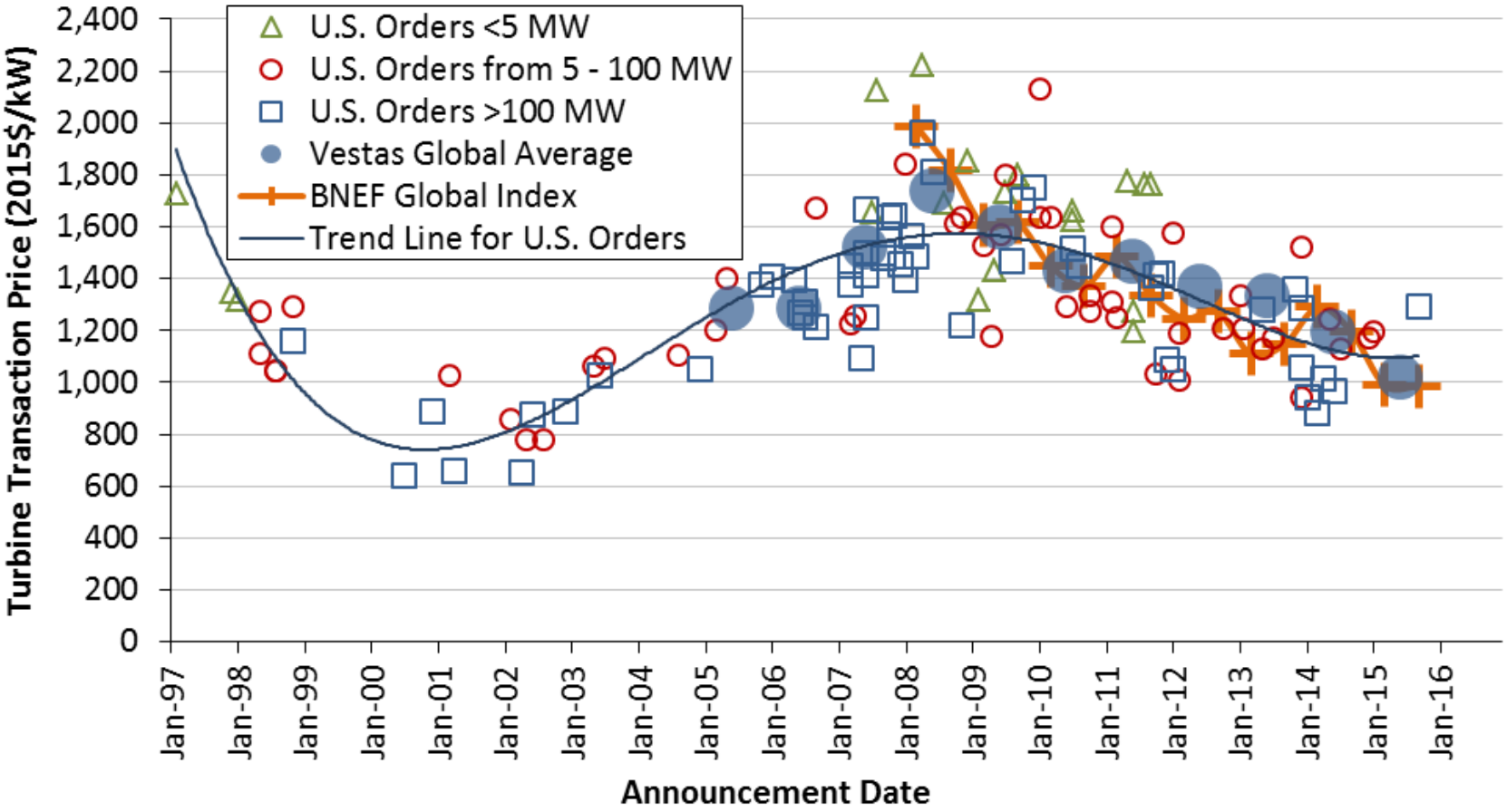
Regional Variations in Capacity Factors Reflect the Strength of the Wind Resource and Adoption of New Turbine Technology



Note: Very limited sample size for 2014 projects in most regions

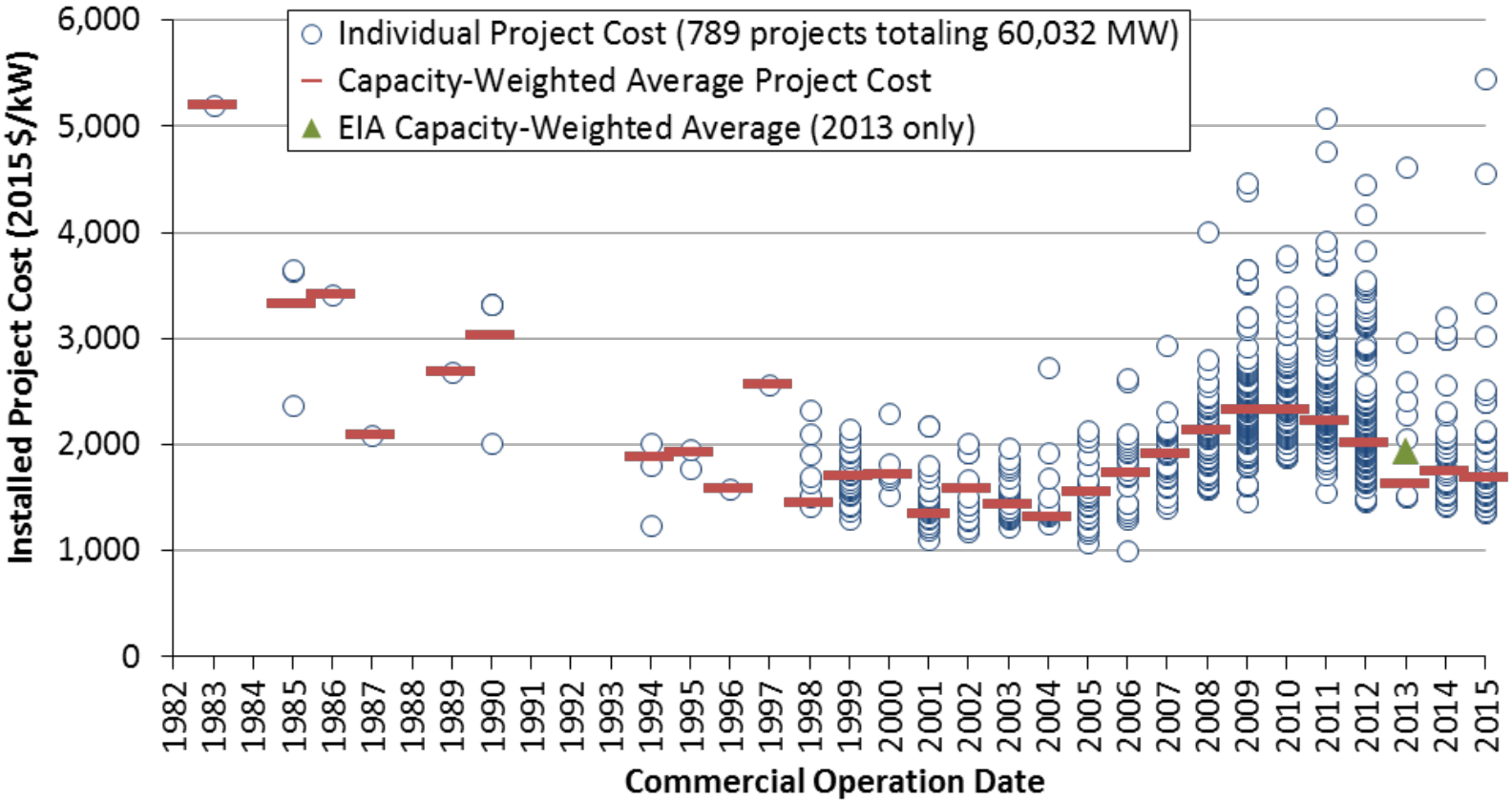
Cost Trends

Wind Turbine Prices Remained Well Below the Levels Seen Several Years Ago



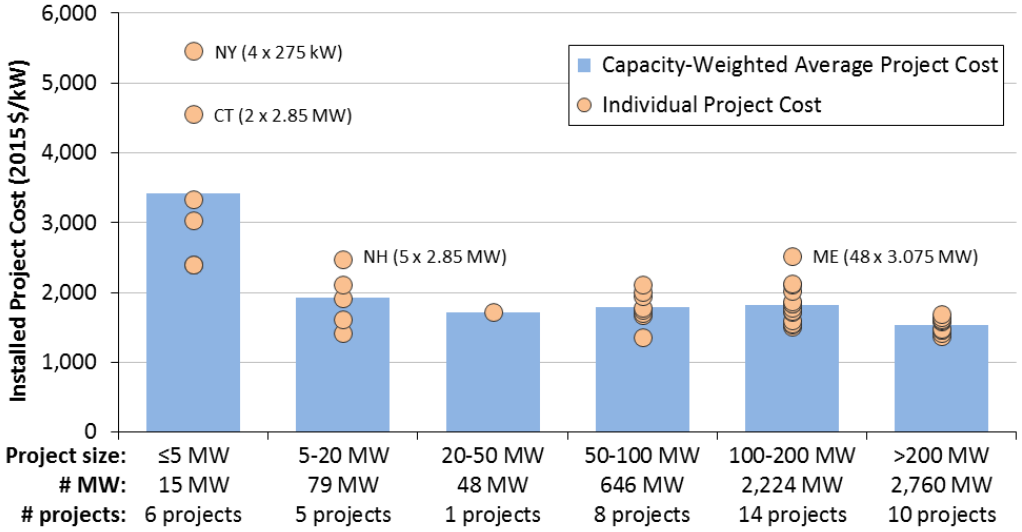
Recent turbine orders reportedly in the range of $850-1,250/kW

Lower Turbine Prices Drive Reductions in Reported Installed Project Costs

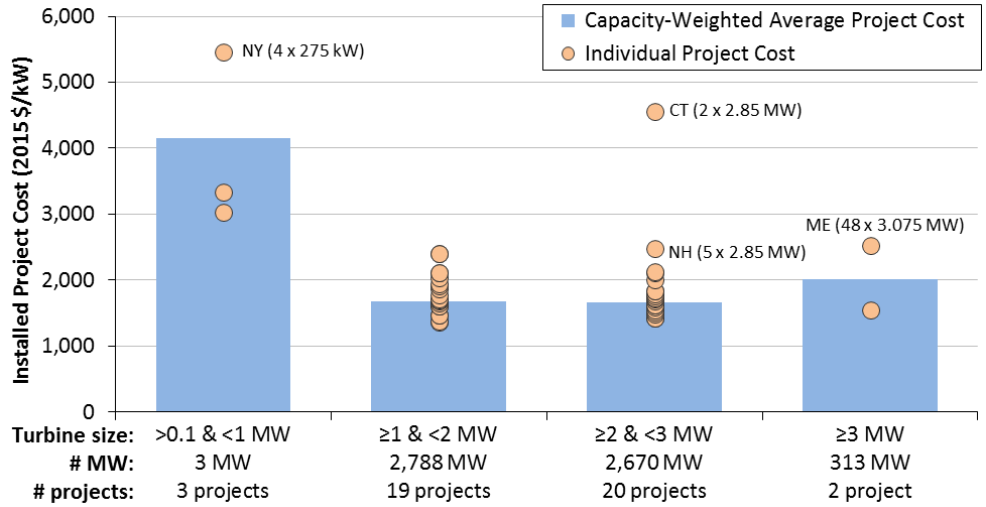


- 2015 projects had an average cost of $1,690/kW, down $640/kW since 2009 and 2010; limited sample of under-construction projects slated for completion in 2016 suggest no material change in costs

Economies of Scale, Especially at Lower End of Project & Turbine Size Range

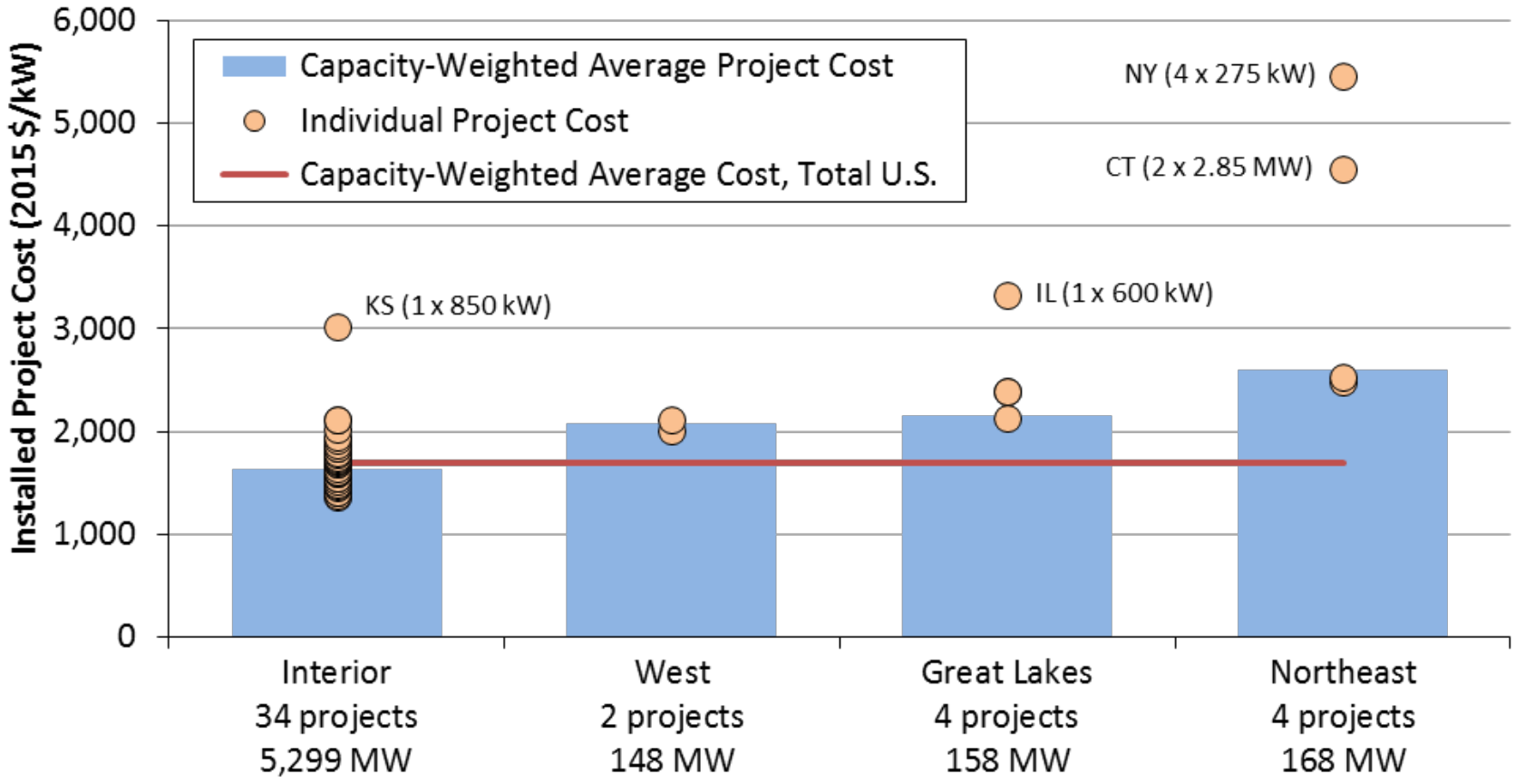


Project Size

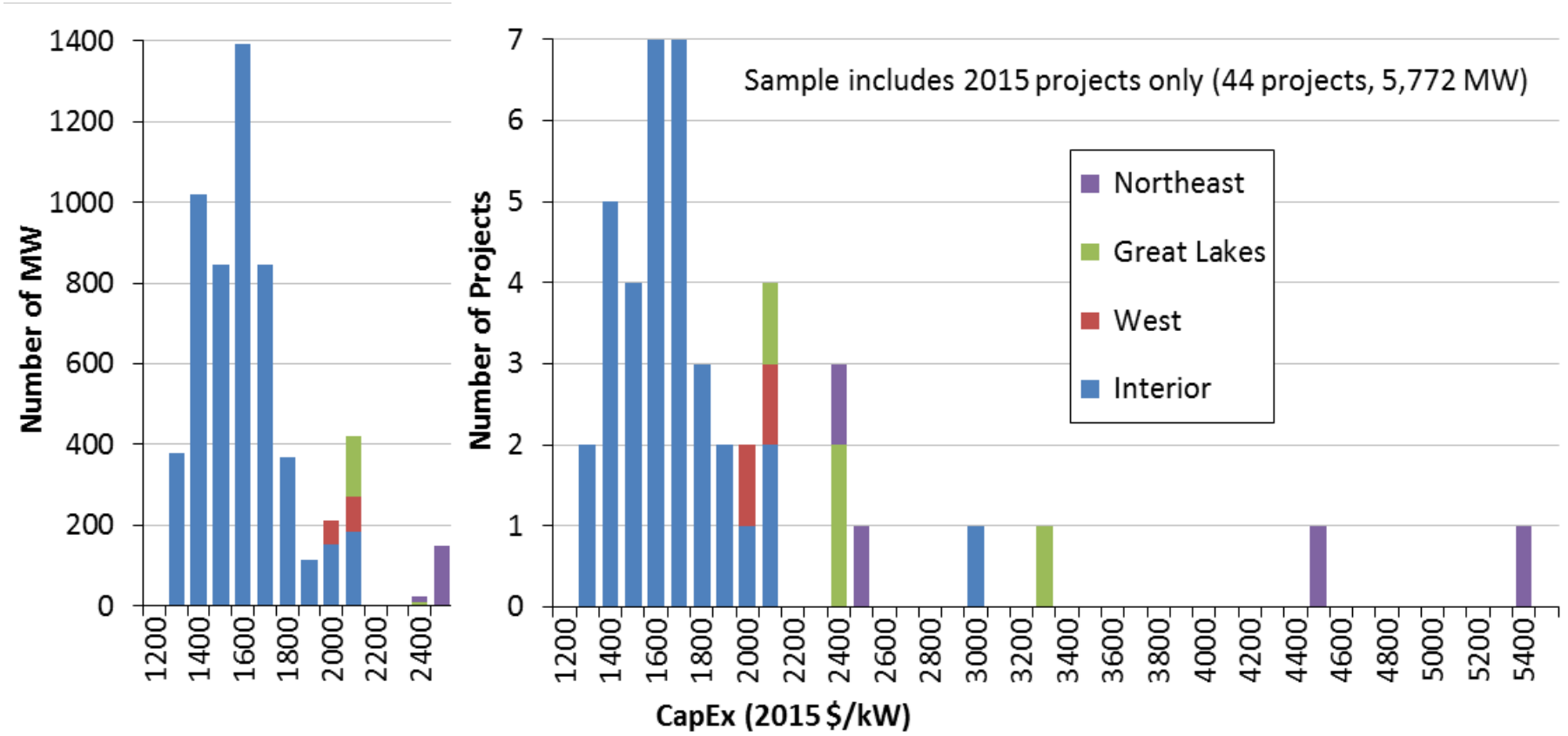


Turbine Size

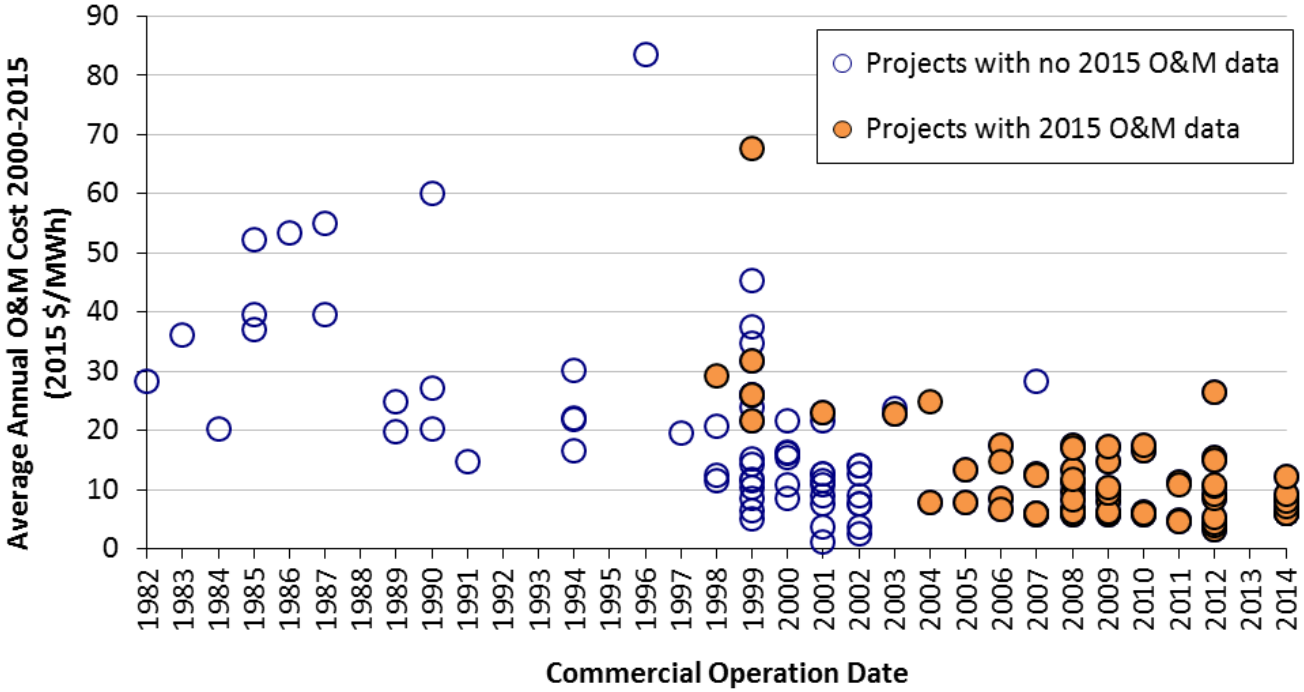
Regional Differences in Average Wind Power Project Costs Are Apparent, but Sample Size Is Limited



Most 2015 Projects—and All of the Low-Cost Projects—Are Located in the Interior; Other Regions Have Higher Costs



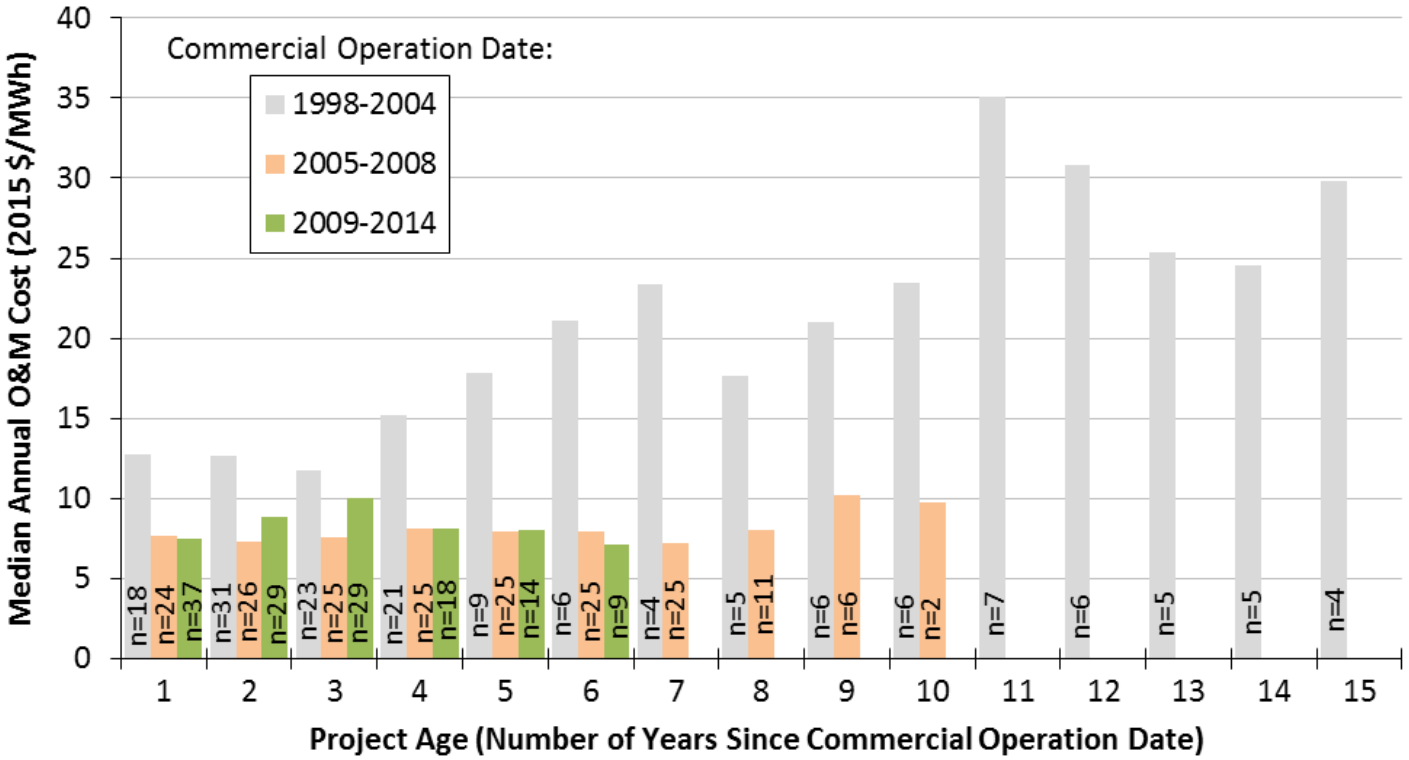
Operations and Maintenance Costs Varied By Project Age and Commercial Operations Date



Capacity-weighted average 2000-15 O&M costs for projects built in the 1980s equal **$35/MWh**, dropping to **$24/MWh** for projects built in 1990s, to **$10/MWh** for projects built in the 2000s, and to **$9/MWh** for projects built since 2010

*Note: Sample is limited; few projects in sample have complete records of O&M costs from 2000-15; O&M costs reported here **DO NOT** include all operating costs*

Operations and Maintenance Costs Varied By Project Age and Commercial Operations Date



Note: Sample size is limited

O&M reported in figure <u>does not</u> include all operating costs: Statements from public companies with large U.S. wind asset bases report total operating costs in 2015 for projects built in the 2000s of ~$25/MWh

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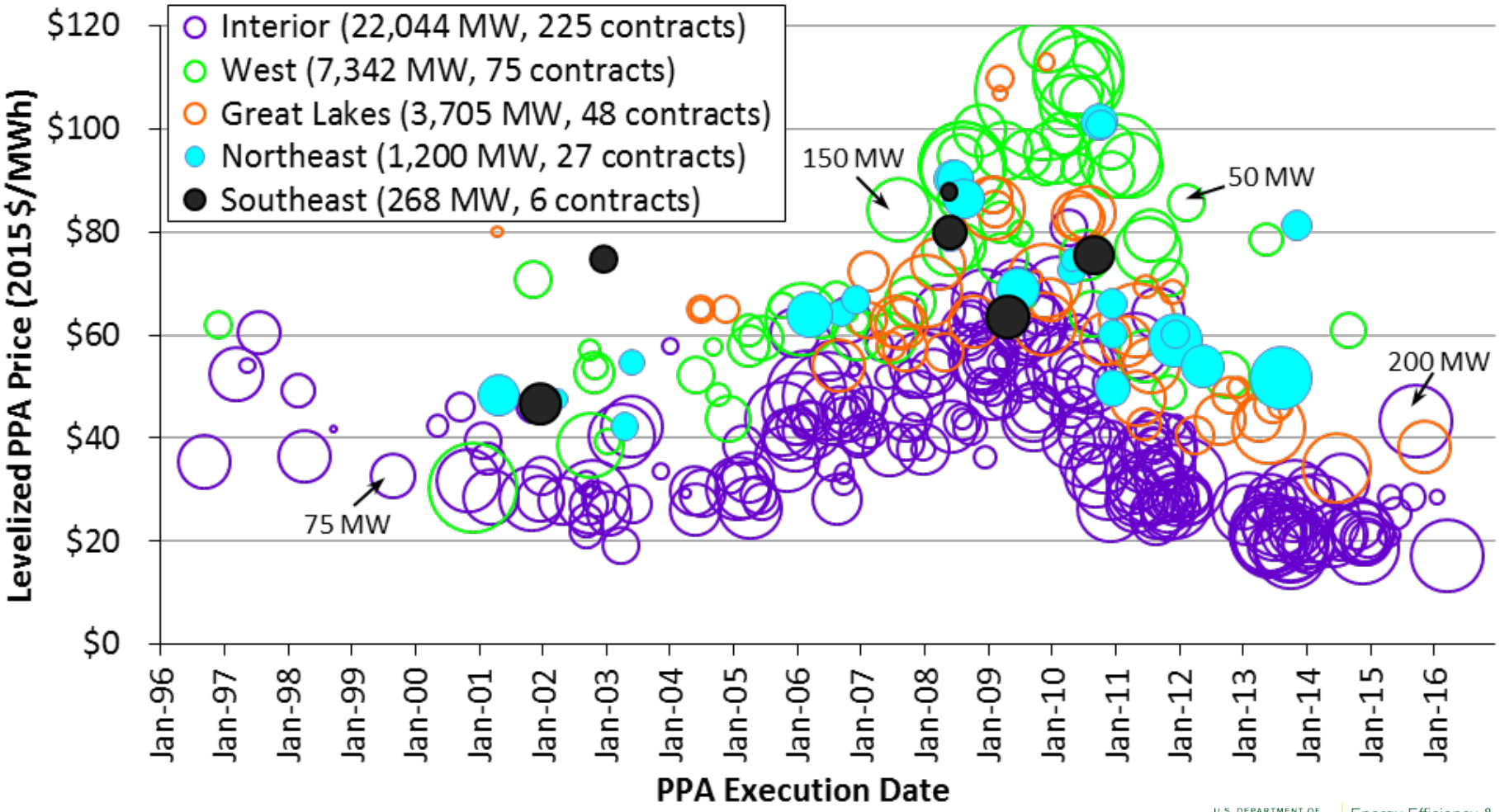
Wind Power Price Trends

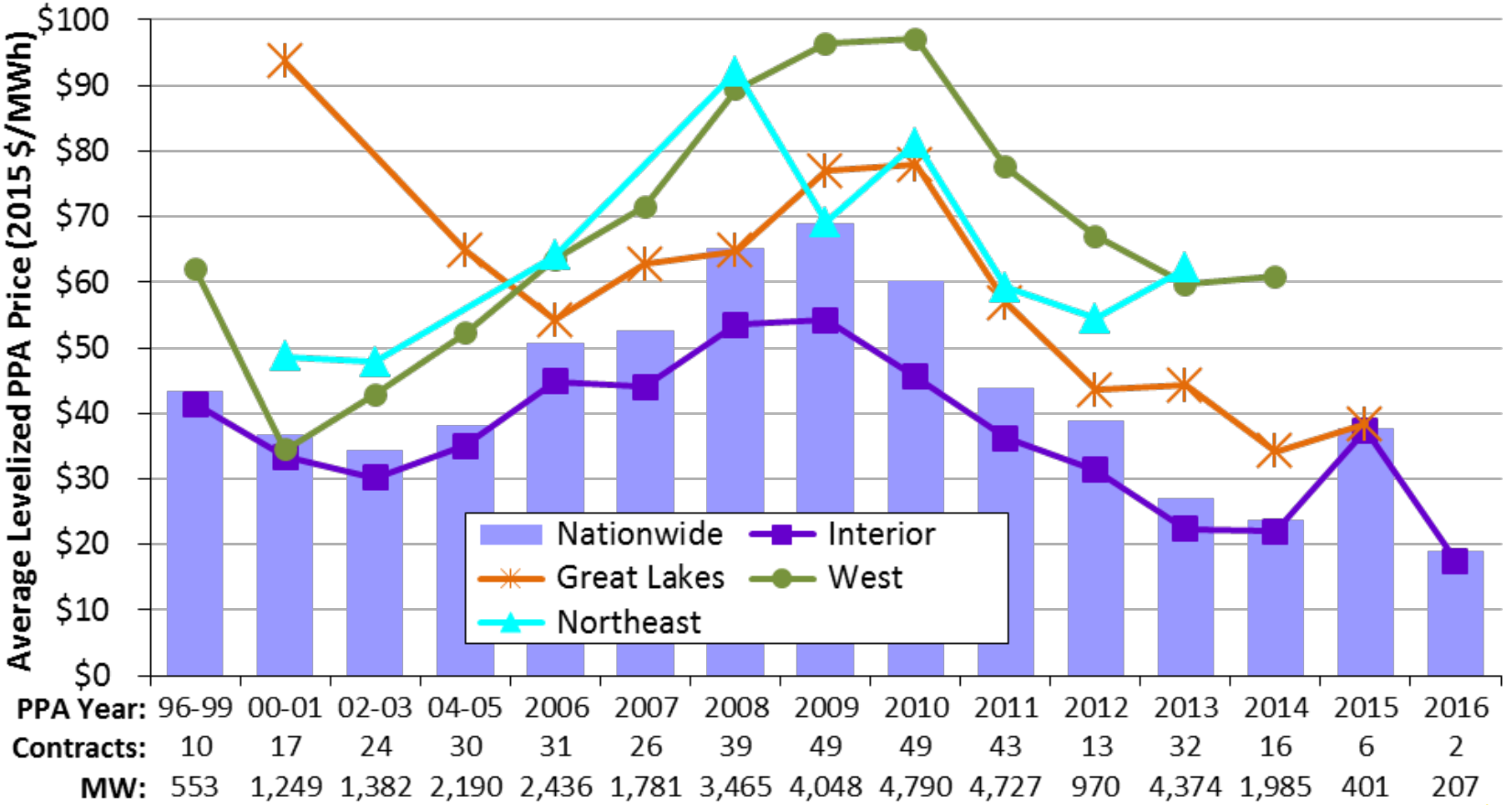
Sample of Wind Power Prices

- 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

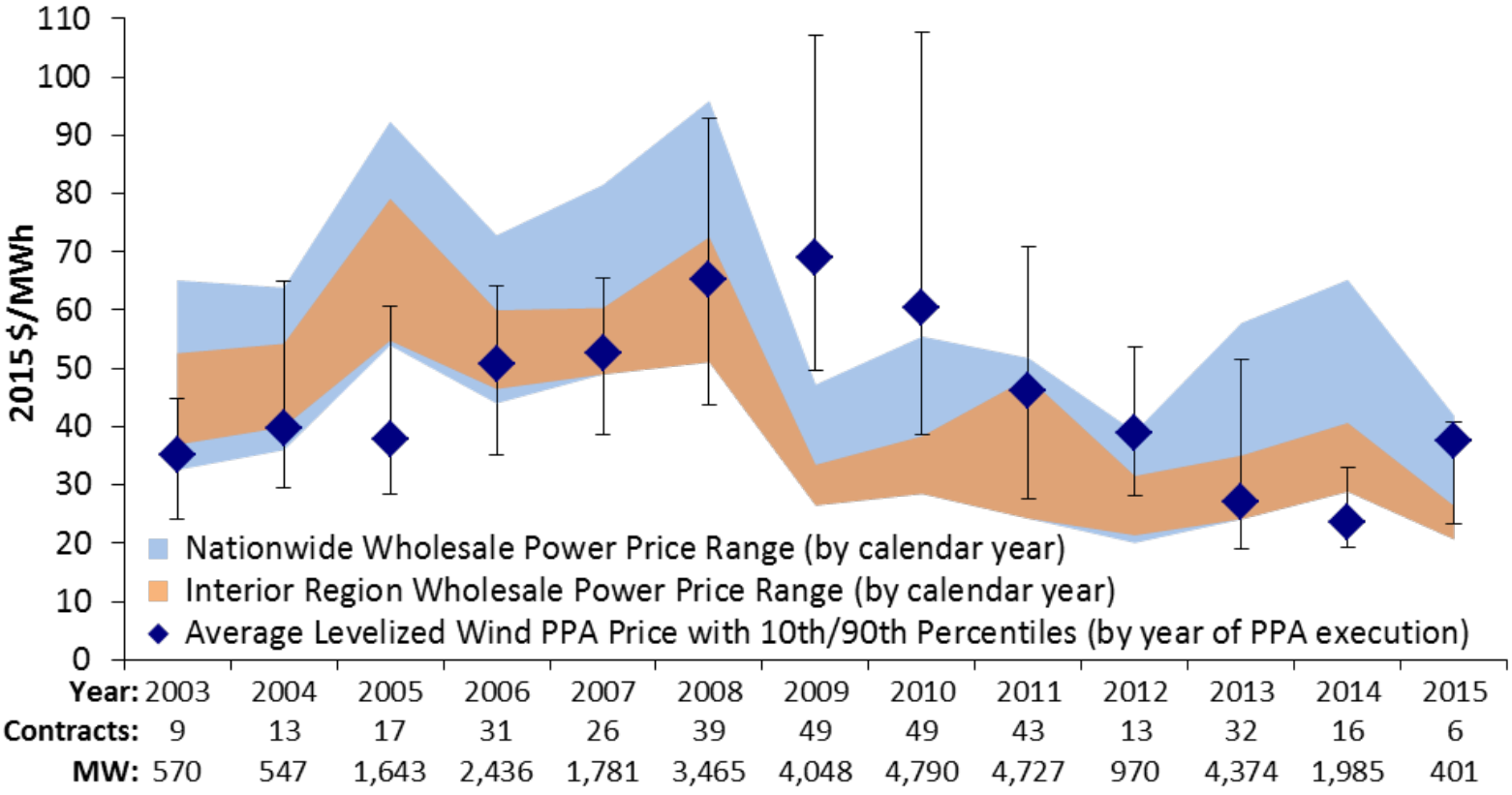
Wind PPA Prices Remain Very Low, Especially in Interior Region



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***

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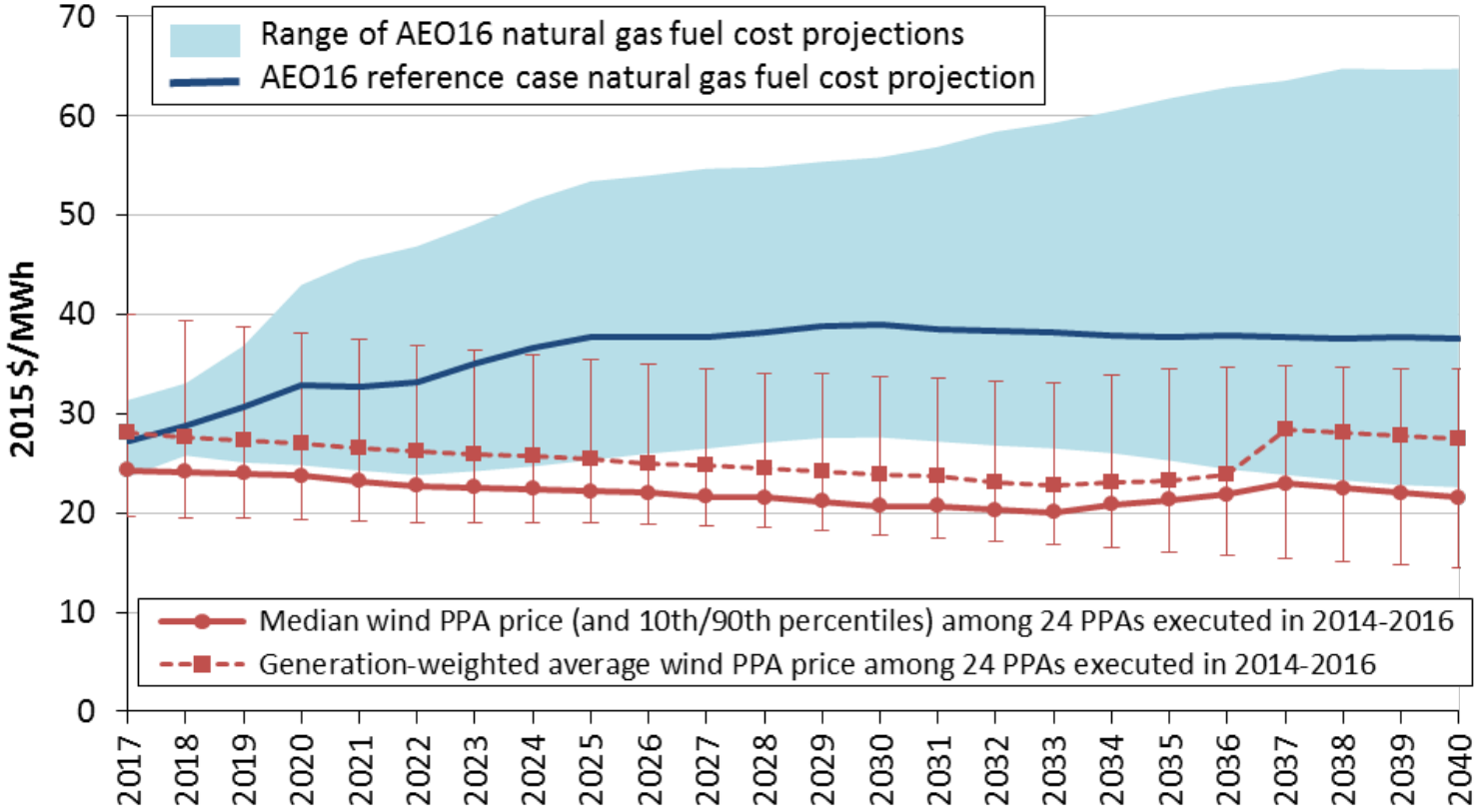
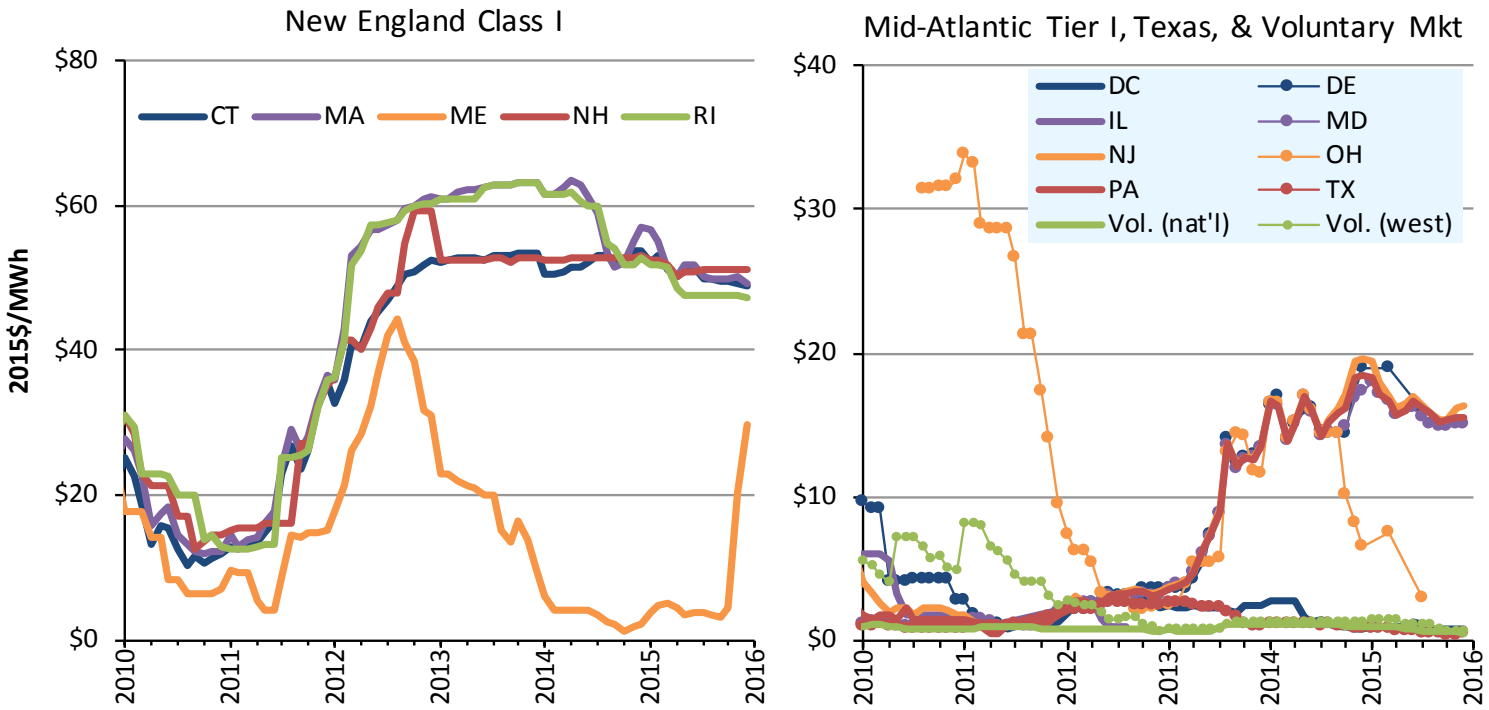
Recent Wind Prices Are Hard to Beat: Competitive with Expected Future Cost of Burning Fuel in Natural Gas Plants



*Price comparison shown here is far from perfect – **see full report for caveats***

Renewable Energy Certificate (REC) Prices Remain High in Northeast, While Falling Modestly among Mid-Atlantic States



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

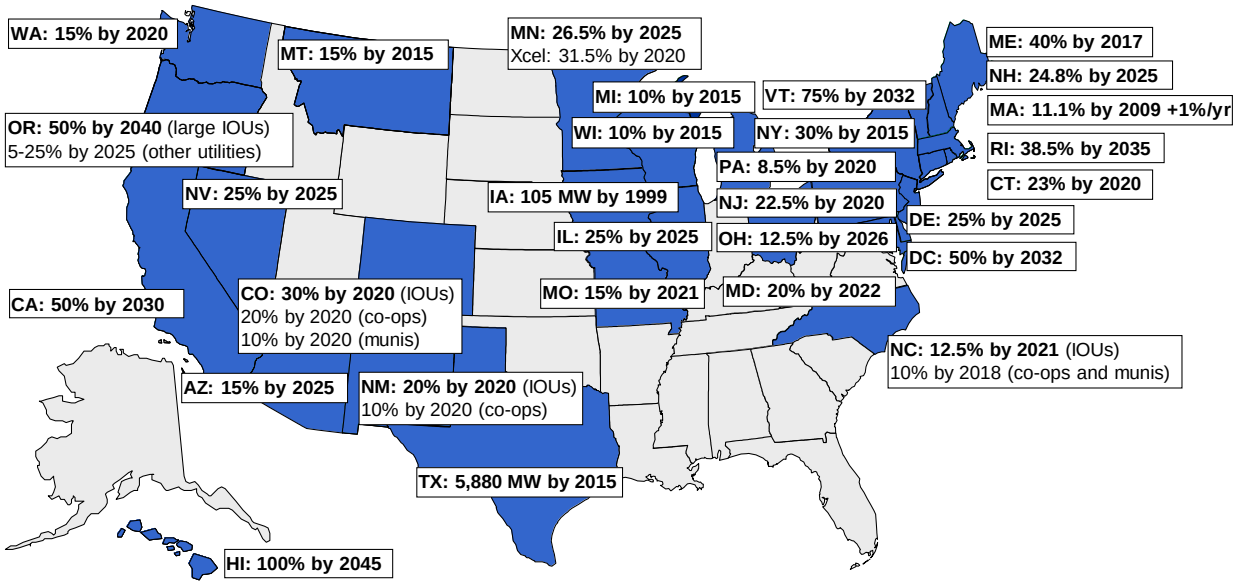
Policy and Market Drivers

Long-Term Extension and Phase Down of PTC Leading to Resurgent Market

- 5-year extension of PTC, plus favorable guidance allowing 4 years for project completion after the start of construction
- Glide path to a lower PTC, with progressive reduction in the value of the credit for projects starting construction after 2016
- PTC will phase down in 20%-per-year increments for projects starting construction in 2017 (80% PTC value), 2018 (60%), and 2019 (40%)

Legislation	Date Enacted	Start of PTC Window	End of PTC Window	Effective PTC Planning Window (considering lapses and early extensions)
Energy Policy Act of 1992	10/24/1992	1/1/1994	6/30/1999	80 months
Ticket to Work and Work Incentives Improvement Act of 1999	12/19/1999 *(lapsed for >5 months)*	7/1/1999	12/31/2001	24 months
Job Creation and Worker Assistance Act	3/9/2002 *(lapsed for >2 months)*	1/1/2002	12/31/2003	22 months
The Working Families Tax Relief Act	10/4/2004 *(lapsed for >9 months)*	1/1/2004	12/31/2005	15 months
Energy Policy Act of 2005	8/8/2005	1/1/2006	12/31/2007	29 months
Tax Relief and Healthcare Act of 2006	12/20/2006	1/1/2008	12/31/2008	24 months
Emergency Economic Stabilization Act of 2008	10/3/2008	1/1/2009	12/31/2009	15 months
The American Recovery and Reinvestment Act of 2009	2/17/2009	1/1/2010	12/31/2012	46 months
American Taxpayer Relief Act of 2012	1/2/2013 *(lapsed for 1-2 days)*	1/1/2013	Start construction by 12/31/2013	12 months (in which to start construction)
Tax Increase Prevention Act of 2014	12/19/2014 *(lapsed for >11 months)*	1/1/2014	Start construction by 12/31/2014	2 weeks (in which to start construction)
Consolidated Appropriations Act of 2016	12/18/2015 *(lapsed for >11 months)*	1/1/2015	Start construction by 12/31/2016	12 months to start construction and receive 100% PTC value
			Start construction by 12/31/2017	24 months to start construction and receive 80% PTC value
			Start construction by 12/31/2018	36 months to start construction and receive 60% PTC value
			Start construction by 12/31/2019	48 months to start construction and receive 40% PTC value

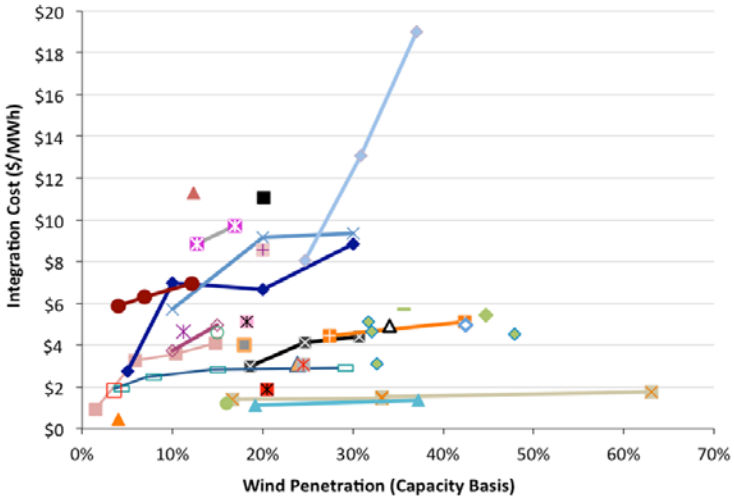
State Policies Help Direct the Location and Amount of Wind Development, but Current Policies Cannot Support Continued Growth at Recent Levels



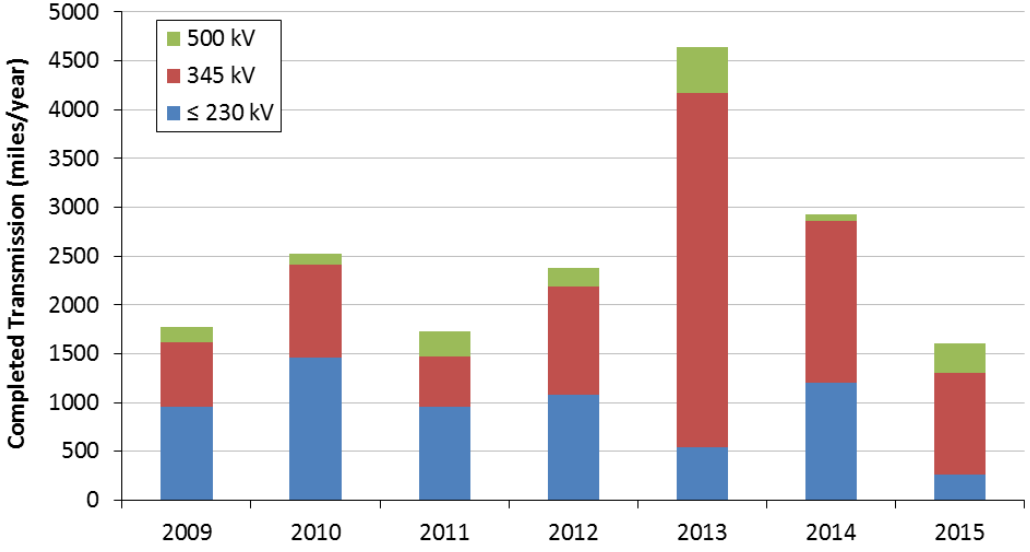
- 29 states and D.C. have mandatory RPS programs
- State RPS' can support ~3.7 GW/yr of renewable energy additions on average through 2030 (less for wind specifically)

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.

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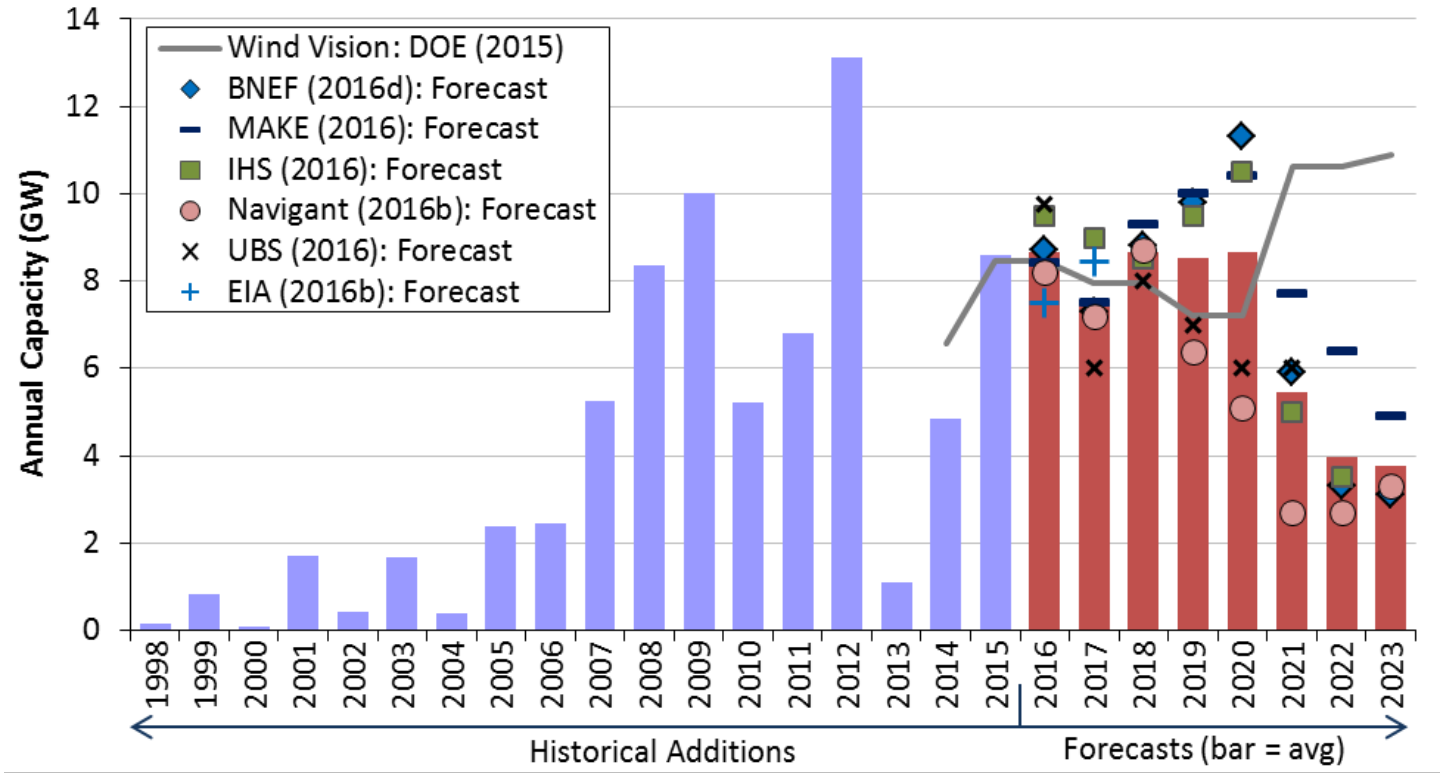
Future Outlook

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

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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

Conclusions

- Annual wind capacity additions surged in 2015, w/ significant additional new builds anticipated over next five years in part due to PTC extension
- Wind has been a significant source of new electric generation capacity additions in the U.S. in recent years
- Supply chain has been under some duress, but domestic manufacturing content for nacelle assembly, blades, and towers is strong
- Turbine scaling is significantly boosting wind project performance, while the installed cost of wind projects has declined
- Wind power sales prices remain near all-time lows, enabling economic competitiveness despite low natural gas prices
- Growth beyond current PTC cycle remains uncertain: could be blunted by declining federal tax support, expectations for low natural gas prices, and modest electricity demand growth

For More Information...

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

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

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