WIND AND WATER POWER TECHNOLOGIES OFFICE

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

2014 Wind Technologies Market Report: Summary

August 2015

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Lawrence Berkeley National Laboratory

2014 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 2014
- Scope primarily includes wind turbines over 100 kW in size
- Separate DOE-funded annual reports on distributed and offshore 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

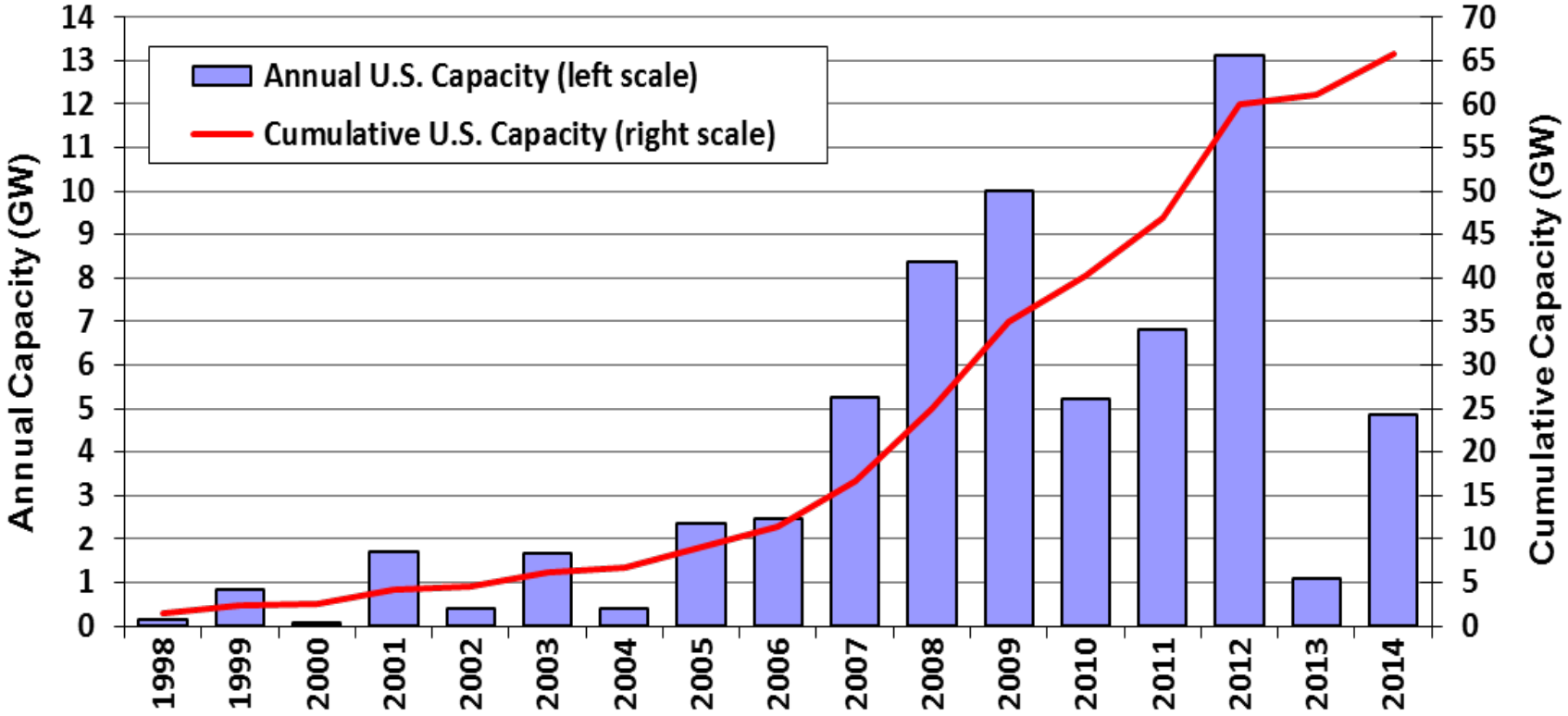
- Installation trends
- Industry trends
- Technology trends
- Performance trends
- Cost trends
- Wind power price trends
- Policy & market drivers
- Future outlook

Key Findings

- Annual wind capacity additions rebounded in 2014, with significant additional new builds anticipated for 2015 and 2016
- Wind has been a significant source of new electric generation capacity additions in the U.S. in recent years
- Supply chain has been under duress, but domestic manufacturing content for nacelle assembly, blades, and towers is strong
- Turbine scaling is boosting expected wind project performance, while the installed cost of wind projects is on the decline
- Wind power sales prices have reached all-time lows, enabling economic competitiveness despite low natural gas prices
- Growth after 2016 remains uncertain, dictated in part by future natural gas prices and policy decisions, though recent declines in the price of wind energy boost future growth prospects

Installation Trends

Wind Power Additions Rebounded in 2014, with 4,854 MW of New Capacity Added



- $8.3 billion invested in wind power project additions in 2014
- Wind build well off annual additions from 2007 through 2012
- Cumulative wind capacity up nearly 8%, bringing total to 65.9 GW

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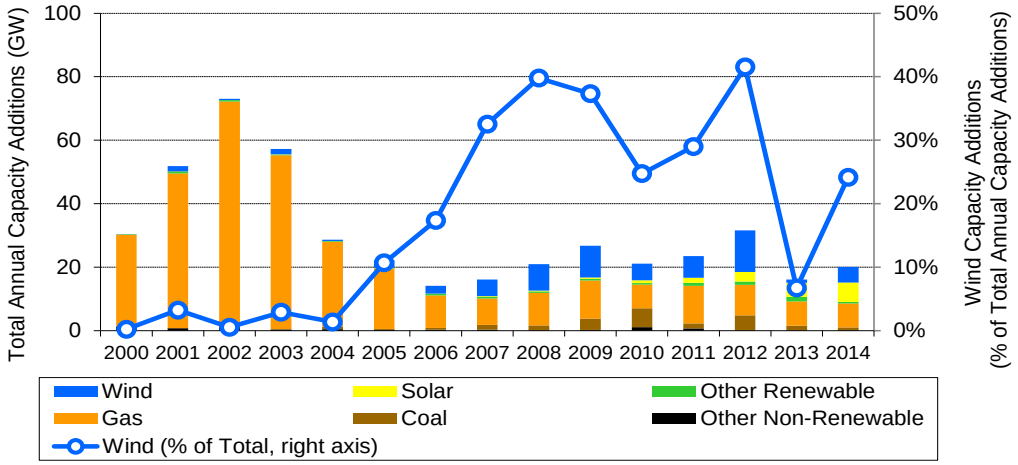
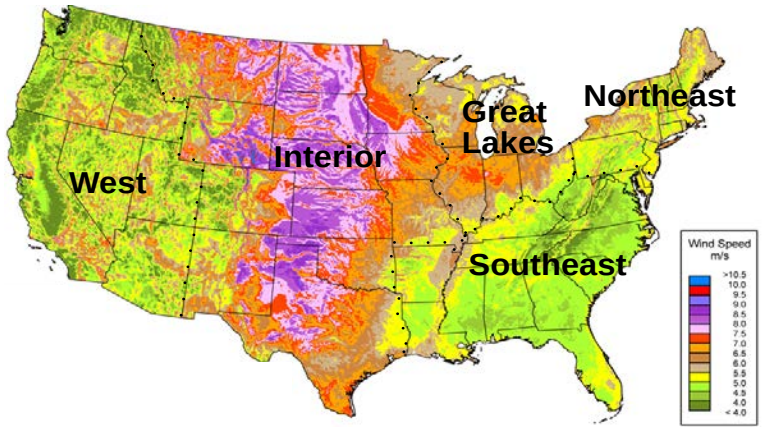
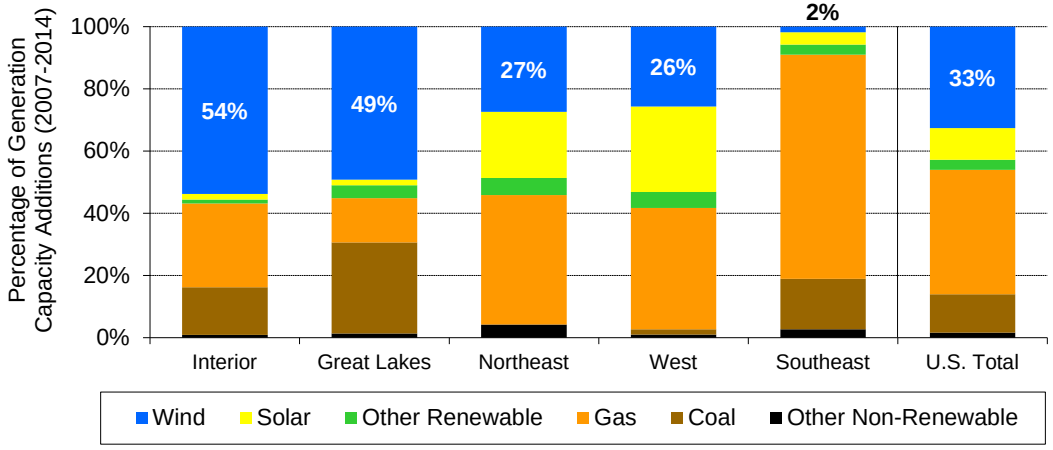
Wind Power Represented 24% of Electric-Generating Capacity Additions in 2014







From 2007-2014, wind comprised 33% of capacity additions nation-wide, and a much higher proportion in some regions

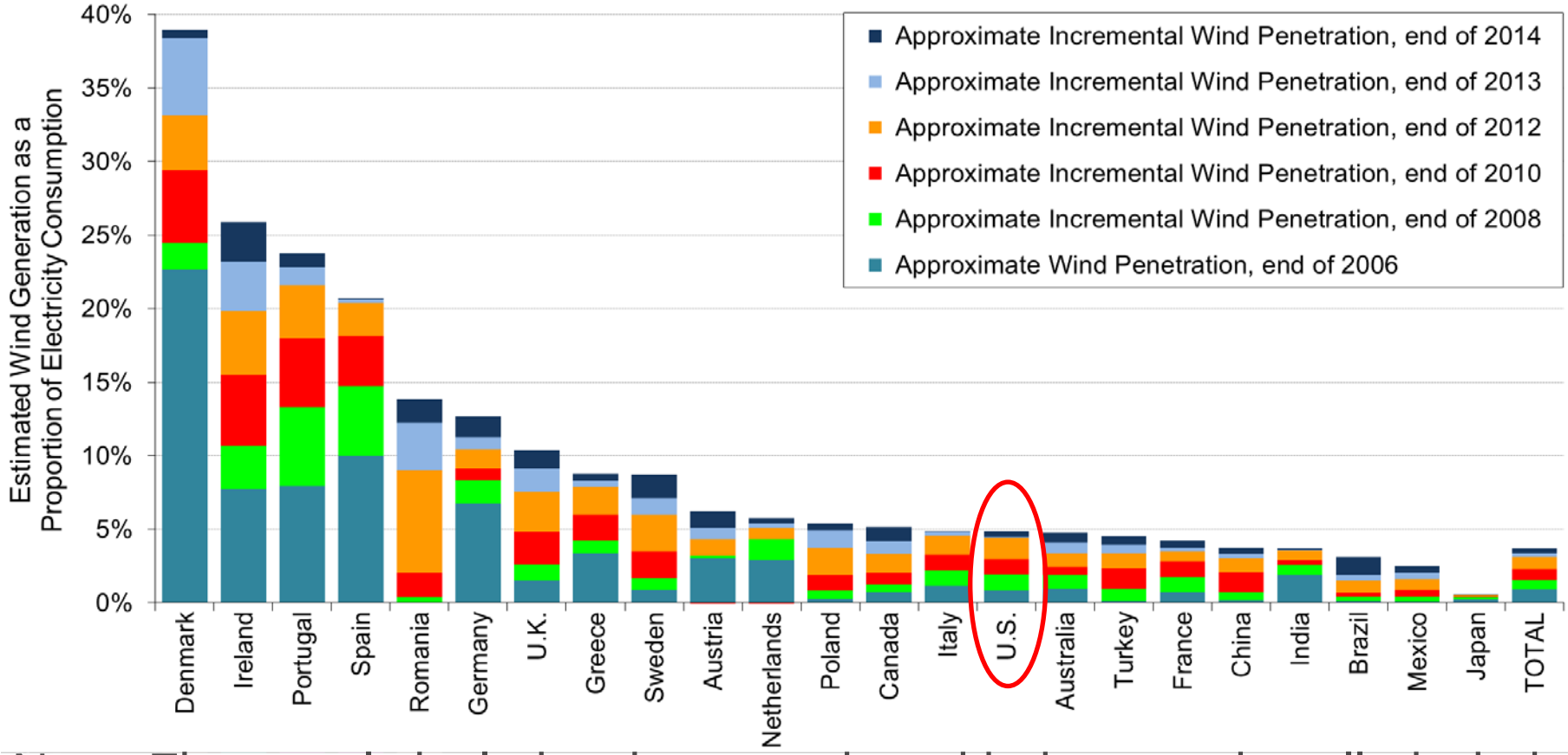
The U.S. Placed 3rd in Annual Wind Power Capacity Additions in 2014

Annual Capacity (2014, MW)		Cumulative Capacity (end of 2014, MW)	
China	23,300	China	114,760
Germany	5,119	**United States**	**65,877**
United States	**4,854**	Germany	39,223
Brazil	2,783	India	22,904
India	2,315	Spain	22,665
Canada	1,871	United Kingdom	12,413
United Kingdom	1,467	Canada	9,684
Sweden	1,050	France	9,170
France	1,042	Italy	8,556
Turkey	804	Brazil	6,652
Rest of World	6,625	*Rest of World*	60,208
TOTAL	**51,230**	**TOTAL**	**372,112**

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

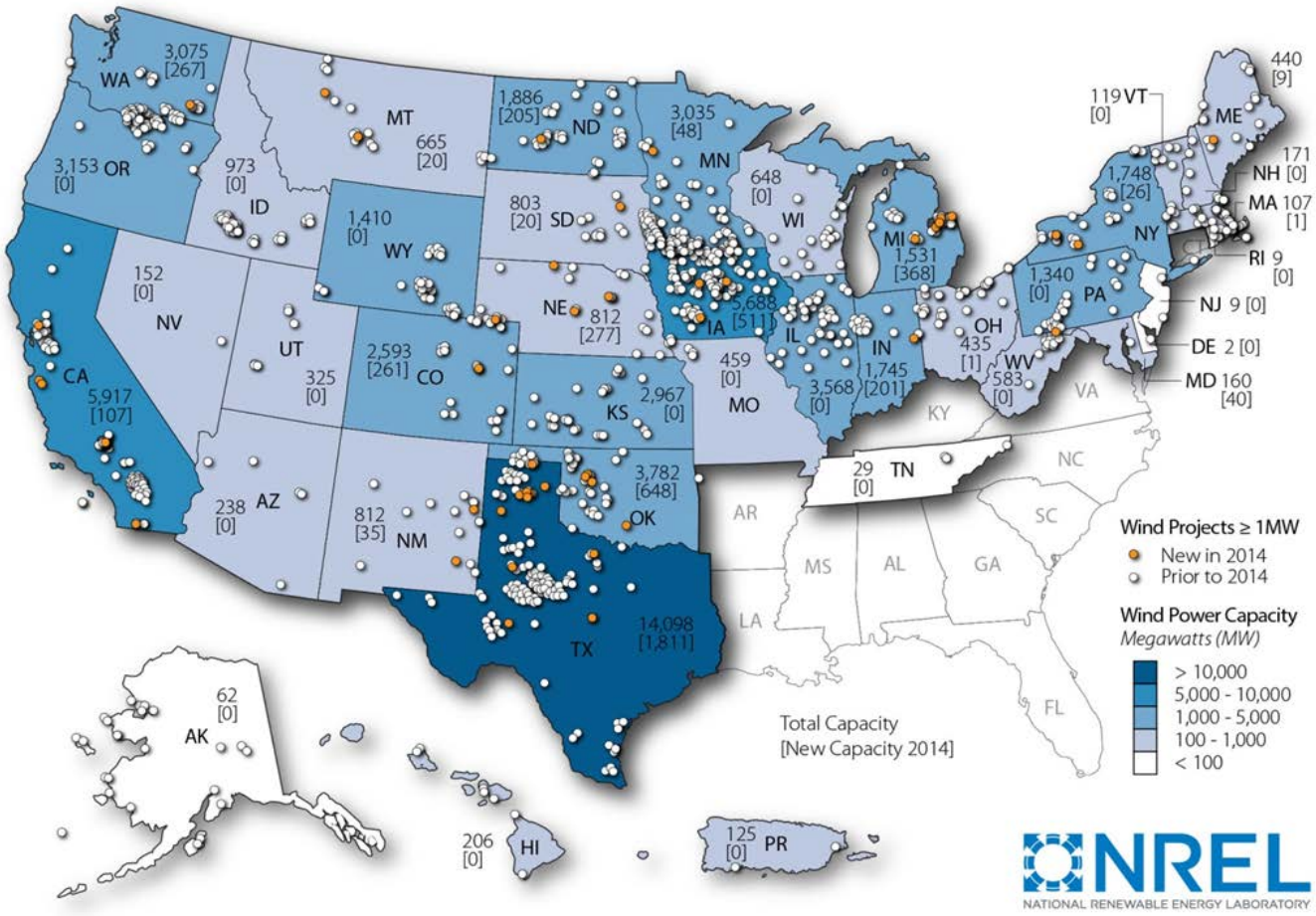
- Global wind additions reached a new high in 2014
- U.S. remains a distant second to China in cumulative capacity
- U.S. led the world in wind energy production in 2014

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 2014

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 2014

Texas Installed the Most Capacity in 2014; 9 States Exceed 12% Wind Energy

Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2014)		Cumulative (end of 2014)		Actual (2014)*	
Texas	1,811	Texas	14,098	Iowa	28.5%
Oklahoma	648	California	5,917	South Dakota	25.3%
Iowa	511	Iowa	5,688	Kansas	21.7%
Michigan	368	Oklahoma	3,782	Idaho	18.3%
Nebraska	277	Illinois	3,568	North Dakota	17.6%
Washington	267	Oregon	3,153	Oklahoma	16.9%
Colorado	261	Washington	3,075	Minnesota	15.9%
North Dakota	205	Minnesota	3,035	Colorado	13.6%
Indiana	201	Kansas	2,967	Oregon	12.7%
California	107	Colorado	2,593	Texas	9.0%
Minnesota	48	North Dakota	1,886	Wyoming	8.9%
Maryland	40	New York	1,748	Maine	8.3%
New Mexico	35	Indiana	1,745	New Mexico	7.0%
New York	26	Michigan	1,531	California	7.0%
Montana	20	Wyoming	1,410	Nebraska	6.9%
South Dakota	20	Pennsylvania	1,340	Montana	6.5%
Maine	9	Idaho	973	Washington	6.3%
Ohio	0.9	New Mexico	812	Hawaii	5.9%
Massachusetts	0.6	Nebraska	812	Illinois	5.0%
		South Dakota	803	Vermont	4.4%
Rest of U.S.	0	*Rest of U.S.*	4,941	*Rest of U.S.*	0.9%
TOTAL	**4,854**	**TOTAL**	**65,877**	**TOTAL**	**4.4%**

* Based on 2014 wind and total generation by state from EIA's *Electric Power Monthly*.

- Texas has more than twice as much wind capacity as any other state
- 23 states had >500 MW of capacity at end of 2014 (16 > 1 GW, 10 > 2 GW)
- 2 states have >25% of total in-state generation from wind (9 states > 12%)

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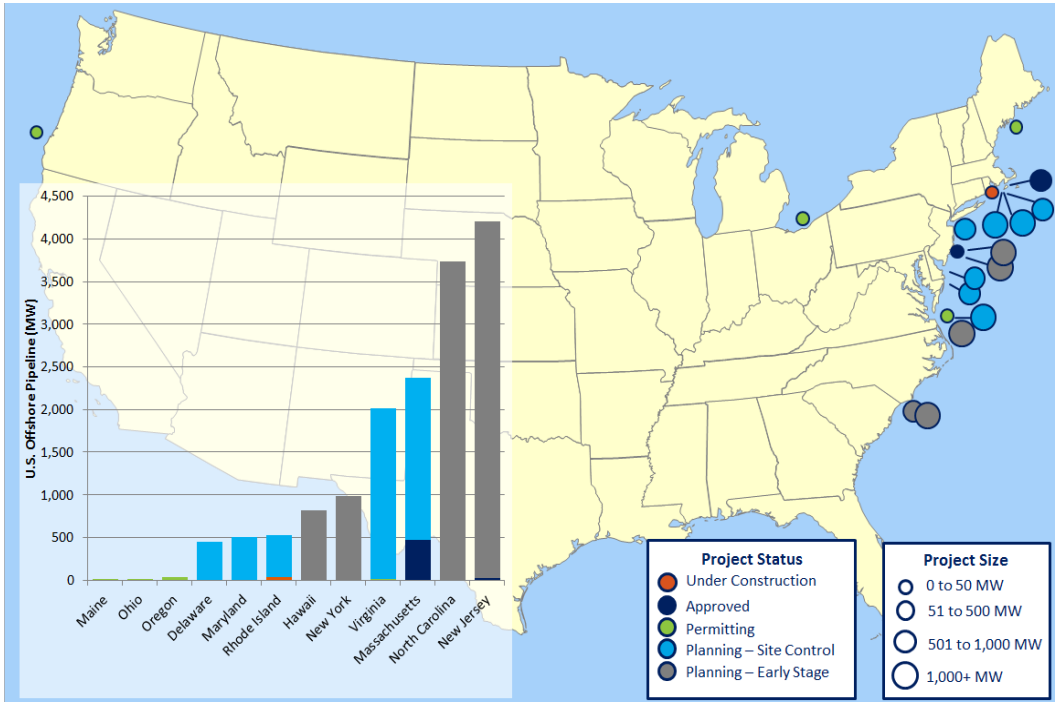
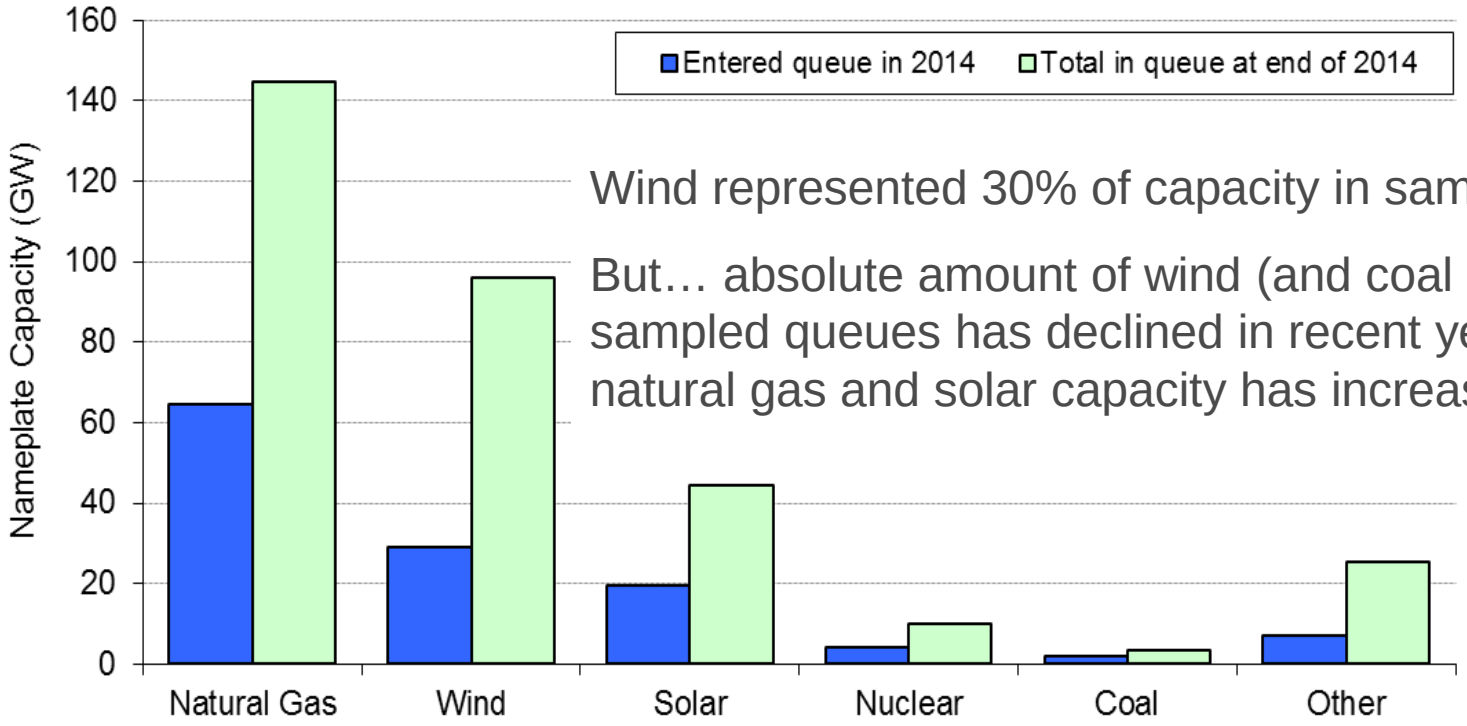
No Commercial Offshore Wind Turbines Commissioned; 1 Project in Construction and 18 in Various Stages of Development



- 30 MW Block Island project (RI) started construction in 2015
- BOEM has granted 5 competitive leases; DOE funding 3 pilot deployments
- Legal and political headwind for high-profile projects:
  - Cape Wind (MA) power purchase agreements cancelled by utilities
  - Fishermen's Atlantic City (NJ) rejected by state PUC
  - Dominion (VA) announced delay due to cost
- Pressing challenges include cost, lack of PPAs and policy incentives, regulatory complexity

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



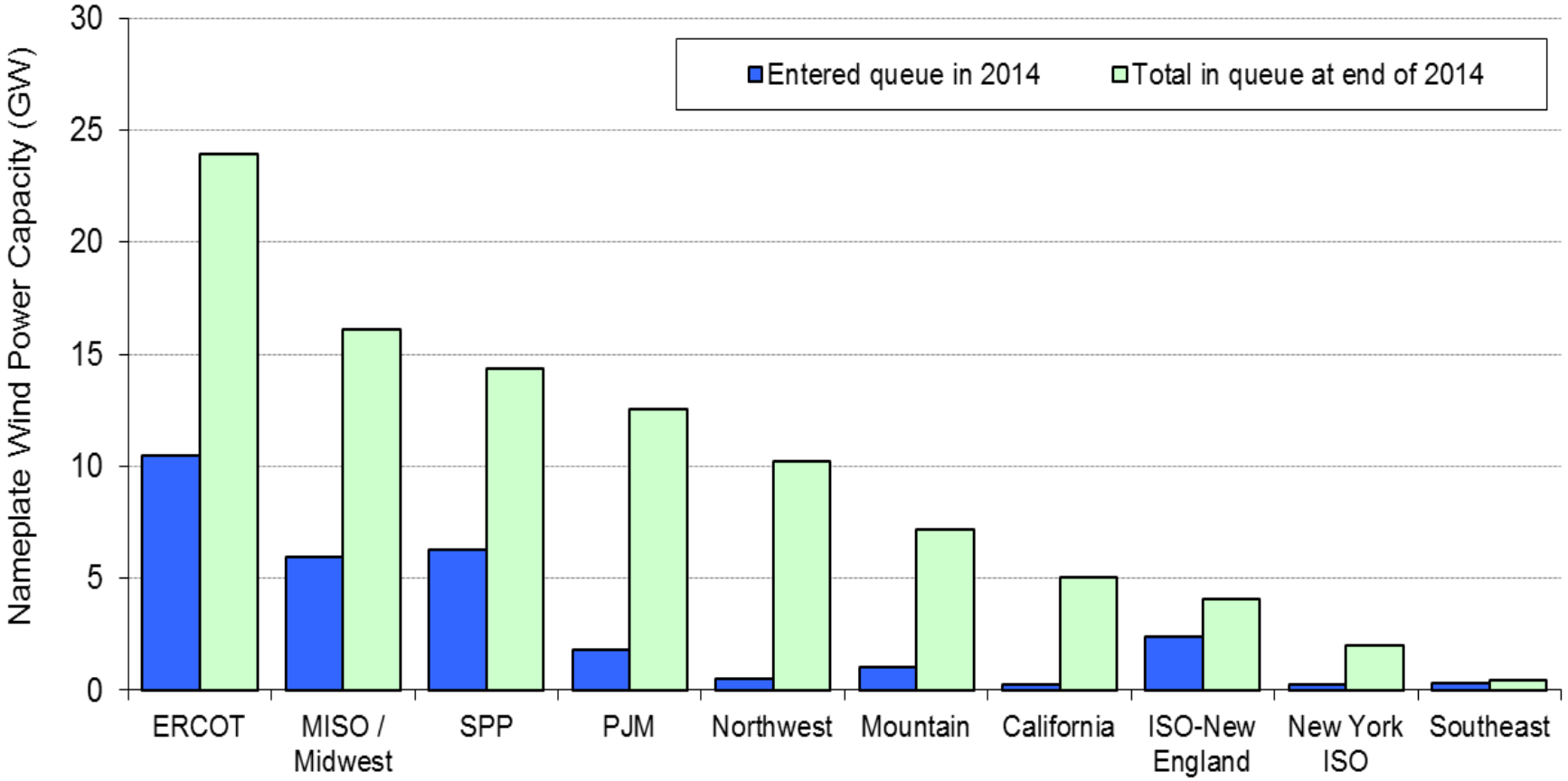
Wind represented 30% of capacity in sampled 35 queues

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

Not all of this capacity will be built….

- AWEA reports 13.6 GW of capacity under construction after 1Q2015

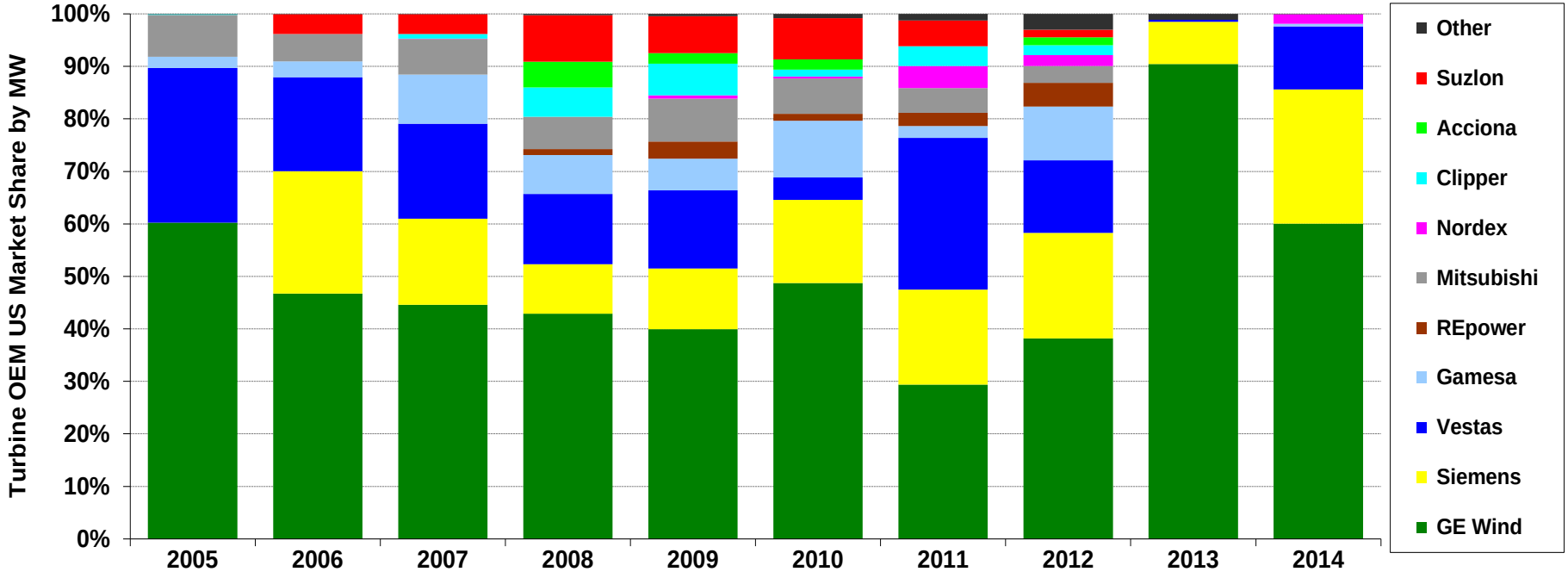
Larger Amounts of Wind Planned for Texas, Midwest, Southwest Power Pool, PJM, and Northwest



Not all of this capacity will be built….

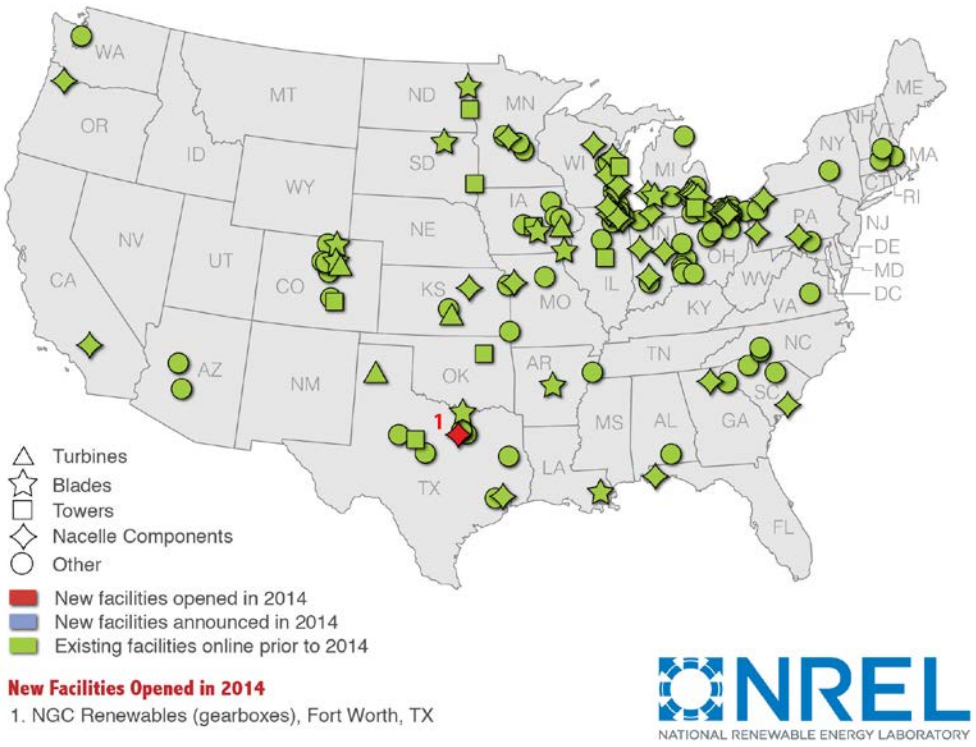
Industry Trends

GE, Siemens, and Vestas Captured 98% of the U.S. Market in 2014



- Recent dominance of the three-largest turbine suppliers in the U.S. market
- Globally, Vestas remained the top supplier, followed by Siemens and GE
- Chinese suppliers occupied 8 of the top 15 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

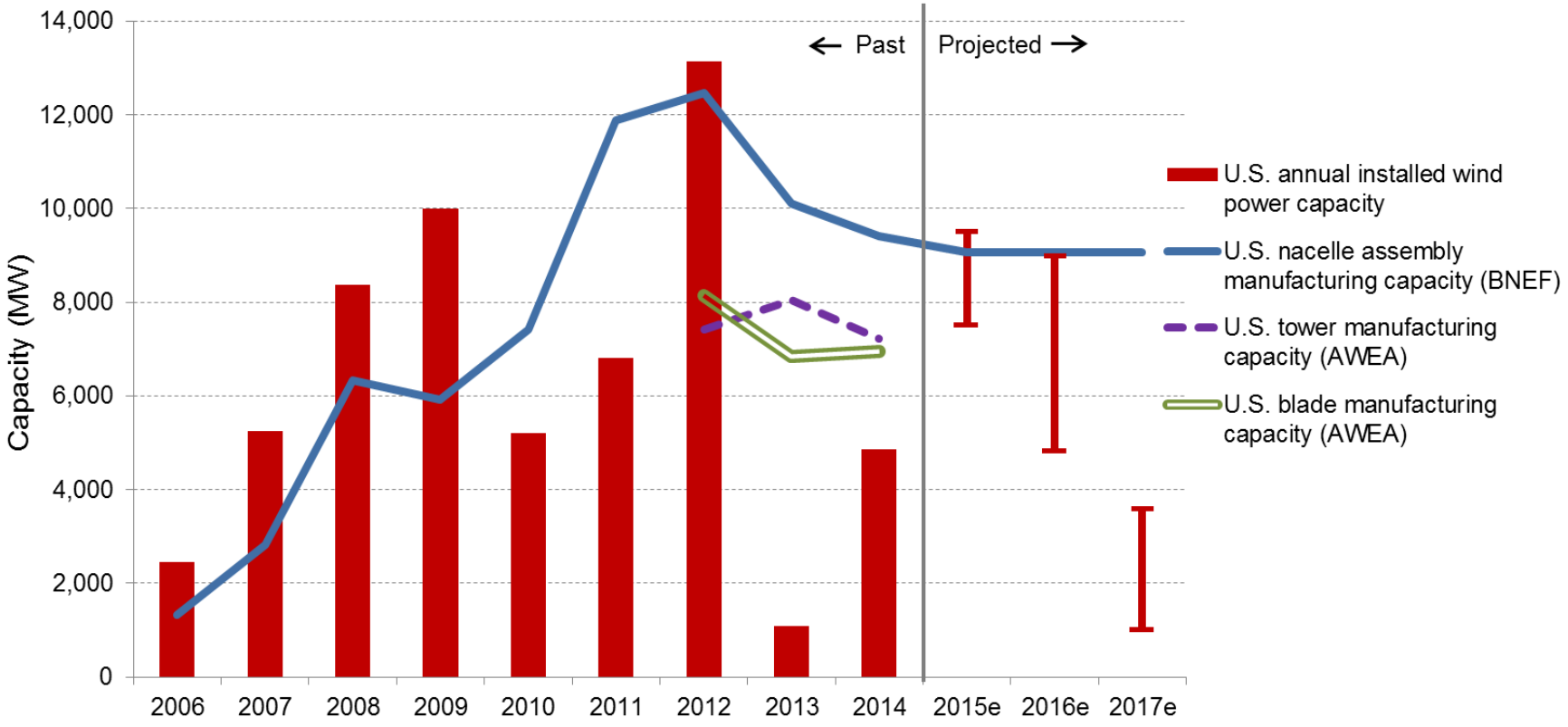


Note: map not intended to be exhaustive

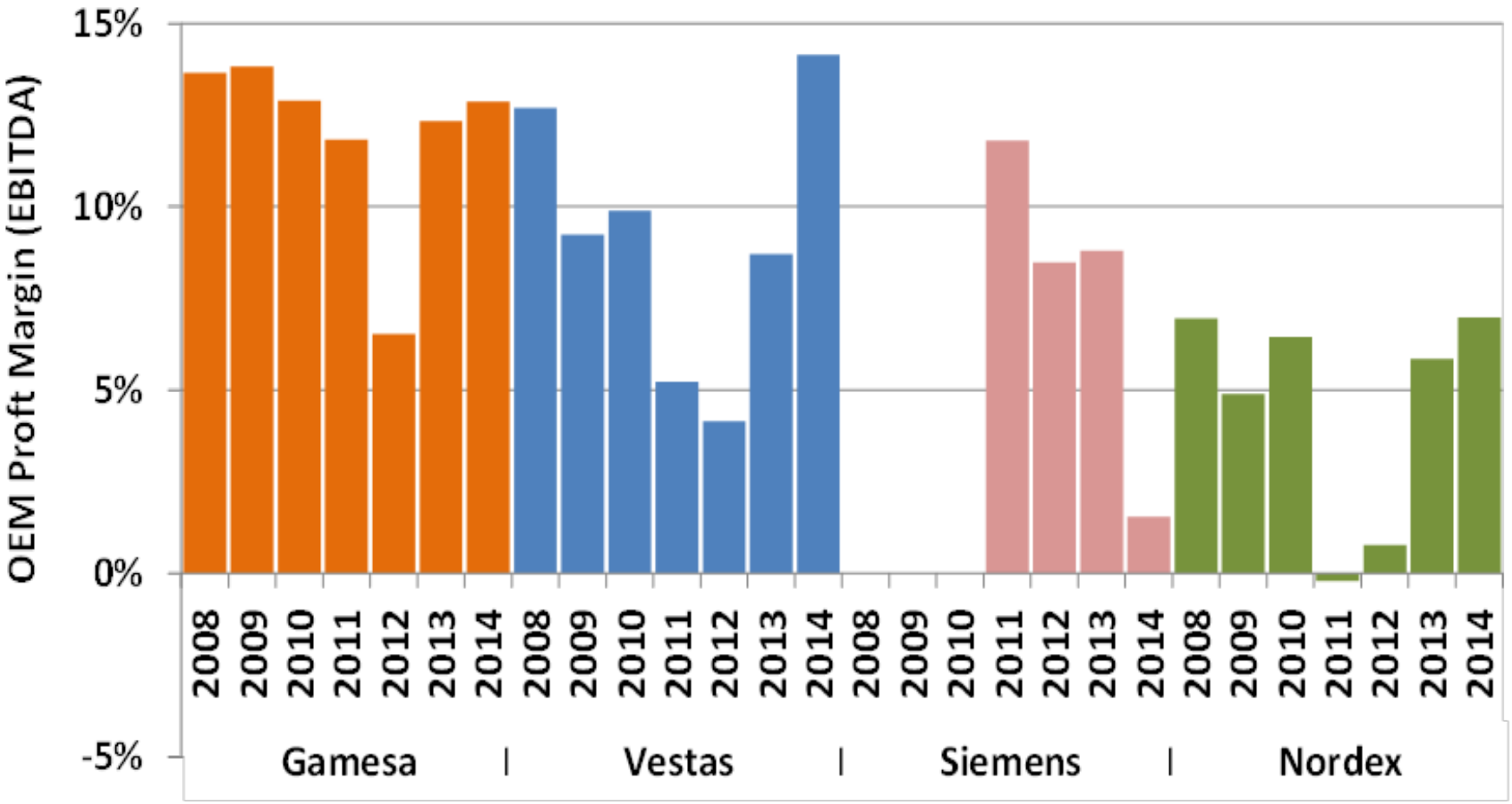
Realignment Continued…

- Uncertain medium-term demand and growing global competition led to 12 domestic manufacturing facility closures in 2014; only 1 new facility opened
- Nonetheless, many supply chain manufacturers remain
- Over last decade, manufacturers have localized and expanded U.S. presence
- "Big 3" OEMs all still have at least one domestic facility
- Wind related jobs increased from 50,500 in 2013 to 73,000 in 2014

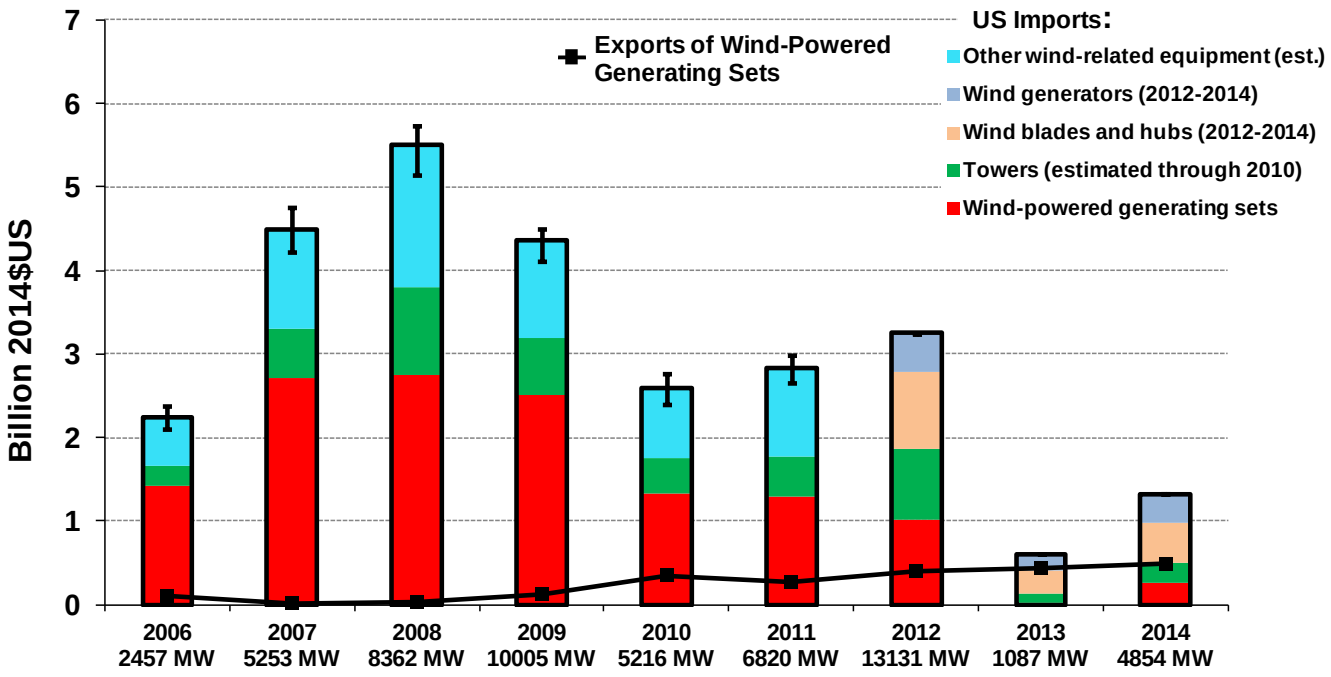
Domestic Manufacturing Capability for Nacelle Assembly, Towers, and Blades Is Reasonably Well Balanced Against Demand Forecasts for 2015 and 2016



Turbine OEM Profitability Has Generally Rebounded Over the Last Two Years



Imports of Wind Equipment Are Sizable; Exports Continue to Grow Slowly

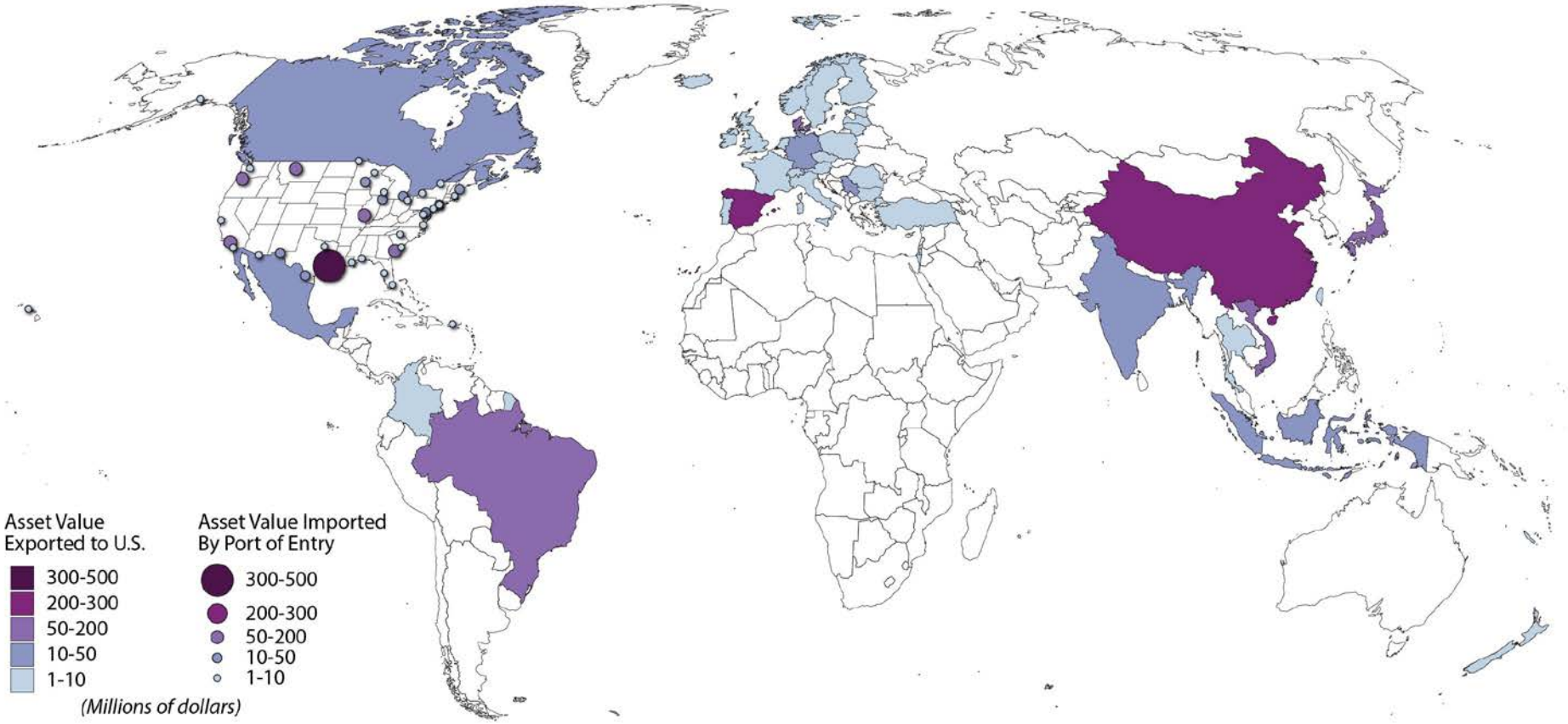


U.S. is a net importer of wind equipment

Exports of wind-powered generating sets increased modestly in 2014 to $488 billion; no ability to track other wind-specific exports, but total tower exports equalled $116 million

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

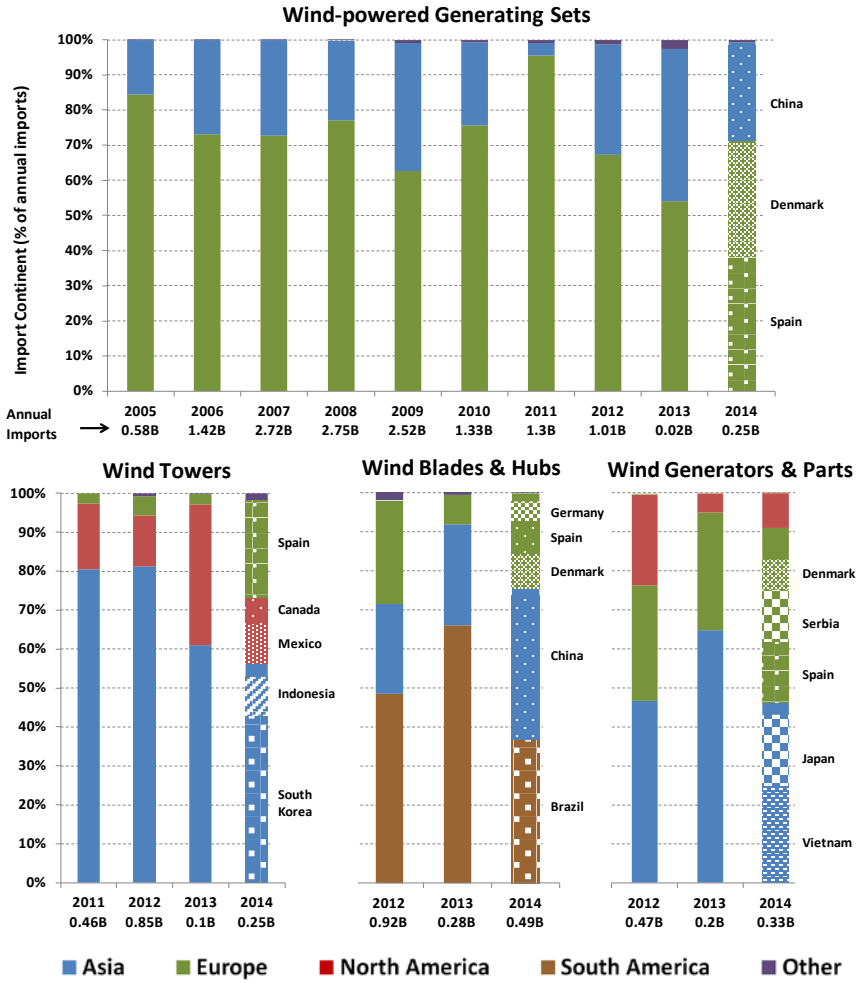
Tracked Wind Equipment Imports in 2014: 42% Asia, 39% Europe, 20% Americas



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 and Asia
- Majority of 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 Brazil and China in recent years
- Globally diverse sourcing strategy for generators & parts, dominated by Asian and European countries



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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

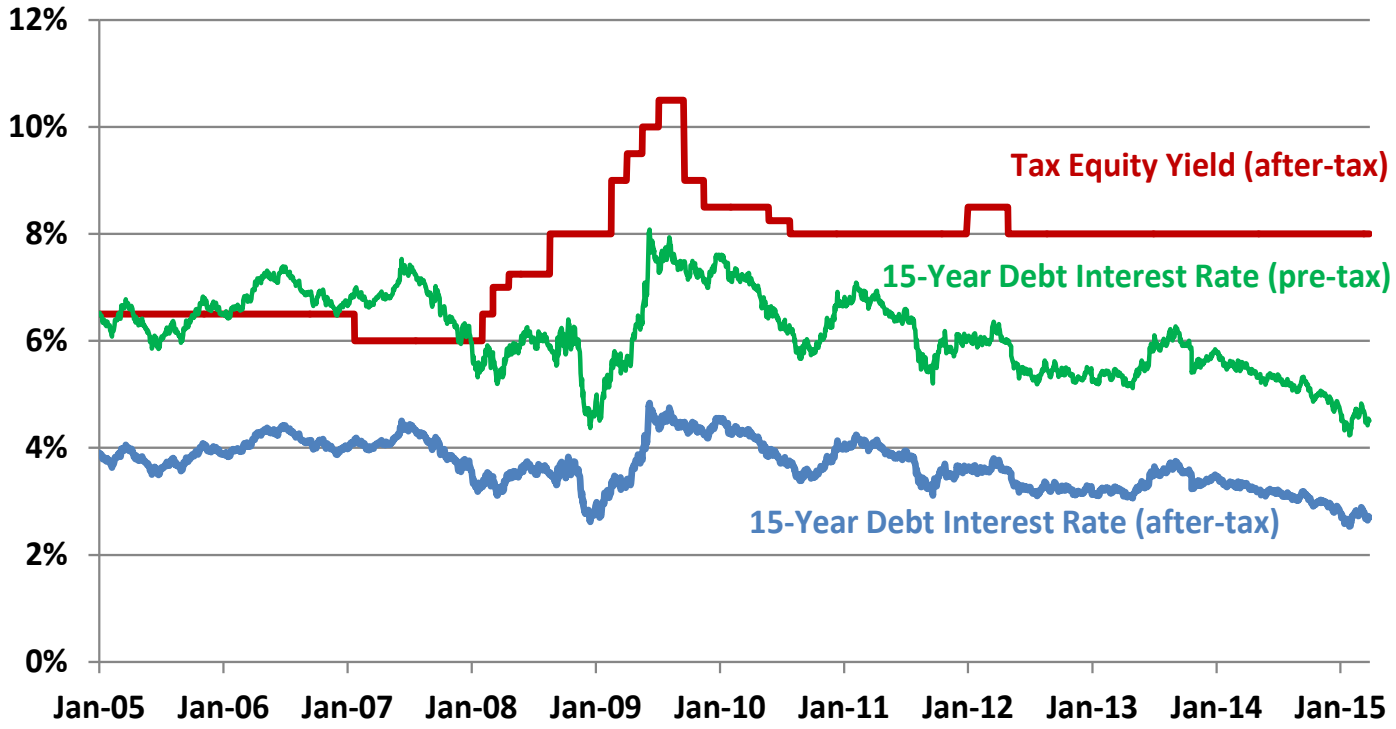
Domestic Content for 2013 – 2014 Turbine Installations in the U.S.

Generators	Towers	Blades & Hubs	Wind-Powered Generating Sets
< 15%	70-80%	45-65%	> 90% of nacelle assembly

Imports occur in untracked trade categories, including many nacelle internals

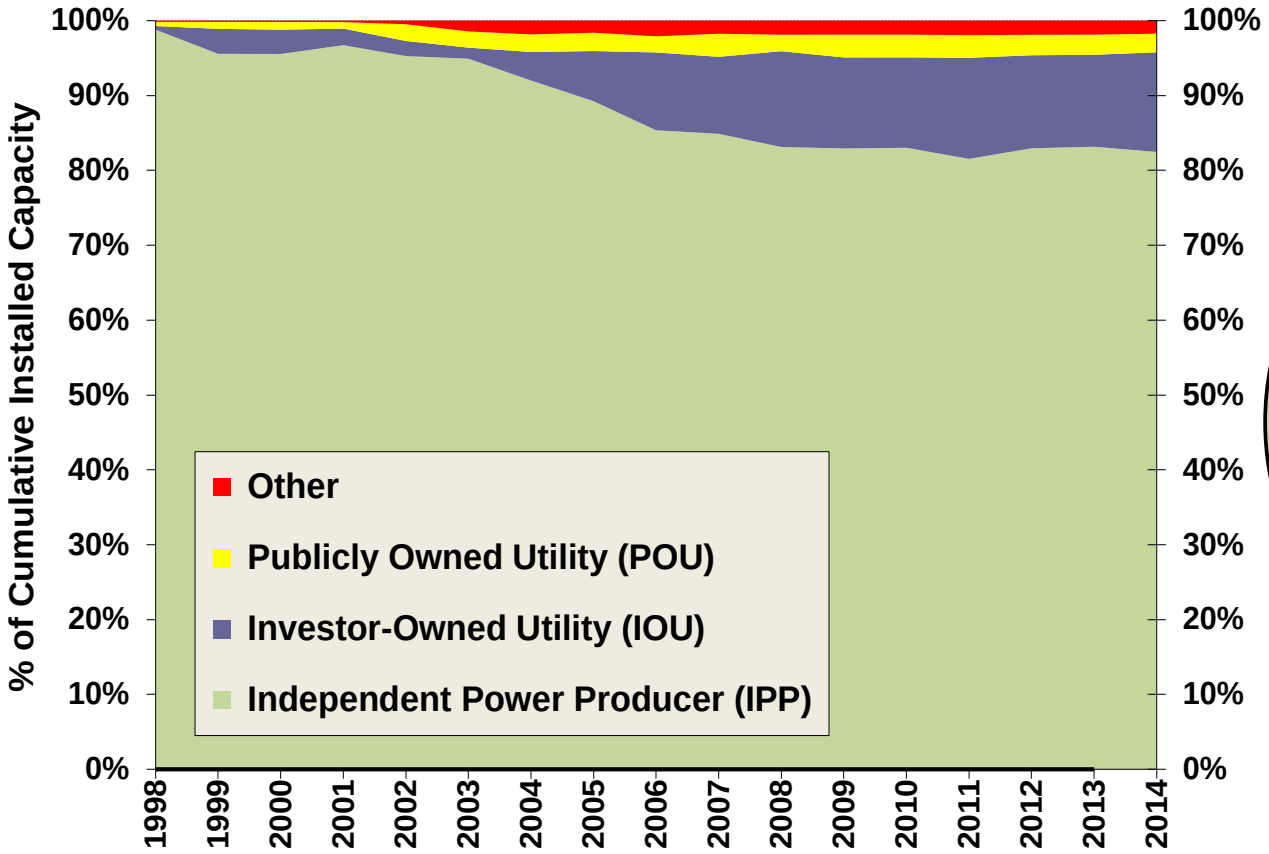
Overall estimated domestic content: ~40% in 2012 for wind turbine equipment; ~60% if considering total projects costs, including balance-of-plant

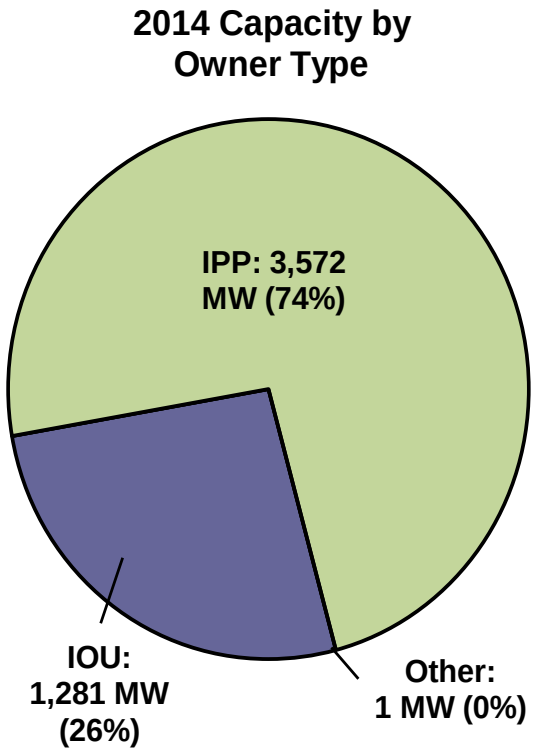
The Project Finance Environment Remained Strong in 2014



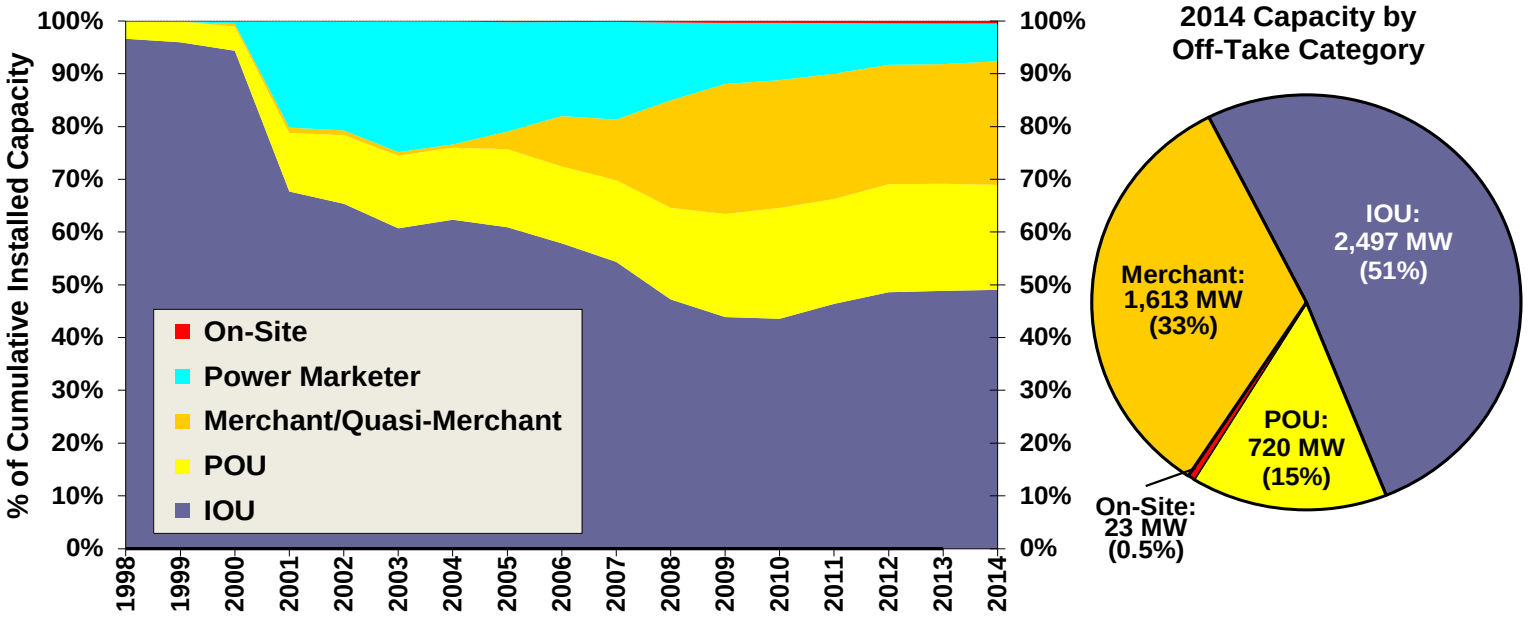
- Project sponsors raised $5.8 billion of tax equity (largest single-year amount on record) and $2.7 billion of debt in 2014
- Tax equity yields held steady, while debt interest rates trended lower

Utility Ownership of Wind Rebounded Somewhat in 2014; IPPs Still Dominate





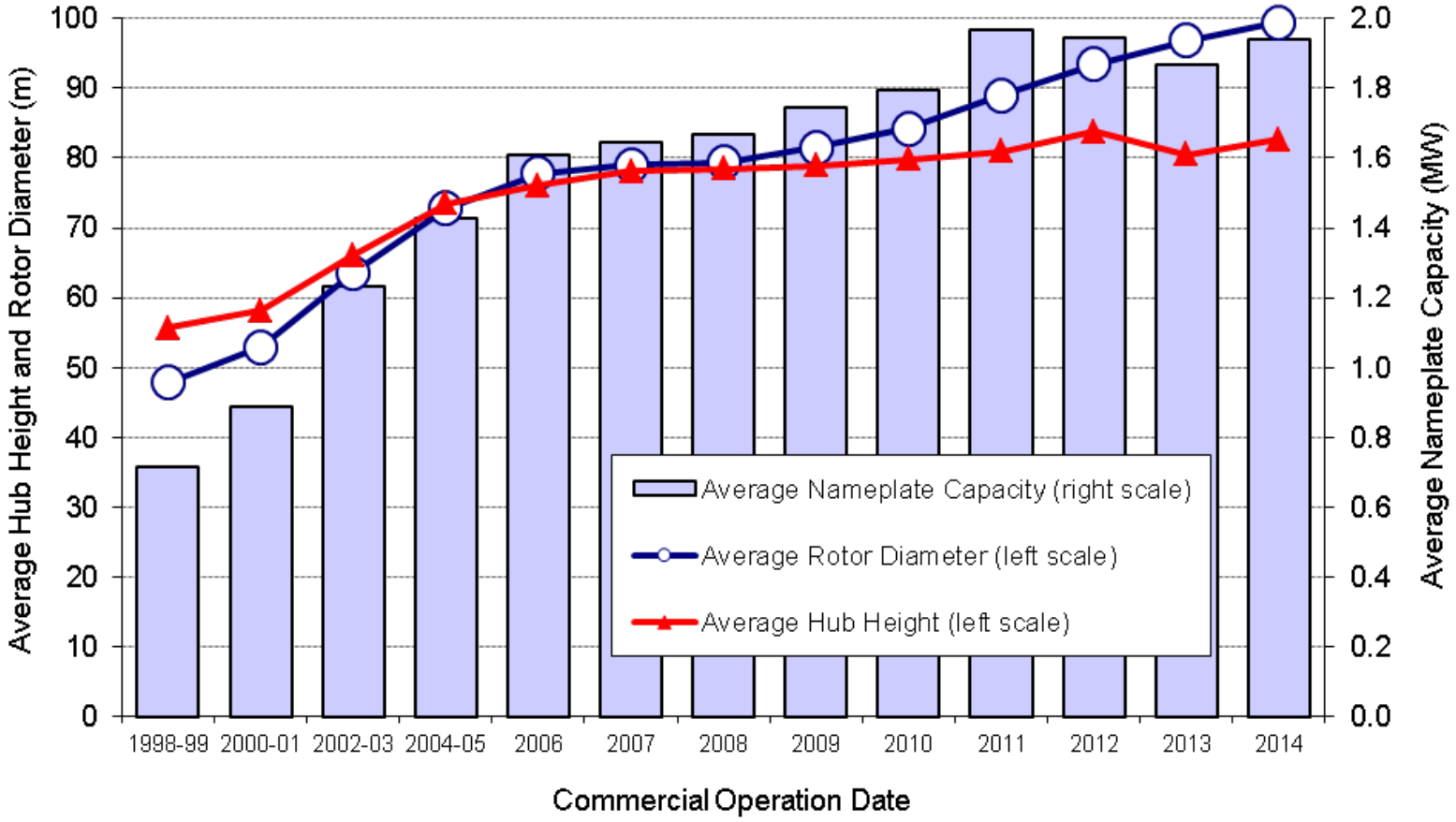
Long-Term Contracted Sales to Utilities Remained the Most Common Off-Take Arrangement, but Merchant Projects Continued to Expand, at Least in Texas



- Recently announced wind purchases of ~2 GW from technology companies and business giants to hospitals, universities, and government agencies

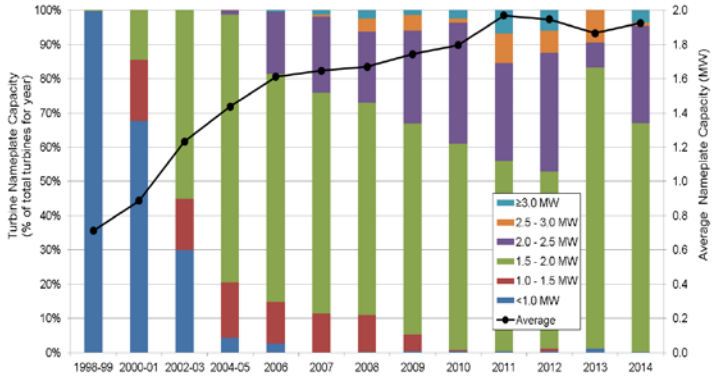
Technology Trends

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

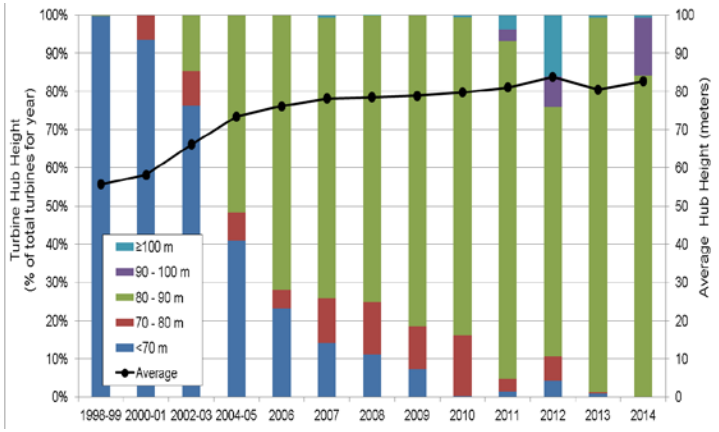


Growth in Rotor Diameter Has Outpaced Growth in Nameplate Capacity and Hub Height in Recent Years

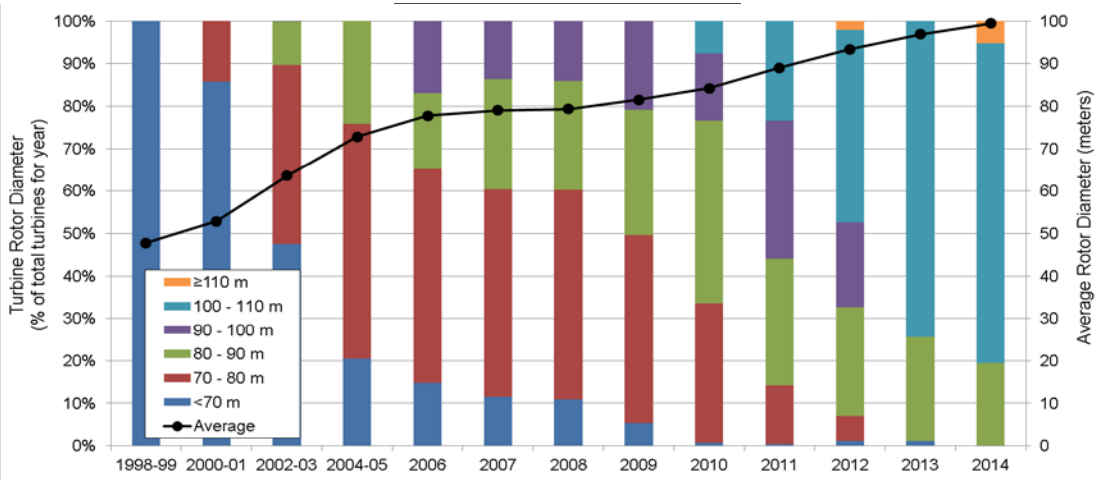
Nameplate Capacity



Hub Height

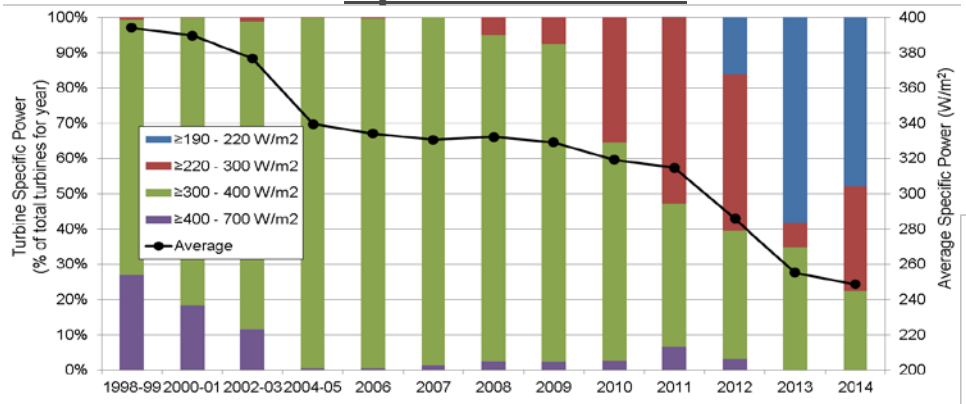


Rotor Diameter

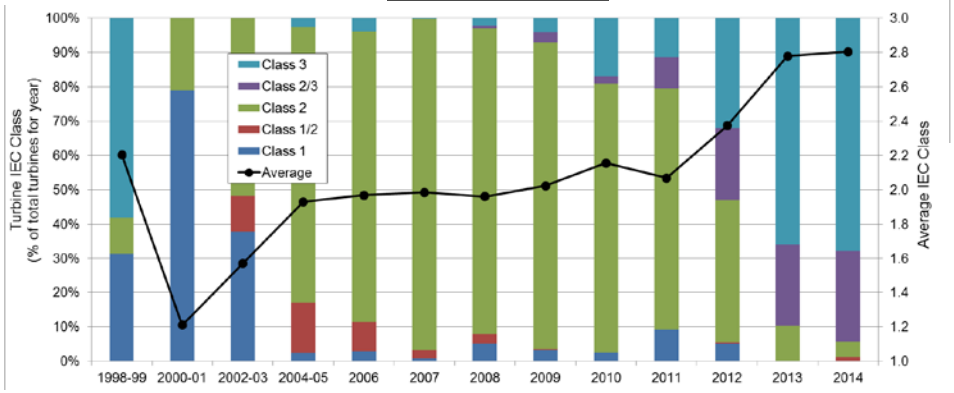


Turbines Originally Designed for Lower Wind Speed Sites Have Rapidly Gained Market Share

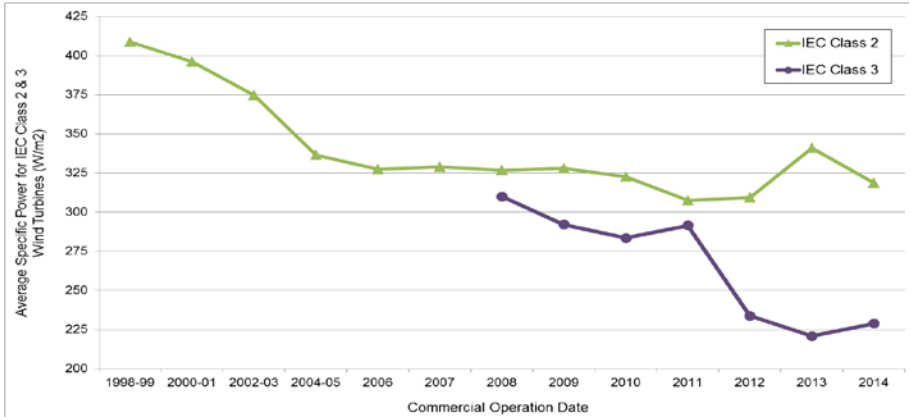
Specific Power



IEC Class

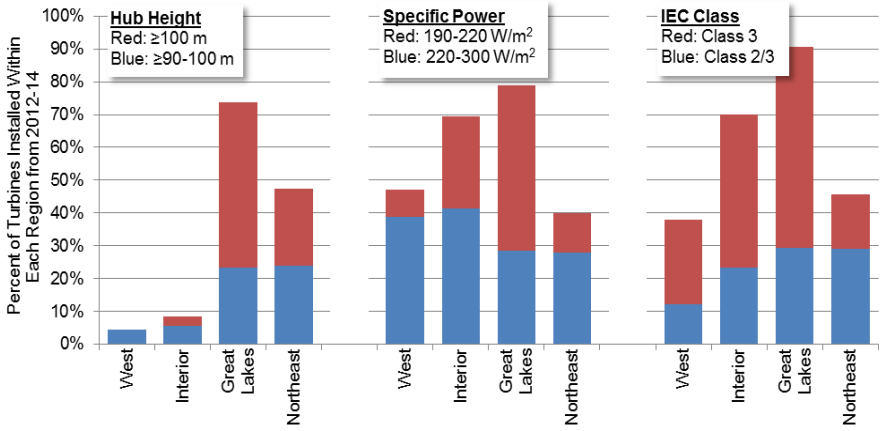


Specific Power by IEC Class 2 & 3

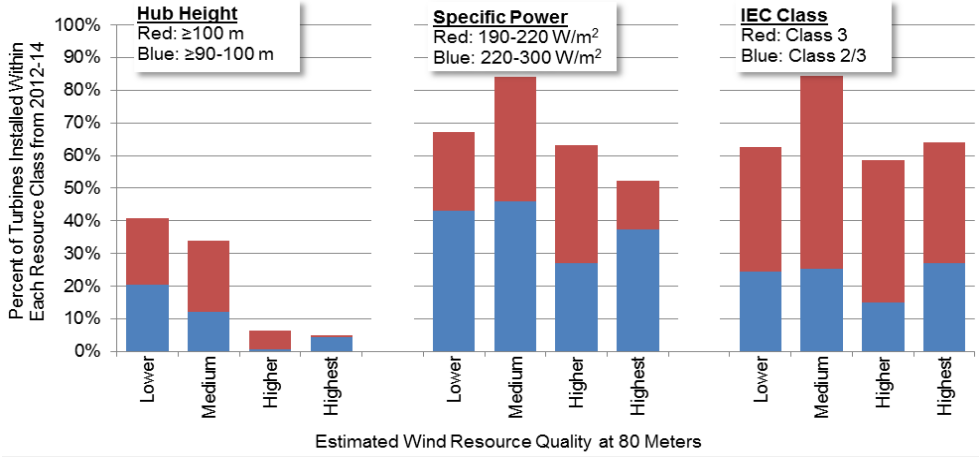


Turbines Originally Designed for Lower Wind Speeds Are Now Regularly Used in Lower and Higher Wind Speed Sites, Whereas Taller Towers Predominate in the Great Lakes and Northeast

By Region

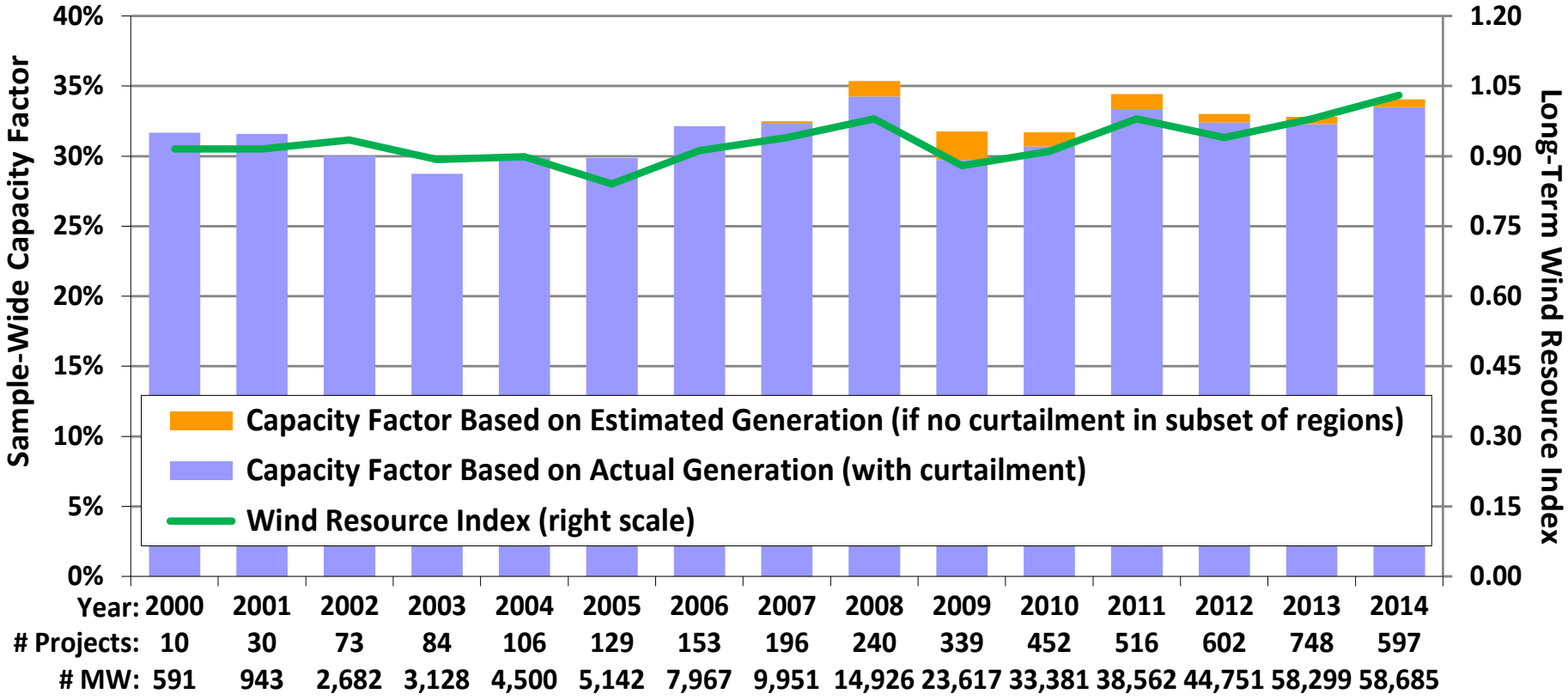


By Wind Resource Quality



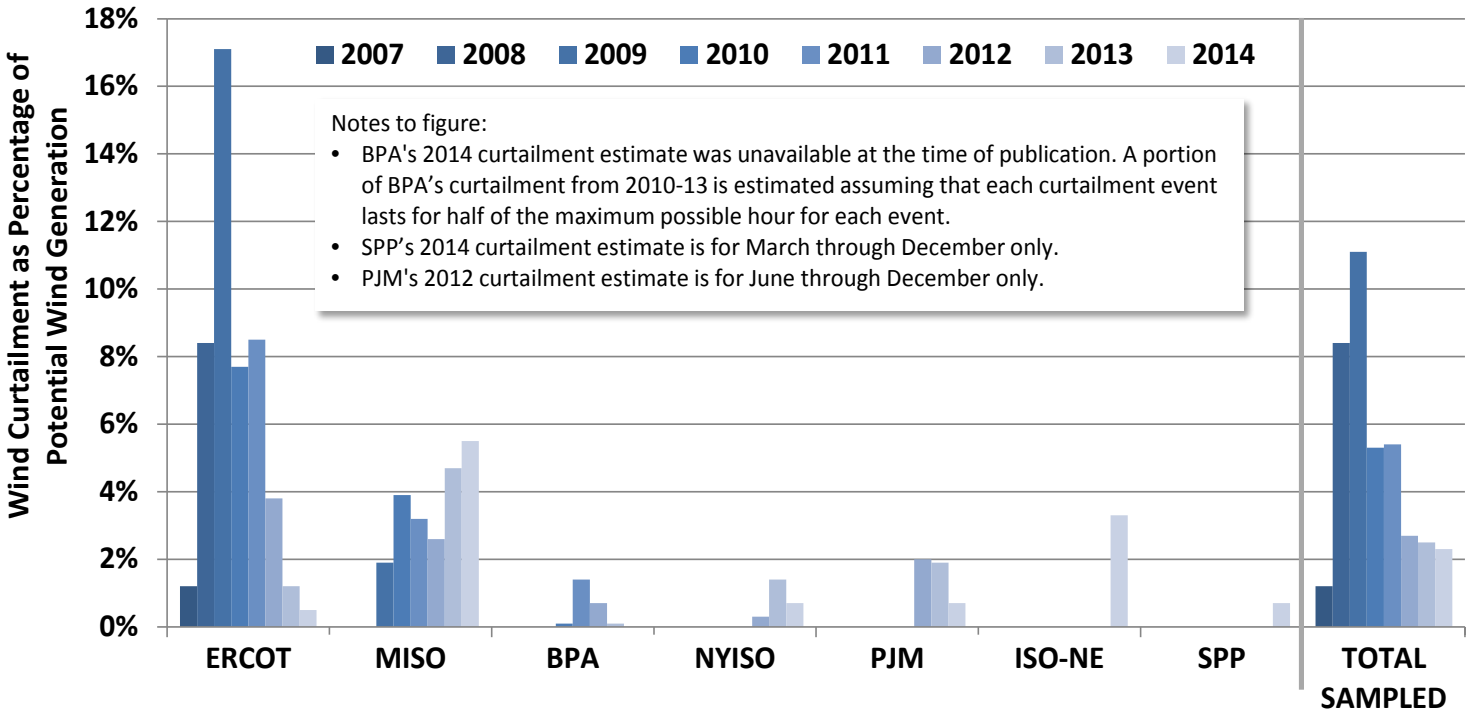
Performance Trends

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

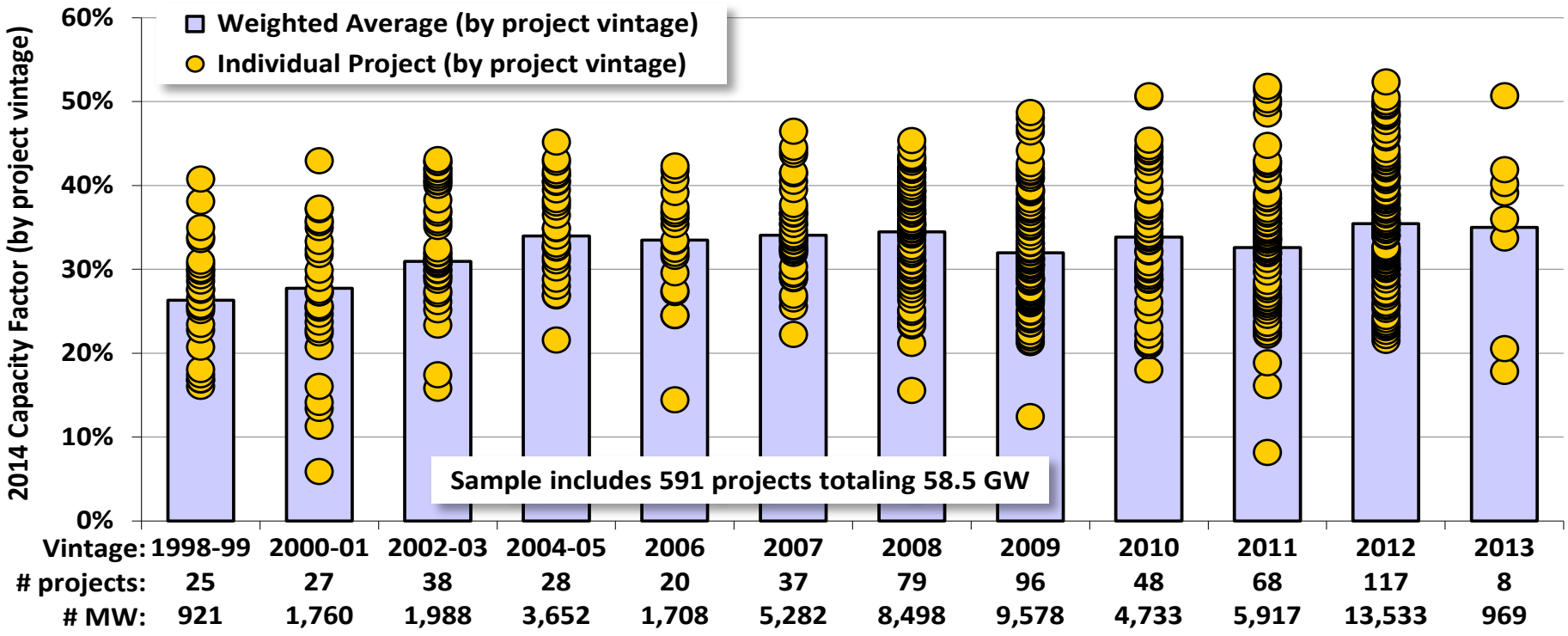
Wind Curtailment Has Generally Declined in Recent Years; Higher in MISO and New England than in Other Regions



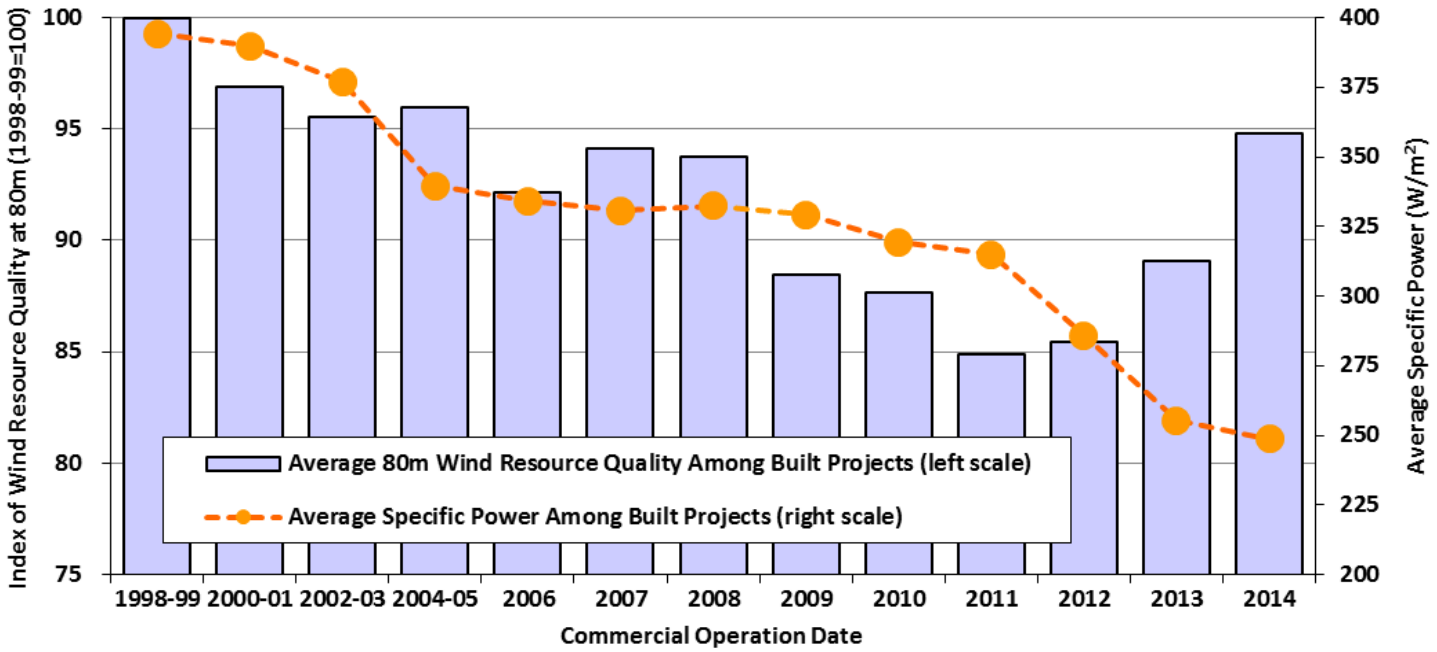
Except for BPA, data represent both forced and economic curtailment

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

Even Controlling for These Factors, Average Capacity Factors for Projects Built After 2005 Have Been Stagnant, Averaging 32% to 35% Nationwide



Trends Explained by Competing Influence of Lower Specific Power and Build-Out of Lower Quality Wind Resource Sites

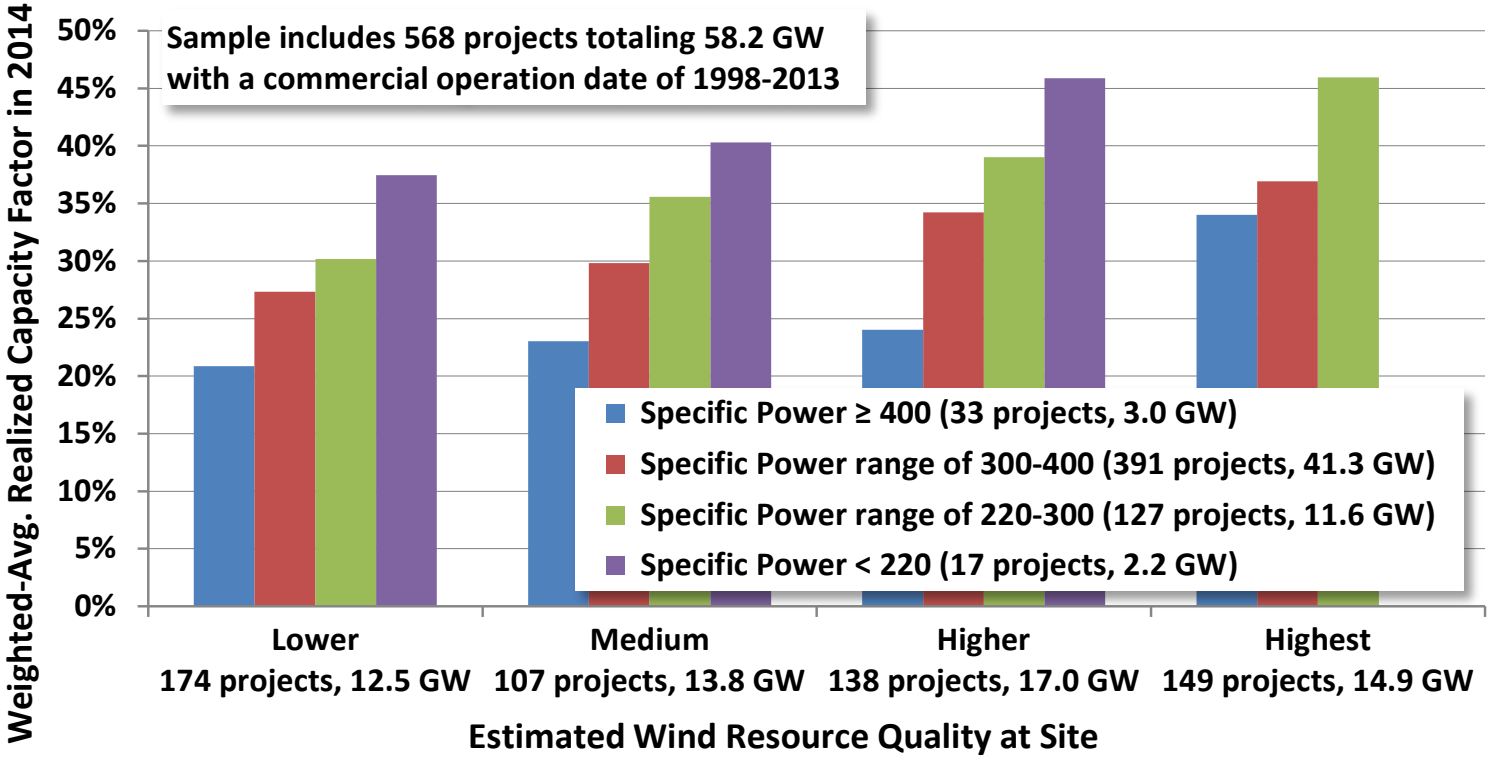


Reversal of build-out in lower wind speed sites in 2013 and 2014: likely to show up in capacity factor data next year

All else equal:

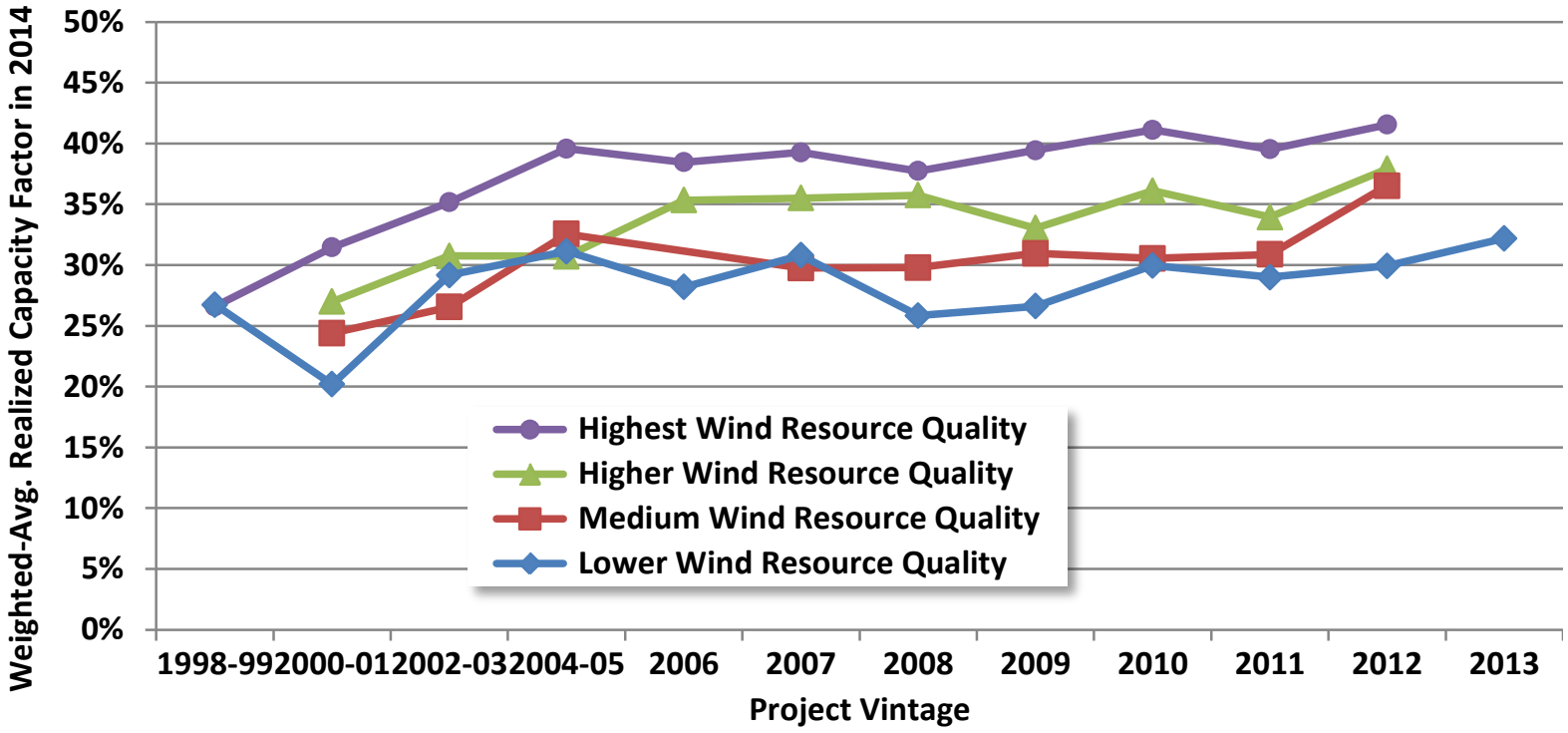
- Drop in average specific power will boost capacity factors
- Building projects in lower wind resource sites will reduce capacity factors

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



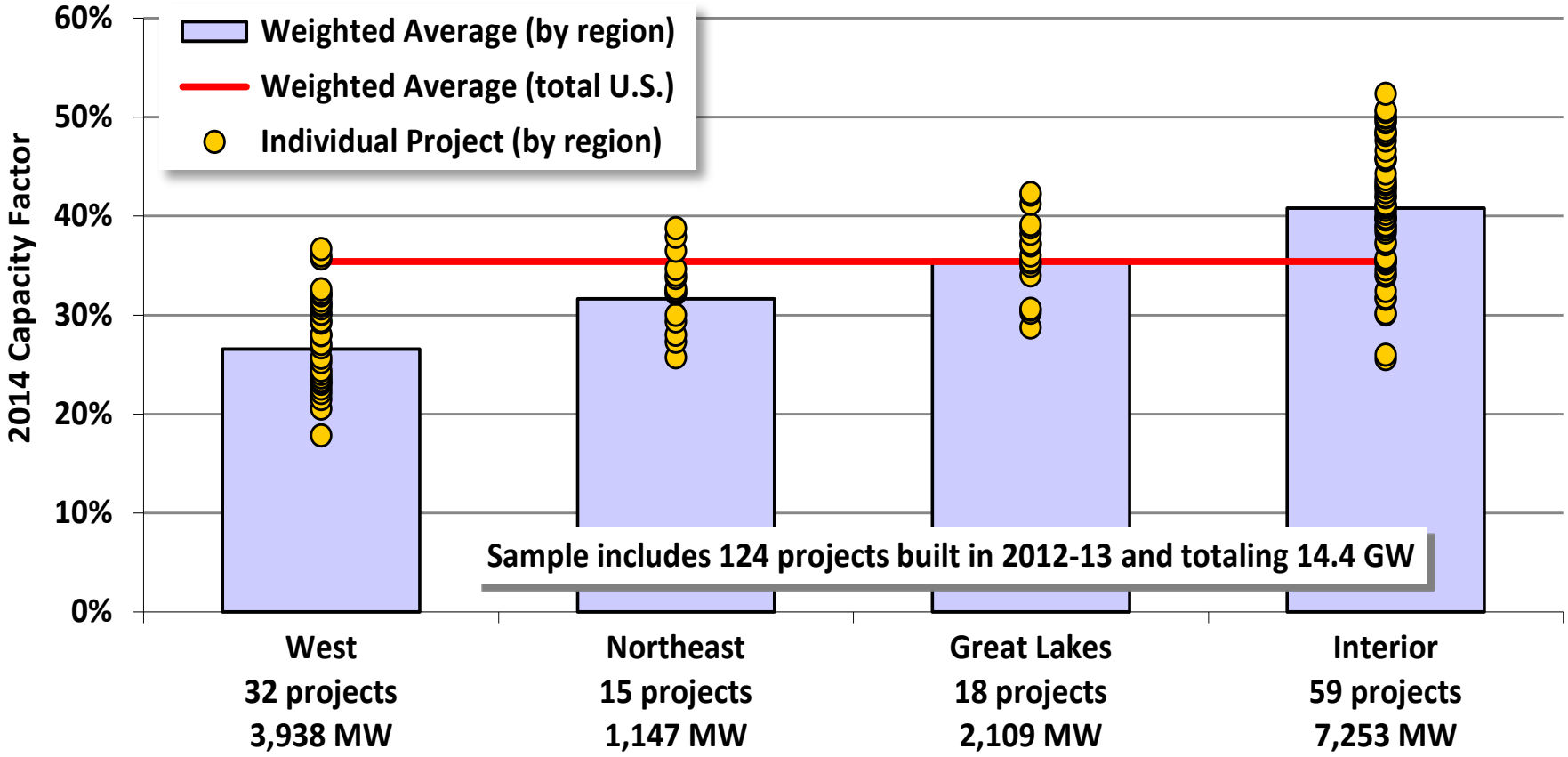
Notwithstanding build-out of lower-quality wind resource sites, turbine design changes are driving capacity factors higher for projects located in given wind resource regimes

Controlling for Wind Resource Quality and Commercial Operation Date Demonstrates Impact of Turbine Evolution



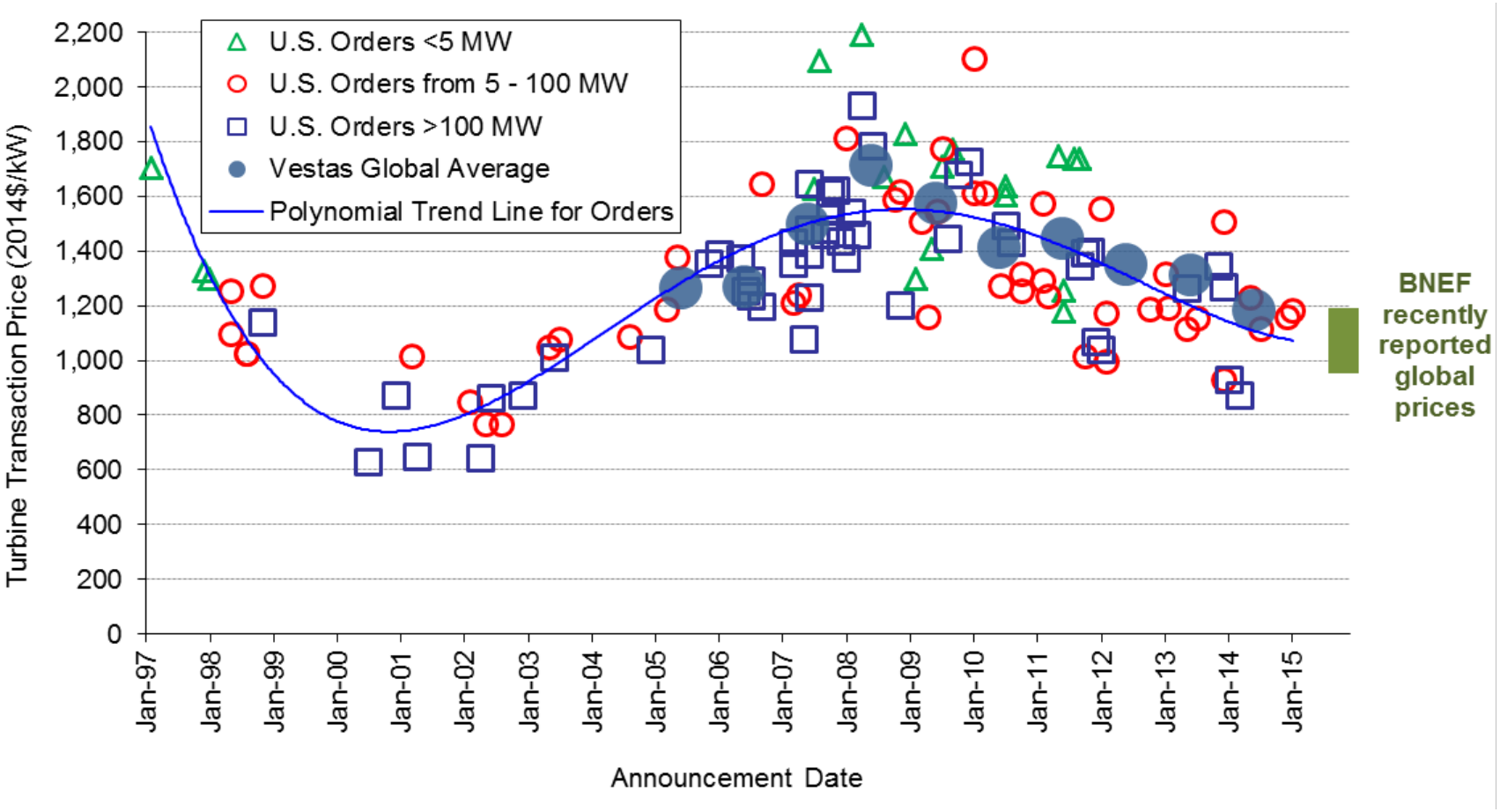
Notwithstanding build-out of lower-quality wind resource sites, turbine design changes are driving capacity factors higher for projects located in given wind resource regimes

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



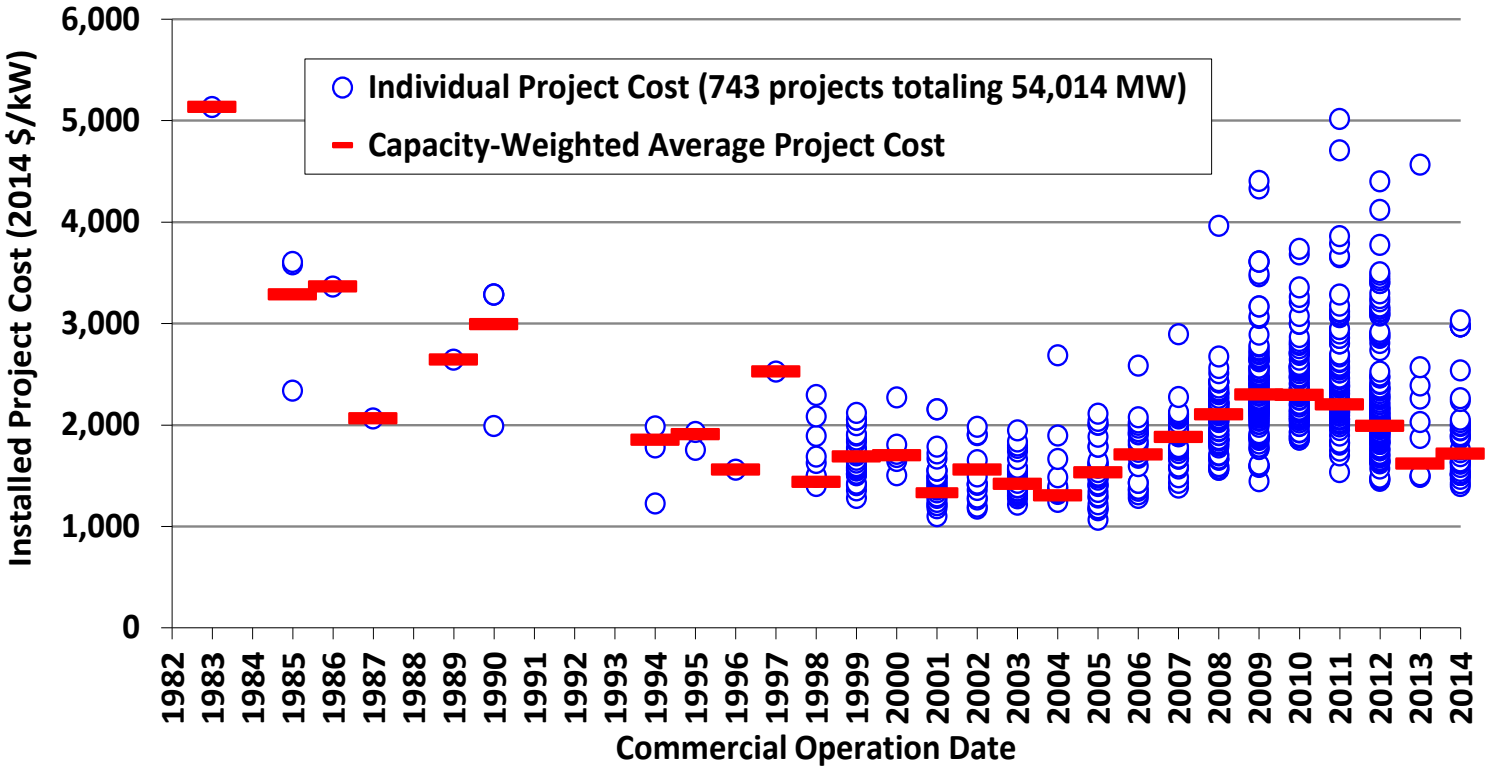
Cost Trends

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



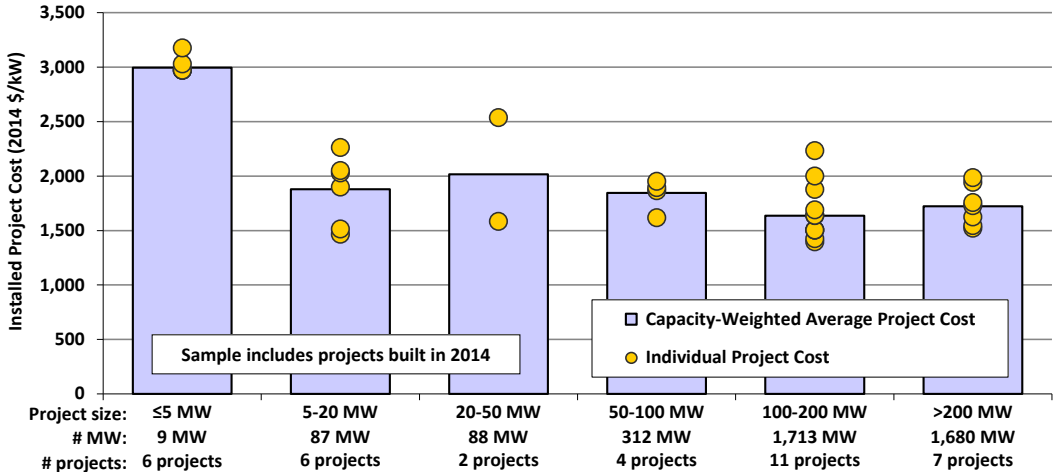
Recent turbine orders reportedly in the range of $850-1,250/kW

Lower Turbine Prices Drive Reductions in Reported Installed Project Costs

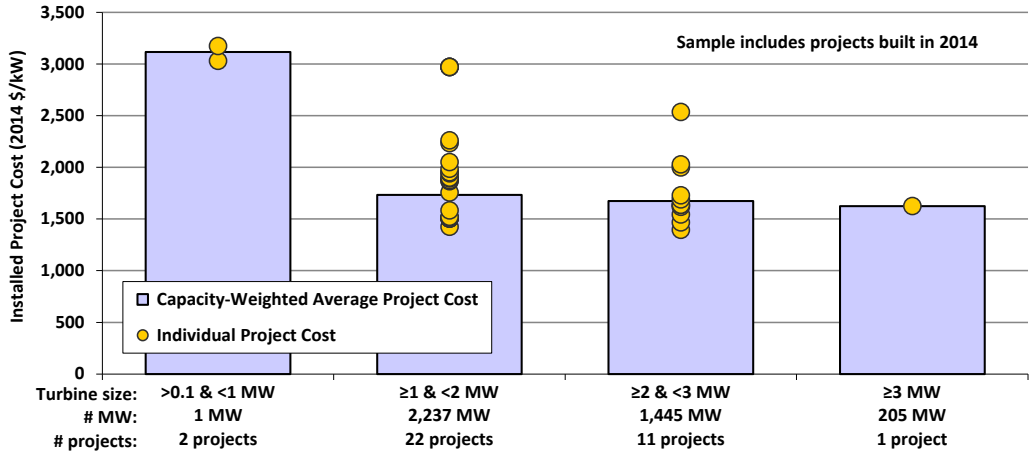


- 2014 projects had an average cost of $1,710/kW, down $580/kW since 2009 and 2010 (up slightly from small sample of 2013 projects)
- Limited sample of under-construction projects slated for completion in 2015 suggest no material change in costs

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

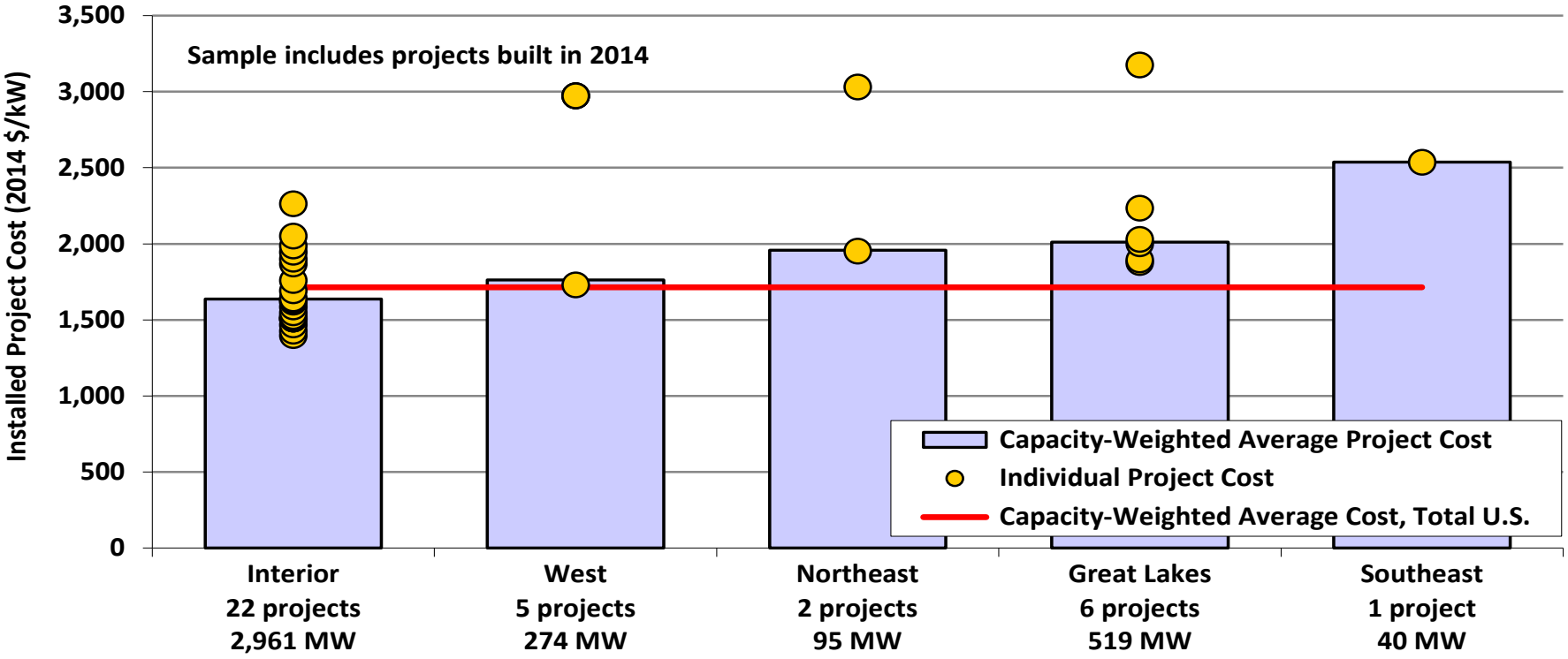


Project Size



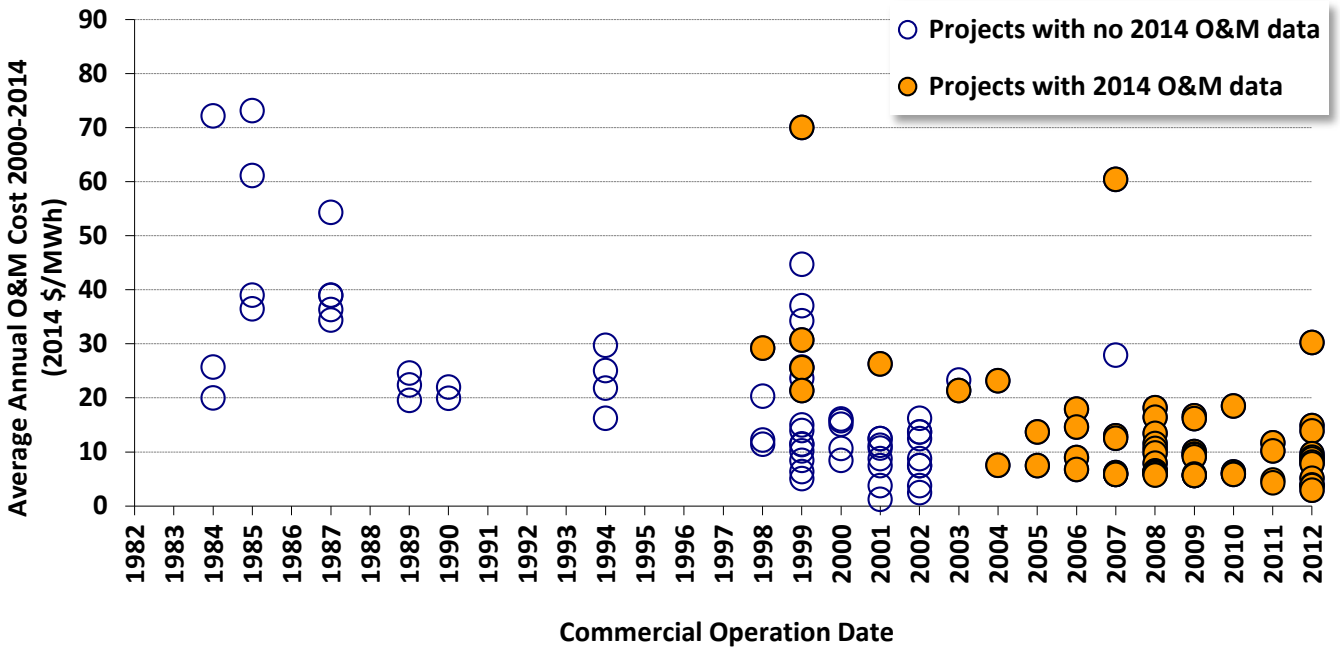
Turbine Size

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



Different permitting/development costs may play a role at both ends of spectrum: it's easier/cheaper to build in the US interior and harder/more expensive along the coasts

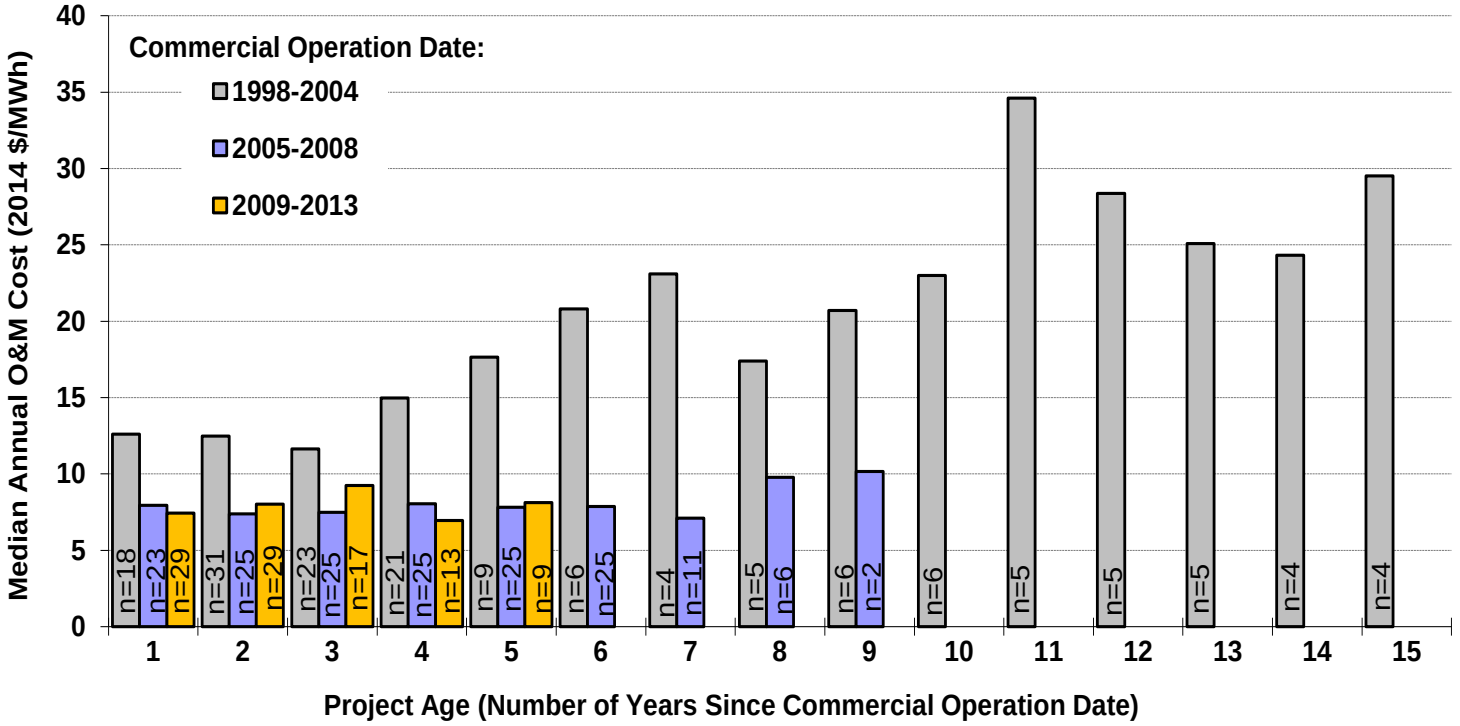
Operations and Maintenance Costs Varied By Project Age and Commercial Operations Date



Capacity-weighted average 2000-14 O&M costs for projects built in the 1980s equal **$34/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, and consists of 147 wind projects totaling 10,350 MW; few projects in sample have complete records of O&M costs from 2000-14; 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

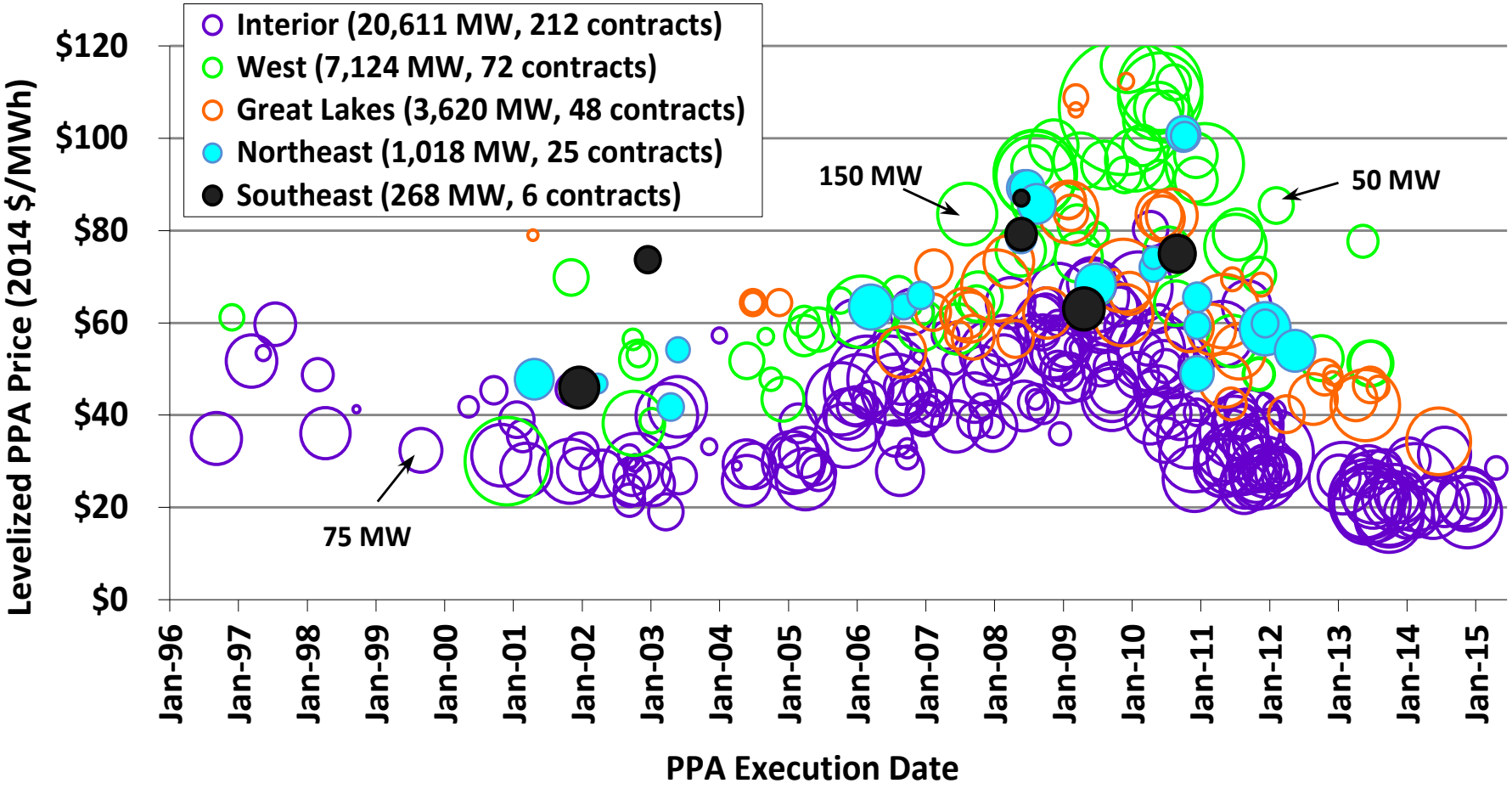
O&M reported in figure does not include all operating costs: Statements from public companies with large U.S. wind asset bases report total operating costs in 2014 for projects built in the 2000s of ~$21-25/MWh

Wind Power Price Trends

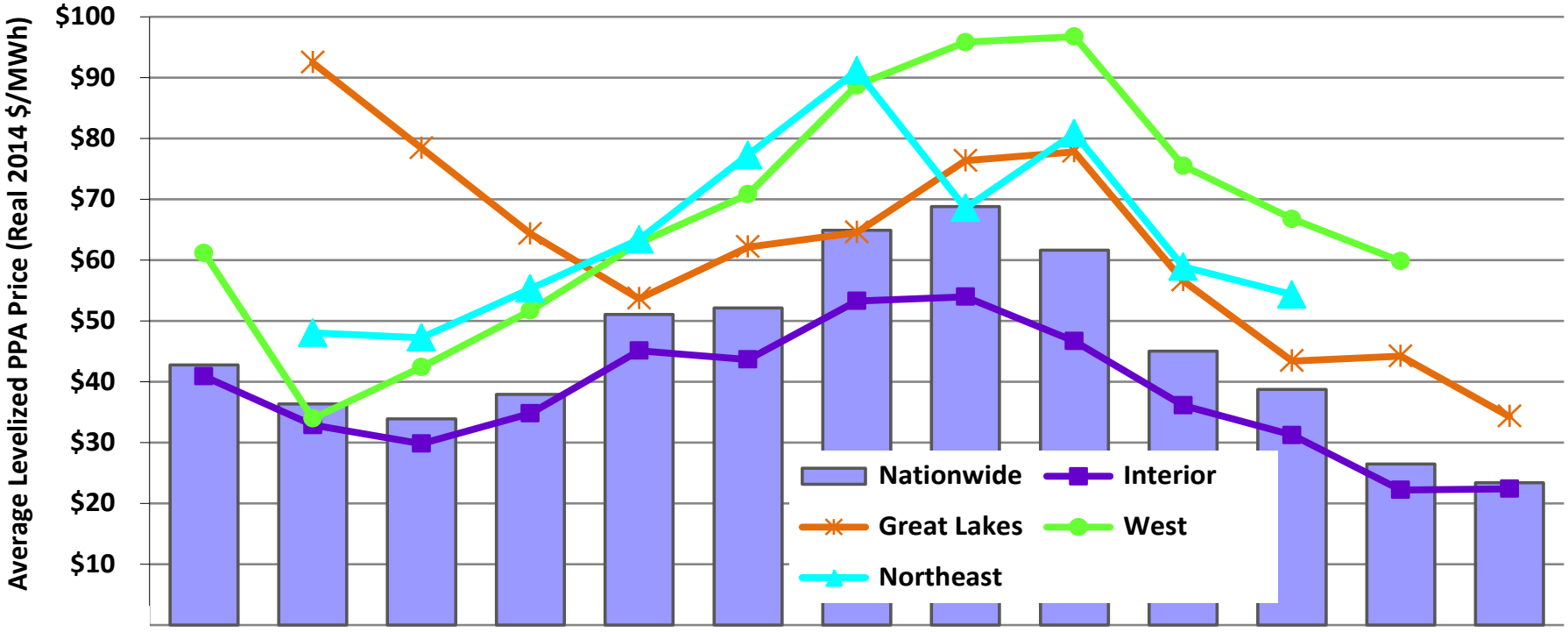
Sample of Wind Power Prices

- Berkeley Lab collects data on historical wind power sales prices, and long-term PPA prices
- PPA sample includes 363 contracts totaling 32,641 MW from projects built from 1998-2014, or planned for installation in 2015 or 2016
- Prices reflect the bundled price of electricity and RECs as sold by the project owner under a power purchase agreement
  - Dataset excludes merchant plants and projects that sell renewable energy certificates (RECs) separately
  - 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 Have Reached All-Time Lows, Dominated by Interior Region

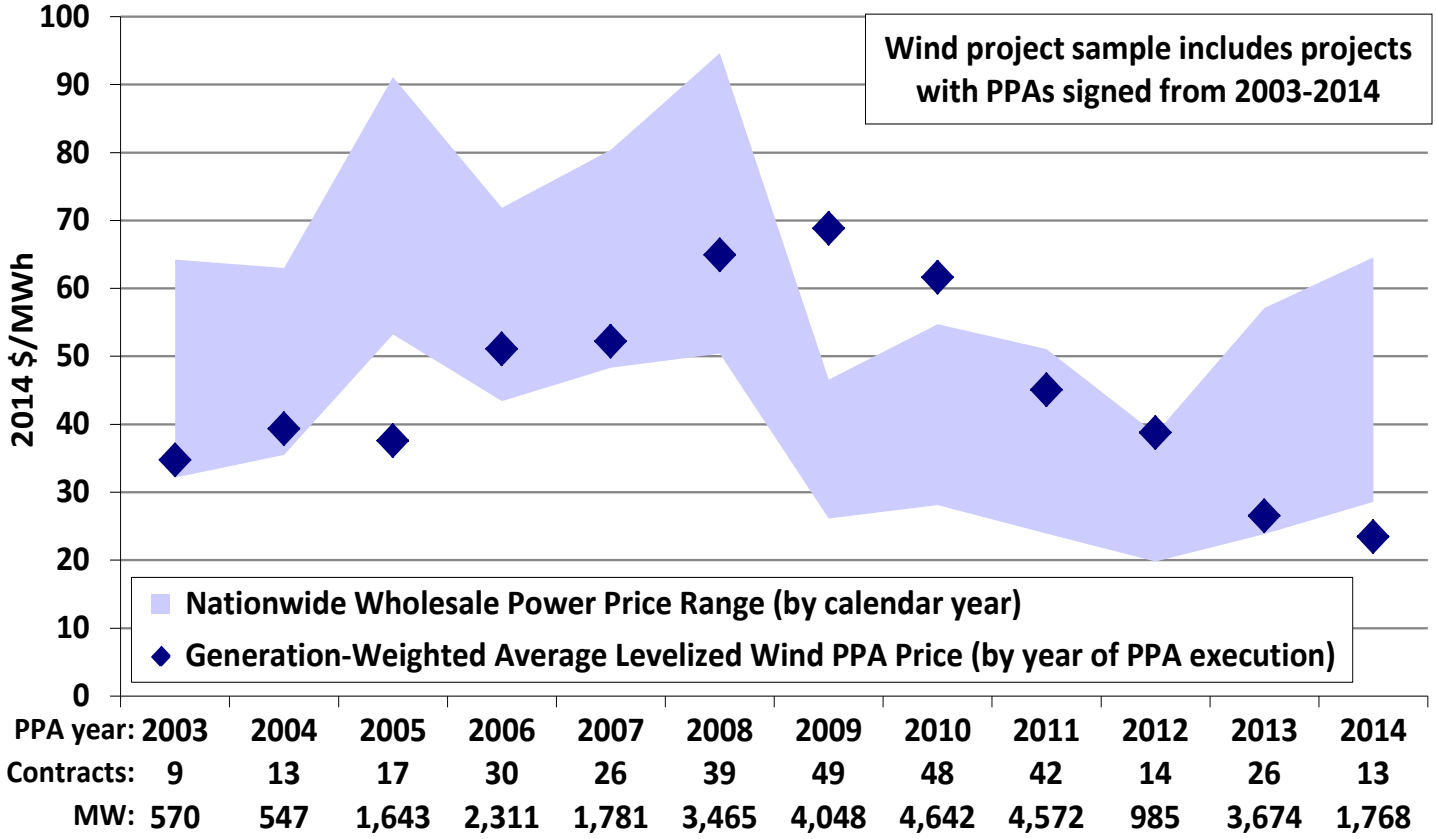


A Smoother Look at the Time Trend Shows Steep Decline in Pricing Since 2009; Especially Low Pricing in Interior Region



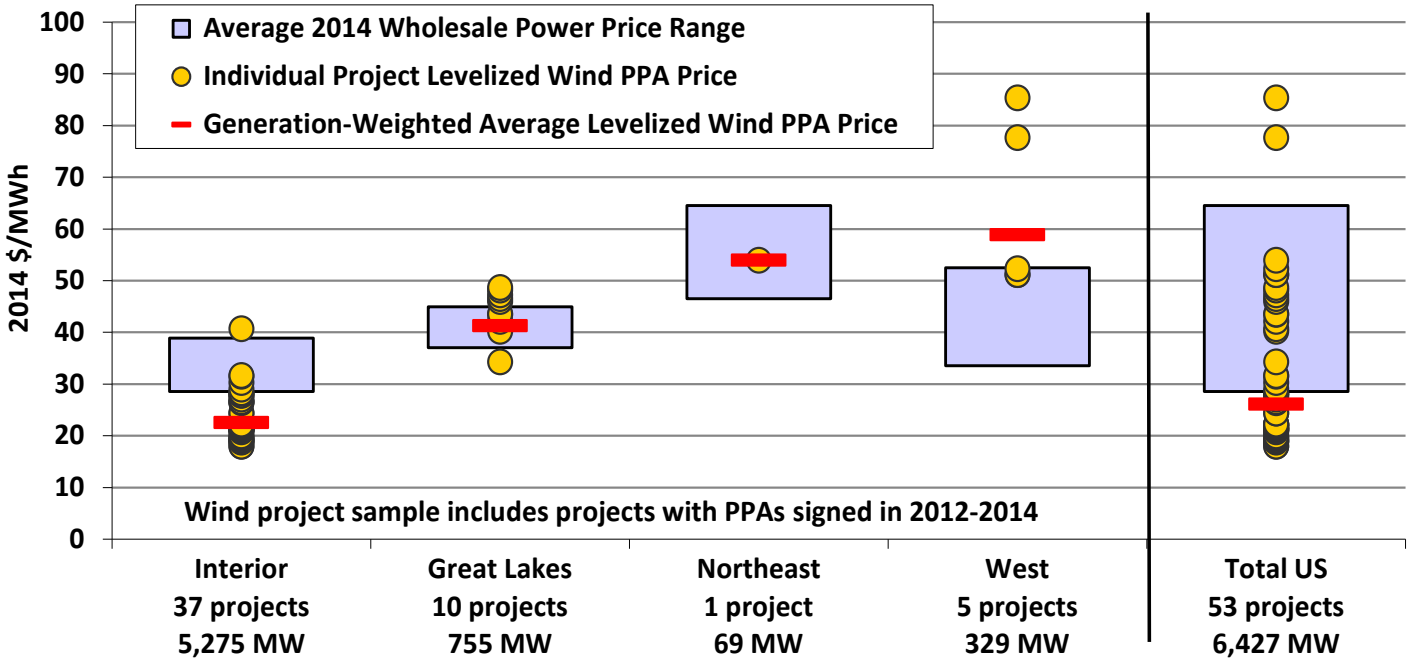
PPA Year:	1996-99	2000-01	2002-03	2004-05	2006	2007	2008	2009	2010	2011	2012	2013	2014
Contracts:	10	17	24	30	30	26	39	49	48	42	14	26	13
MW:	553	1,249	1,382	2,190	2,311	1,781	3,465	4,048	4,642	4,572	985	3,674	1,768

Relative Competitiveness of Wind Power Improved in 2014: Comparison to Wholesale Electricity Prices



- Wholesale price range reflects flat block of power across 23 pricing nodes across the U.S.
- Price comparison shown here is far from perfect – ***see full report for caveats***

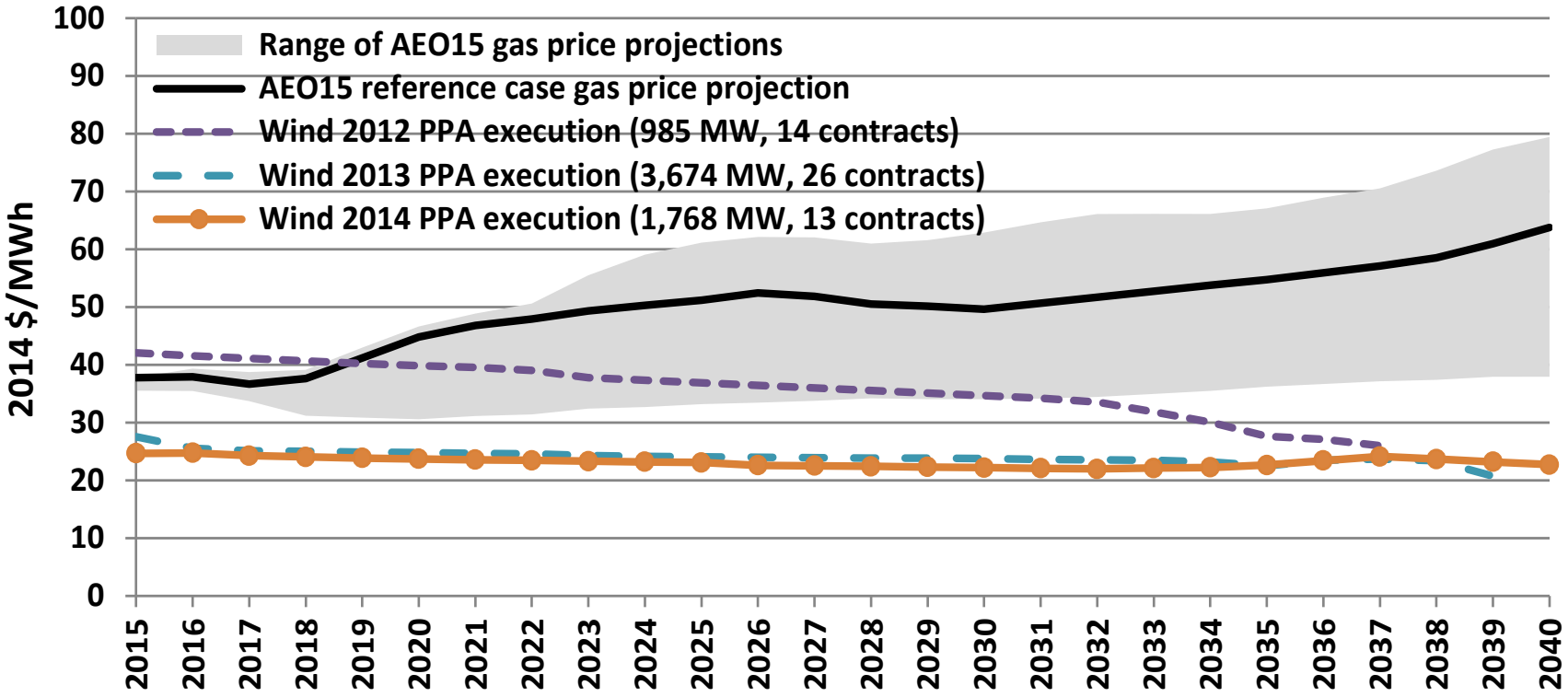
Comparison Between Wholesale Prices and Wind PPA Prices Varies by Region



*Notes: Wind PPAs included are those signed from 2012-2014. Within a region there are a range of wholesale prices because multiple price hubs exist in each area; price comparison shown here is far from perfect – **see full report for caveats***

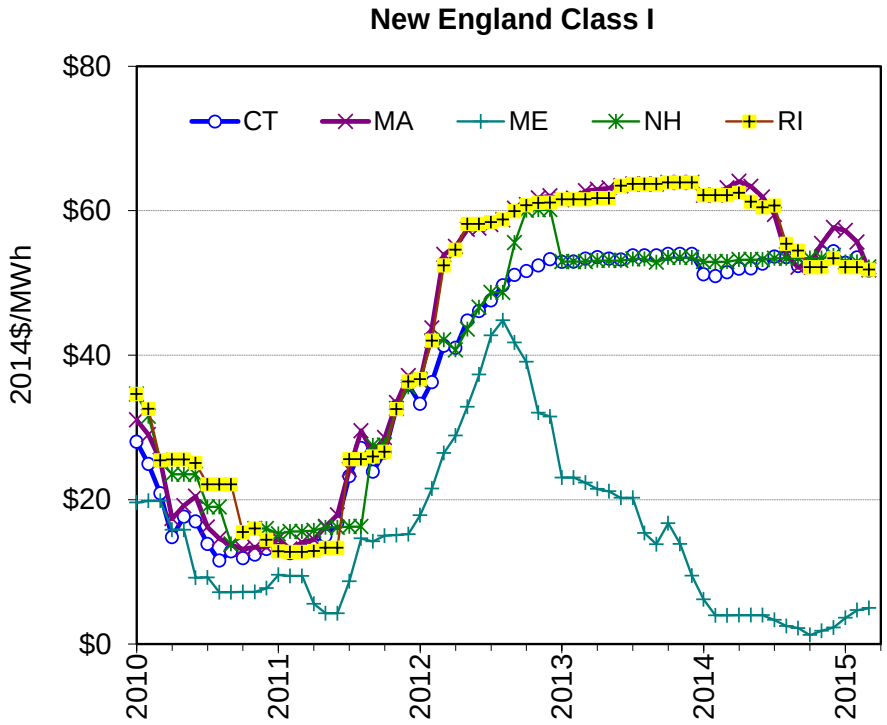
Wind PPA prices most competitive with wholesale prices in the Interior region

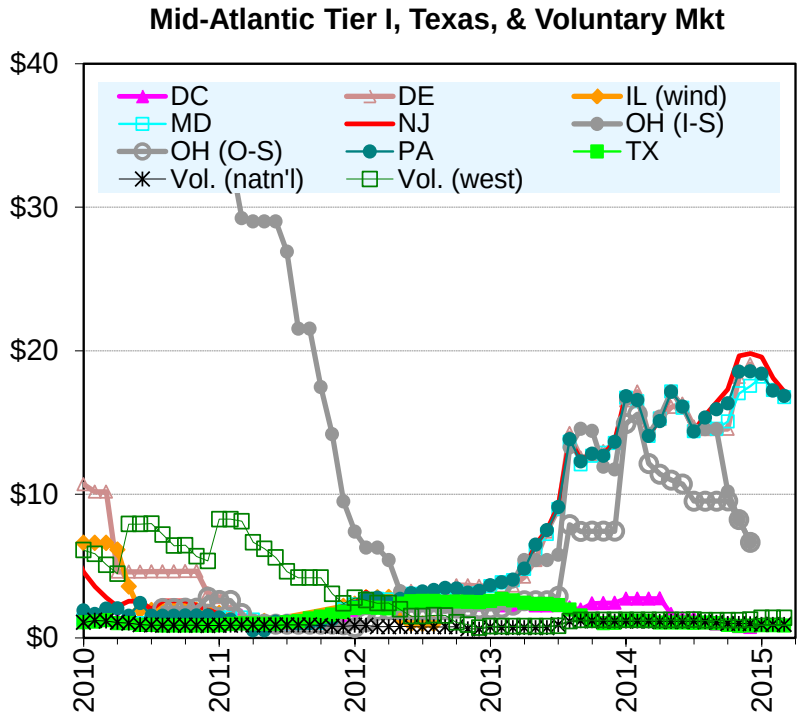
Recent Wind Prices Are Hard to Beat: Competitive with Expected Future Cost of Burning Fuel in Natural Gas Plants



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

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





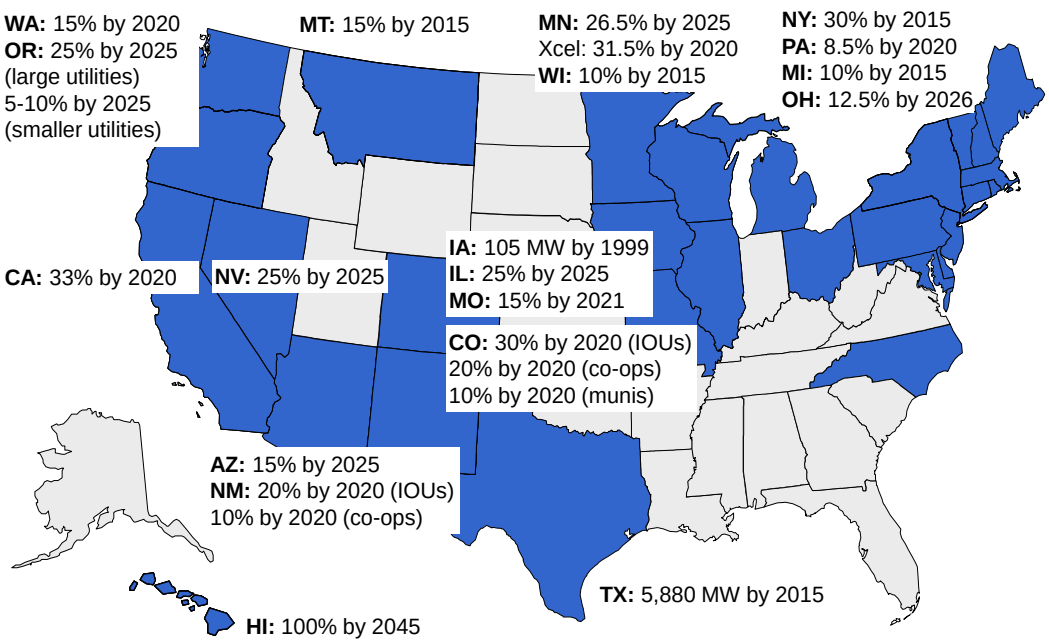
REC prices vary by: market type (compliance vs. voluntary); geographic region; specific design of state RPS policies

Policy and Market Drivers

Availability of Federal Incentives for Wind Projects Built in the Near Term Has Is Leading to a Resurgent Domestic Market, but a Possible Policy Cliff Awaits

- Near-term availability of the PTC/ITC for those projects that reached the “under construction” milestone by the end of 2014 will enable solid growth in 2015 and 2016; uncertain prospects after that
- Prospective impacts of more-stringent EPA environmental regulations, including those related to power-sector carbon emissions, may create new markets for wind energy

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

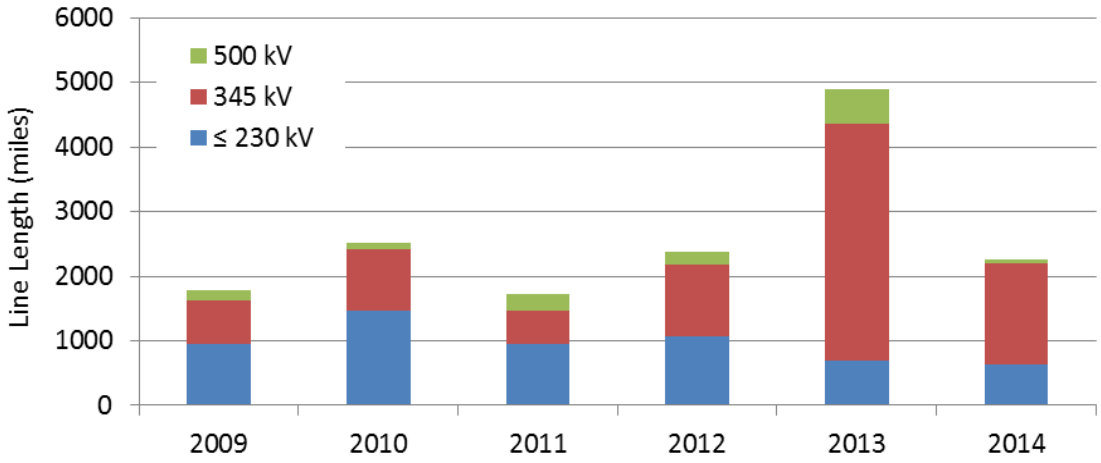


Source: Berkeley Lab

- 29 states and D.C. have mandatory RPS programs
- State RPS' can support ~4-5 GW/yr of renewable energy additions on average through 2025 (less for wind specifically)

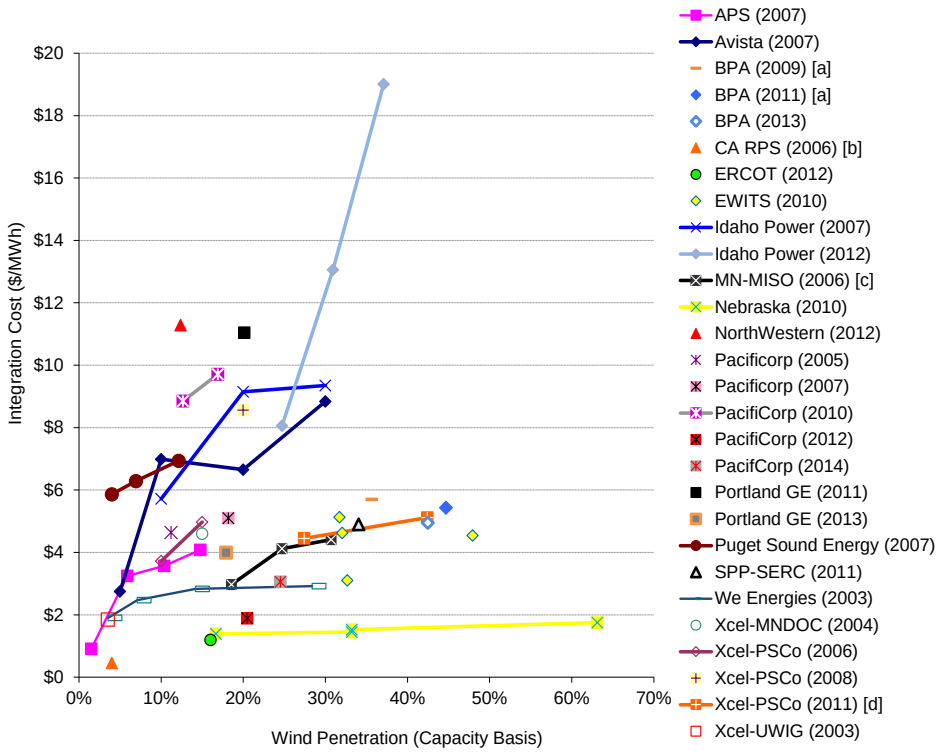
Solid Progress on Overcoming Transmission Barriers Continued

- Over 2,000 circuit miles of new transmission built in 2014; lower than 2013 but consistent with 2009-2012
- 22,000 additional circuit miles proposed by March 2017, with half having a high probability of completion
- AWEA has identified 18 near-term transmission projects that – if all were completed – could carry 55-60 GW of additional wind power capacity
- FERC continued to implement Order 1000, requiring public utility transmission providers to improve planning processes and determine a cost allocation methodology for new transmission investments



System Operators Are Implementing Methods to Accommodate Increased Penetrations of Wind

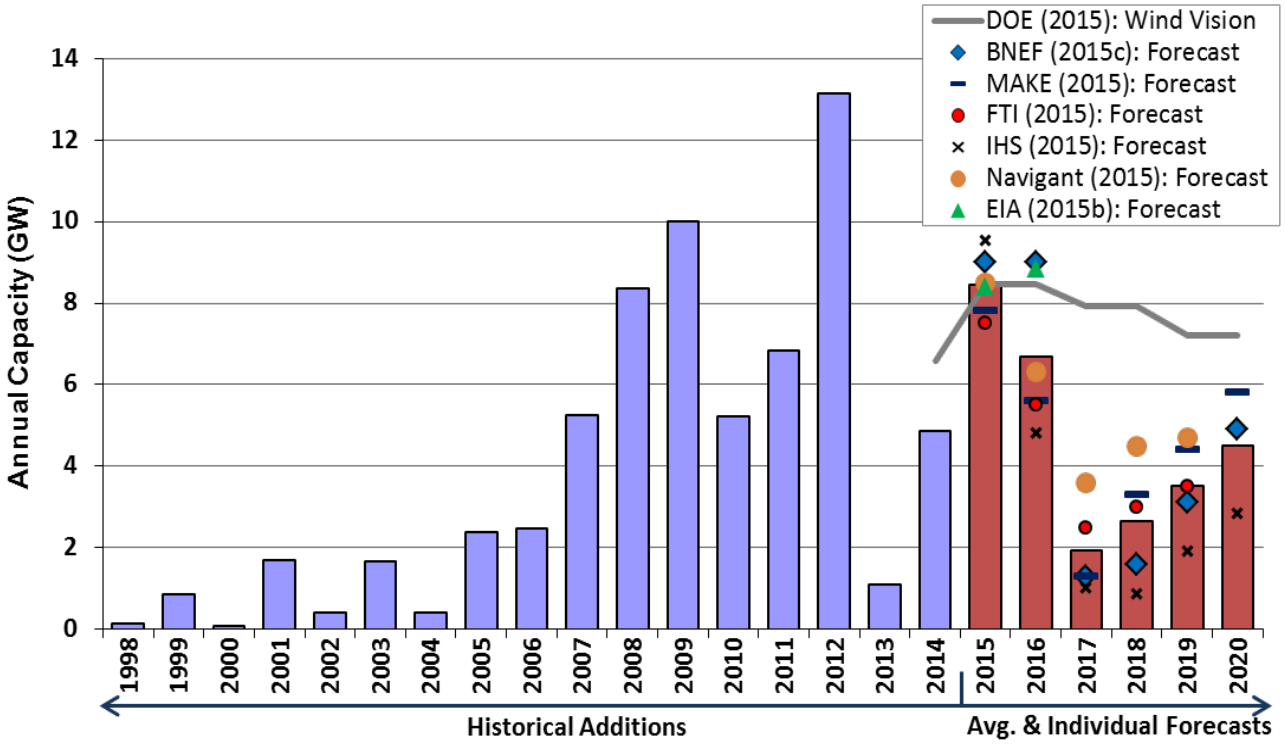
Integrating wind energy into power systems is manageable, but not free of additional costs



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. There has been some recent literature questioning the methods used to estimate wind integration costs and the ability to disentangle those costs explicitly, while also highlighting the fact that other generating options also impose integration challenges and costs.

Future Outlook

Sizable Wind Additions Anticipated for 2015 & 2016; Downturn and Increased Uncertainty in 2017 and Beyond



Wind additions in 2014 and anticipated additions from 2017-2020 fall below the deployment trajectory analyzed in DOE's *Wind Vision* report

Current Low Prices for Wind, Future Technological Advancement and New EPA Regulations May Support Higher Growth in Future, but Headwinds Include…

- Lack of clarity about fate 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 rebounded in 2014, with significant additional new builds anticipated for 2015 and 2016
- Wind has been a significant source of new electric generation capacity additions in the U.S. in recent years
- Supply chain has been under duress, but domestic manufacturing content for nacelle assembly, blades, and towers is strong
- Turbine scaling is boosting expected wind project performance, while the installed cost of wind projects is on the decline
- Wind power sales prices have reached all-time lows, enabling economic competitiveness despite low natural gas prices
- Growth after 2016 remains uncertain, dictated in part by future natural gas prices and policy decisions, though recent declines in the price of wind energy boost future growth prospects

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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