

# WIND AND WATER POWER TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy



August 20, 2014

# 2013 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 2013
- 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/wind-program>



# Report Contents

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



# New to the Current Edition of the Report

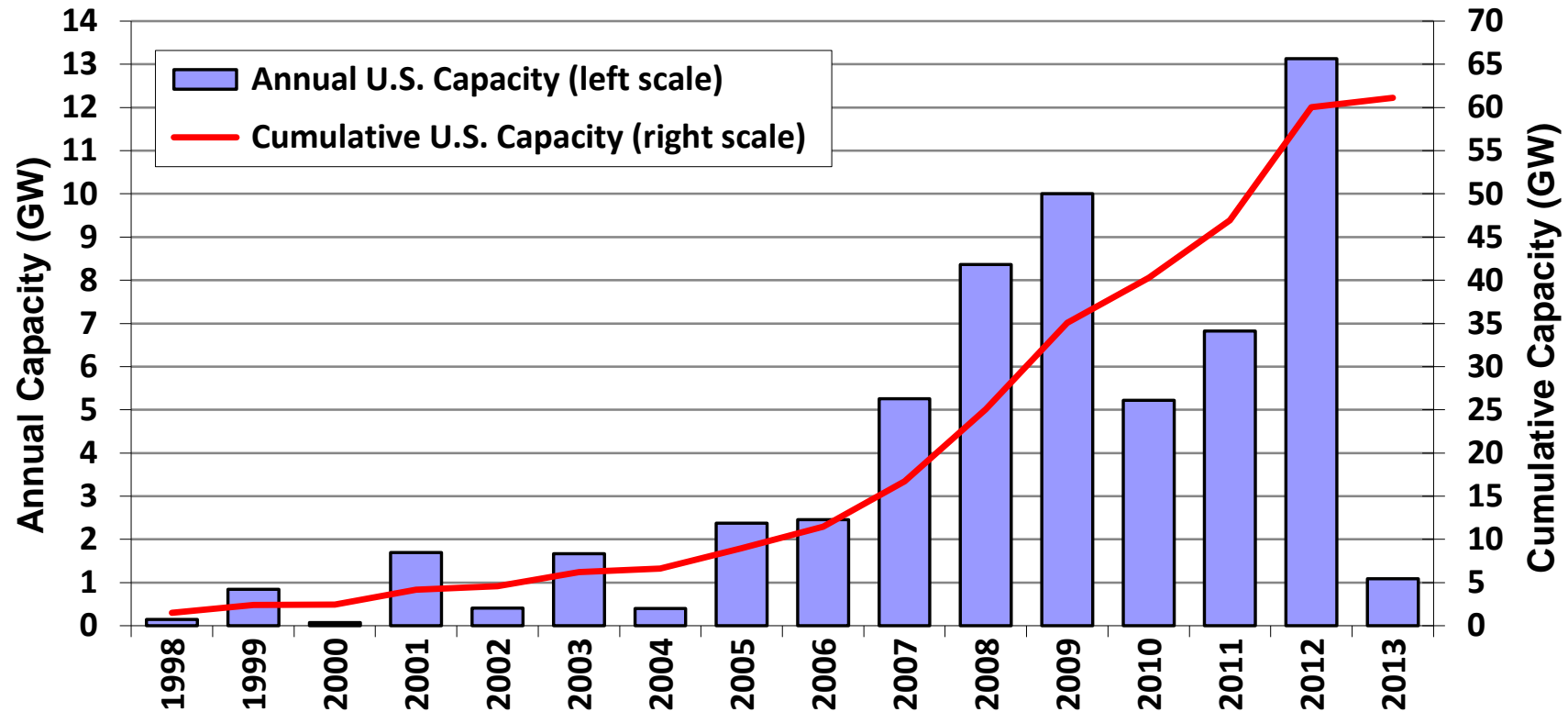
- New chapter on technology trends, including the expanded use of turbines originally designed for lower wind speed sites
- Comparison of wind power sales prices to projections of future natural gas prices
- Expansion and refinement of manufacturing, supply chain, and domestic content assessments

# Key Findings

- Annual wind additions were modest in 2013, but signals point to more-robust growth in 2014/15
- Notwithstanding 2013, wind has been a significant source of new generation in the U.S. since 2007
- 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 is on the decline
- Trends are enabling very aggressive wind power pricing and solid economics in many regions despite low natural gas prices
- Growth after 2015 remains uncertain, dictated in part by future natural gas prices, fossil plant retirements, and policy decisions, though technological advancements and recent declines in the price of wind energy have boosted future growth prospects

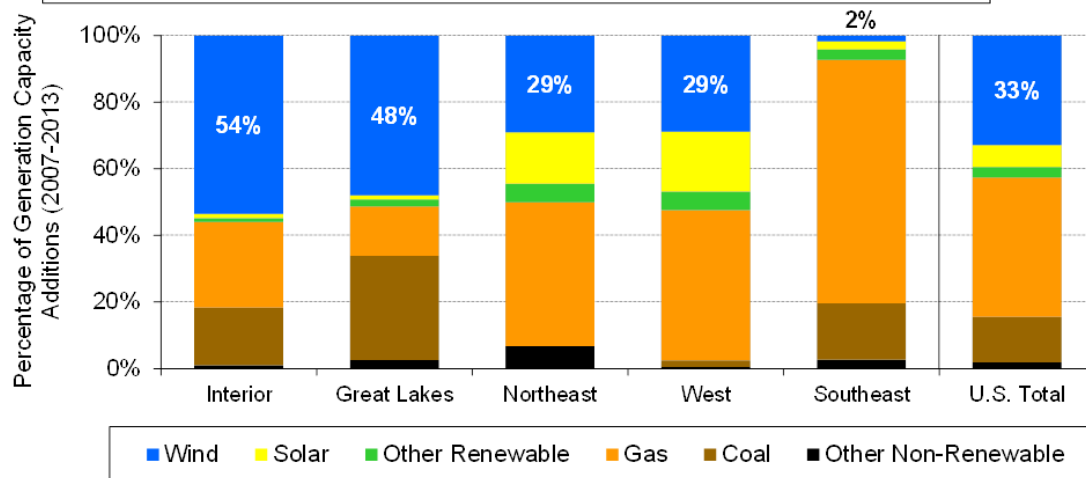
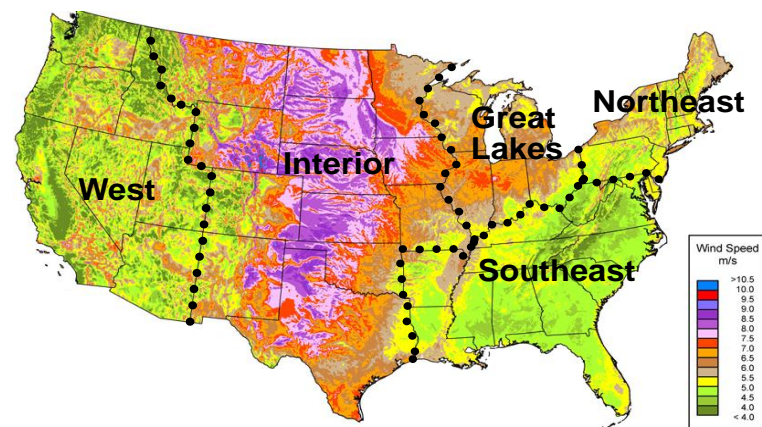
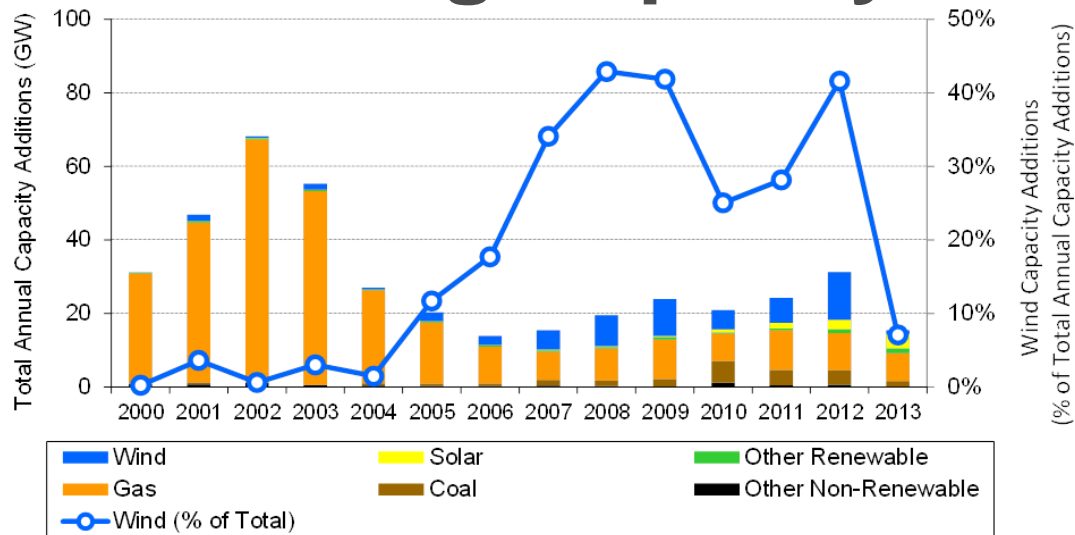
# Installation Trends

# Wind Power Additions Stalled in 2013, with only 1,087 MW of New Capacity Added



- Capacity additions in 2013 were just 8% of 2012 additions
- \$1.8 billion invested in wind power project additions
- Cumulative wind capacity up by less than 2%, bringing total to 61 GW

# Wind Represented 7% of Electric-Generating Capacity Additions in 2013



But... from 2007-2013, wind represented 33% of capacity additions nationwide, and a much higher proportion in some regions



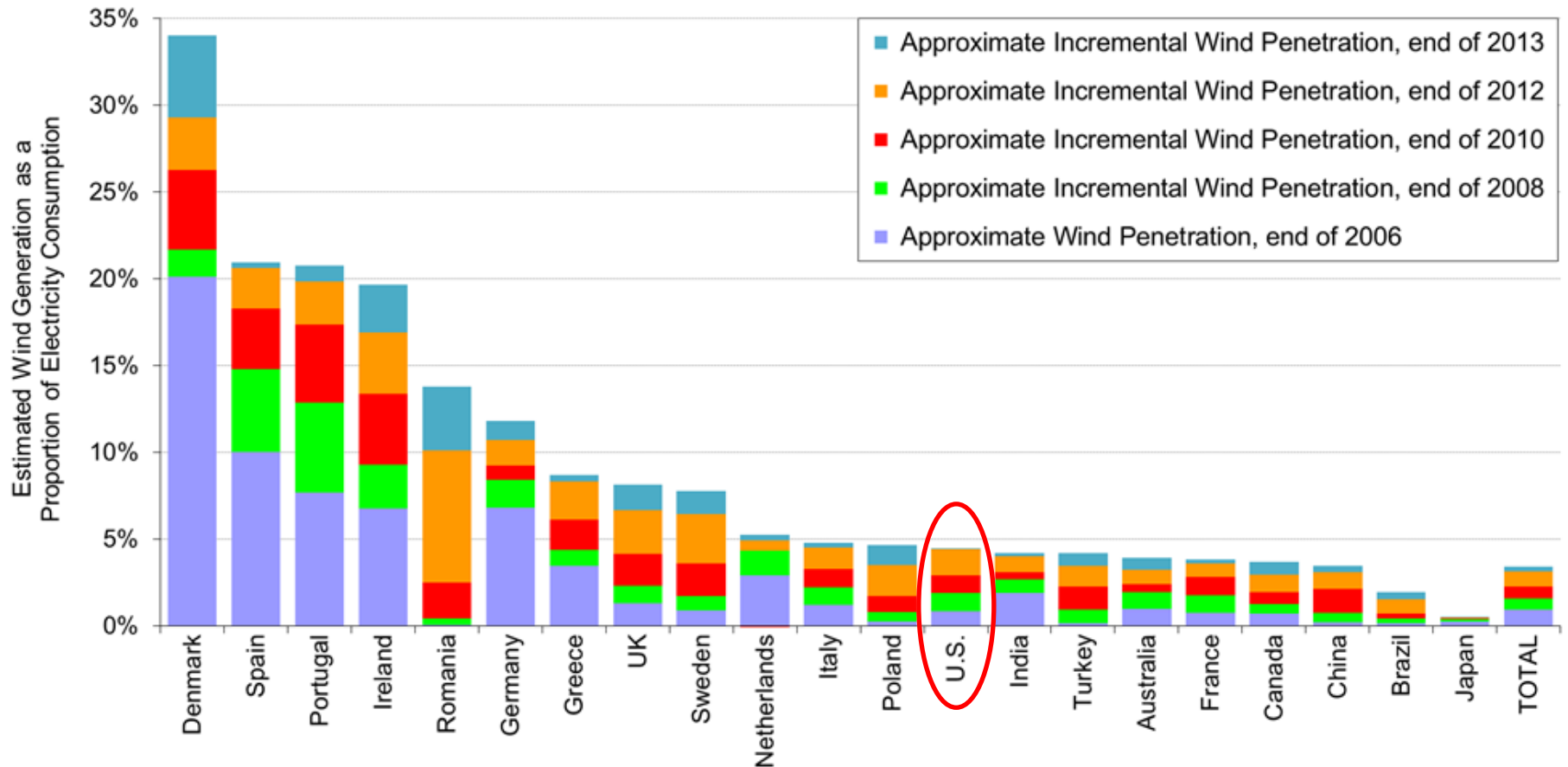
# The U.S. Fell to 6<sup>th</sup> Place in Annual Wind Power Capacity Additions

Annual Capacity (2013, MW)		Cumulative Capacity (end of 2013, MW)	
China	16,088	China	91,460
Germany	3,237	<b>United States</b>	<b>61,110</b>
India	1,987	Germany	34,468
United Kingdom	1,833	Spain	22,637
Canada	1,599	India	20,589
<b>United States</b>	<b>1,087</b>	United Kingdom	10,946
Brazil	948	Italy	8,448
Poland	894	France	8,128
Sweden	724	Canada	7,813
Romania	695	Denmark	4,747
<i>Rest of World</i>	7,045	<i>Rest of World</i>	51,031
<b>TOTAL</b>	<b>36,137</b>	<b>TOTAL</b>	<b>321,377</b>

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

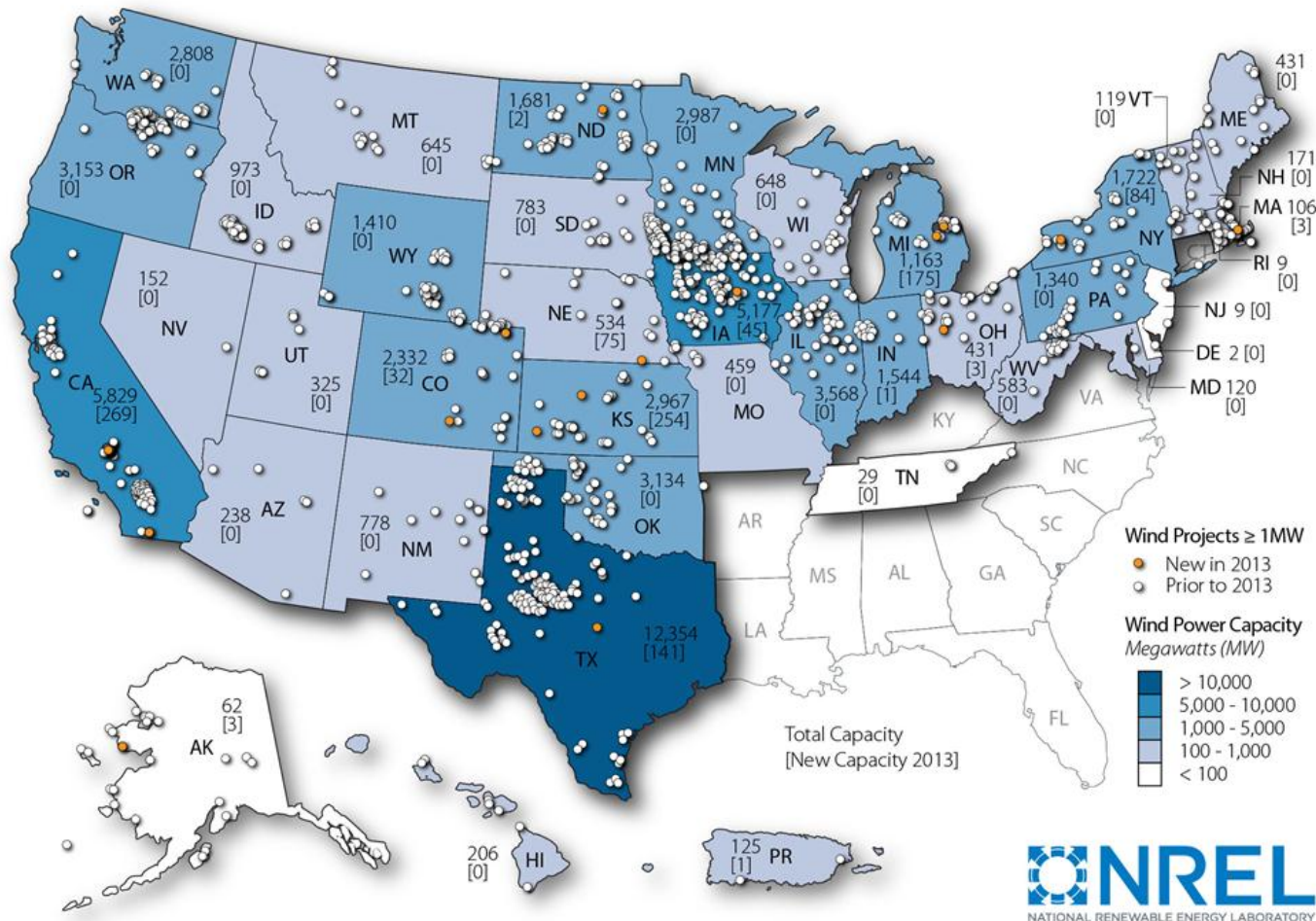
- Led by decline in U.S. market, global additions 20% lower in 2013
- U.S. remains a distant second to China in cumulative capacity

# 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 2012

# Geographic Spread of Wind Power Projects in the United States Is



Note: Numbers within states represent cumulative installed wind capacity and, in brackets, annual additions in 2013.

# California Installed the Most Capacity in 2013; 9 States Exceed 12% Wind Energy

Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2013)		Cumulative (end of 2013)		Actual (2013)*	
California	269	Texas	12,354	Iowa	27.4%
Kansas	254	California	5,829	South Dakota	26.0%
Michigan	175	Iowa	5,177	Kansas	19.4%
Texas	141	Illinois	3,568	Idaho	16.2%
New York	84	Oregon	3,153	Minnesota	15.7%
Nebraska	75	Oklahoma	3,134	North Dakota	15.6%
Iowa	45	Minnesota	2,987	Oklahoma	14.8%
Colorado	32	Kansas	2,967	Colorado	13.8%
Ohio	3	Washington	2,808	Oregon	12.4%
Massachusetts	3	Colorado	2,332	Wyoming	8.4%
Alaska	3	New York	1,722	Texas	8.3%
North Dakota	2	North Dakota	1,681	Maine	7.4%
Indiana	1	Indiana	1,544	California	6.6%
Puerto Rico	1	Wyoming	1,410	Washington	6.2%
		Pennsylvania	1,340	New Mexico	6.1%
		Michigan	1,163	Montana	6.0%
		Idaho	973	Hawaii	5.1%
		South Dakota	783	Nebraska	4.8%
		New Mexico	778	Illinois	4.7%
		Montana	645	Vermont	3.4%
Rest of U.S.	0	Rest of U.S.	4,762	Rest of U.S.	0.8%
<b>TOTAL</b>	<b>1,087</b>	<b>TOTAL</b>	<b>61,110</b>	<b>TOTAL</b>	<b>4.1%</b>

- Texas has more than twice as much wind capacity as any other state
- 23 states had >500 MW of capacity at end of 2013 (16 > 1 GW, 10 > 2 GW)
- 2 states have >25% of total in-state generation from wind (9 states > 12%)

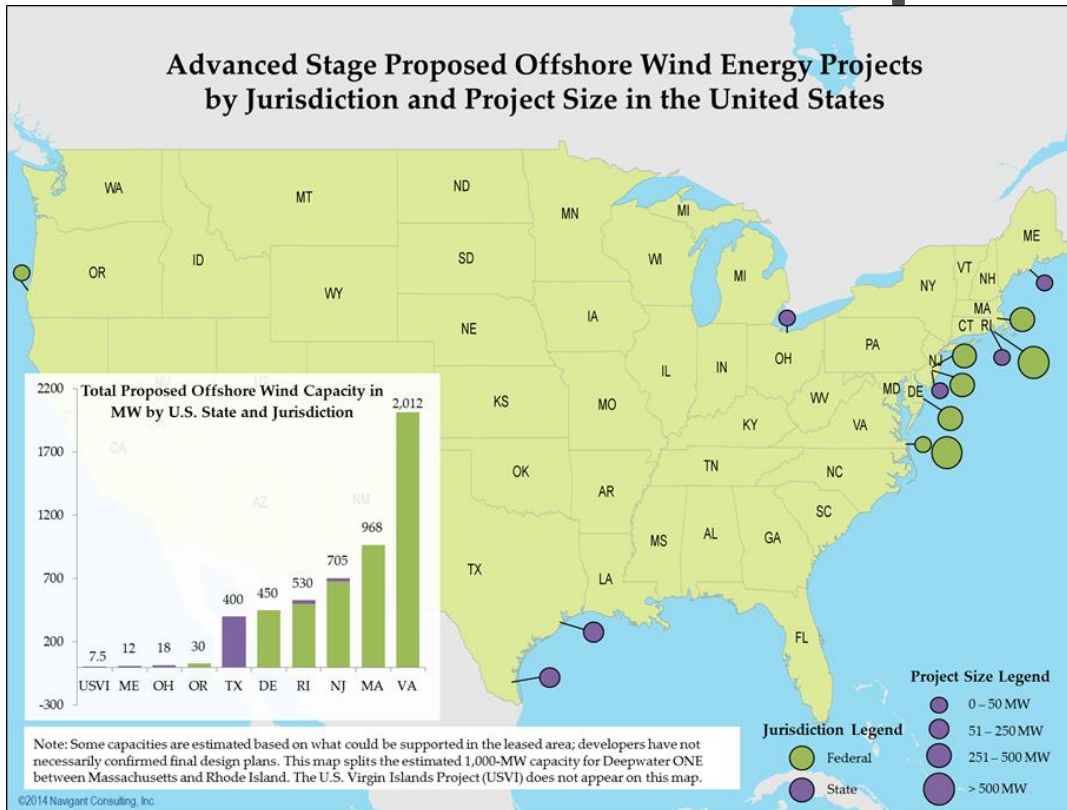
\* Based on 2013 wind and total generation by state from EIA's *Electric Power Monthly*.

Source: AWEA project database, EIA



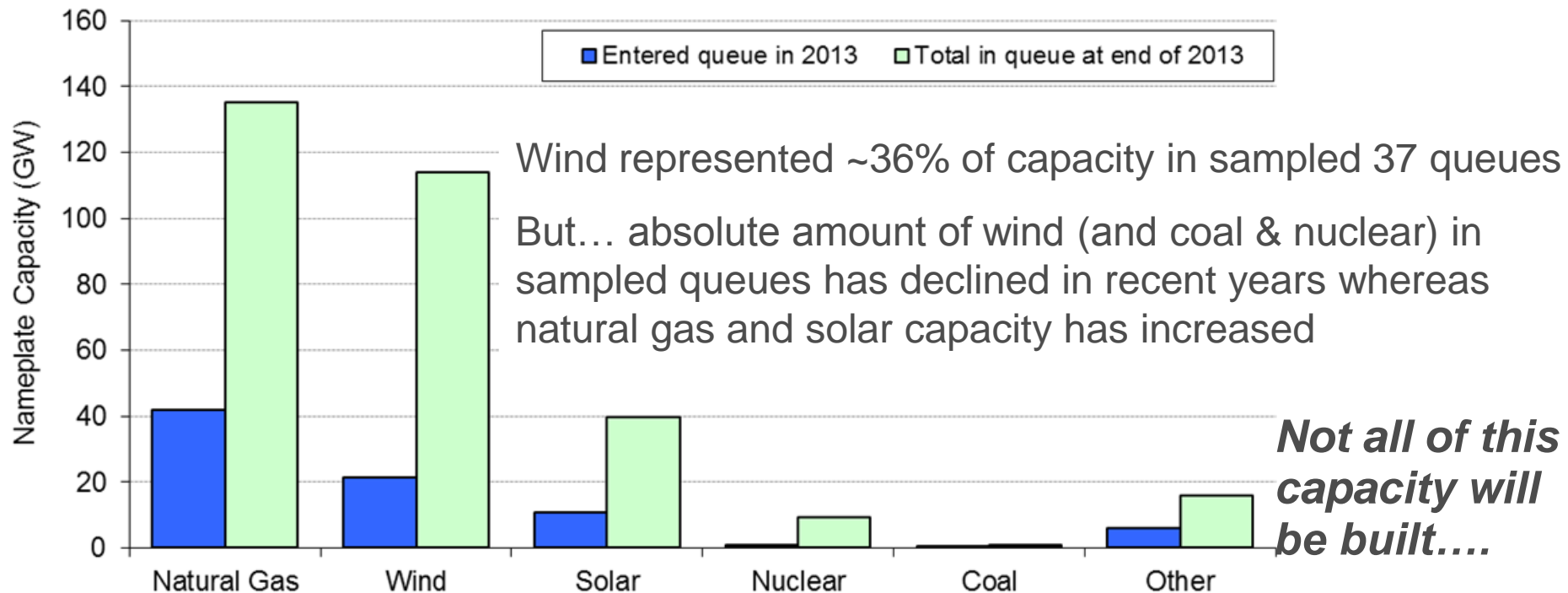
# No Commercial Offshore Turbines Commissioned in the U.S., but 15 Projects Totaling 5.1 GW Are Somewhat More Advanced in Development

Advanced Stage Proposed Offshore Wind Energy Projects  
by Jurisdiction and Project Size in the United States



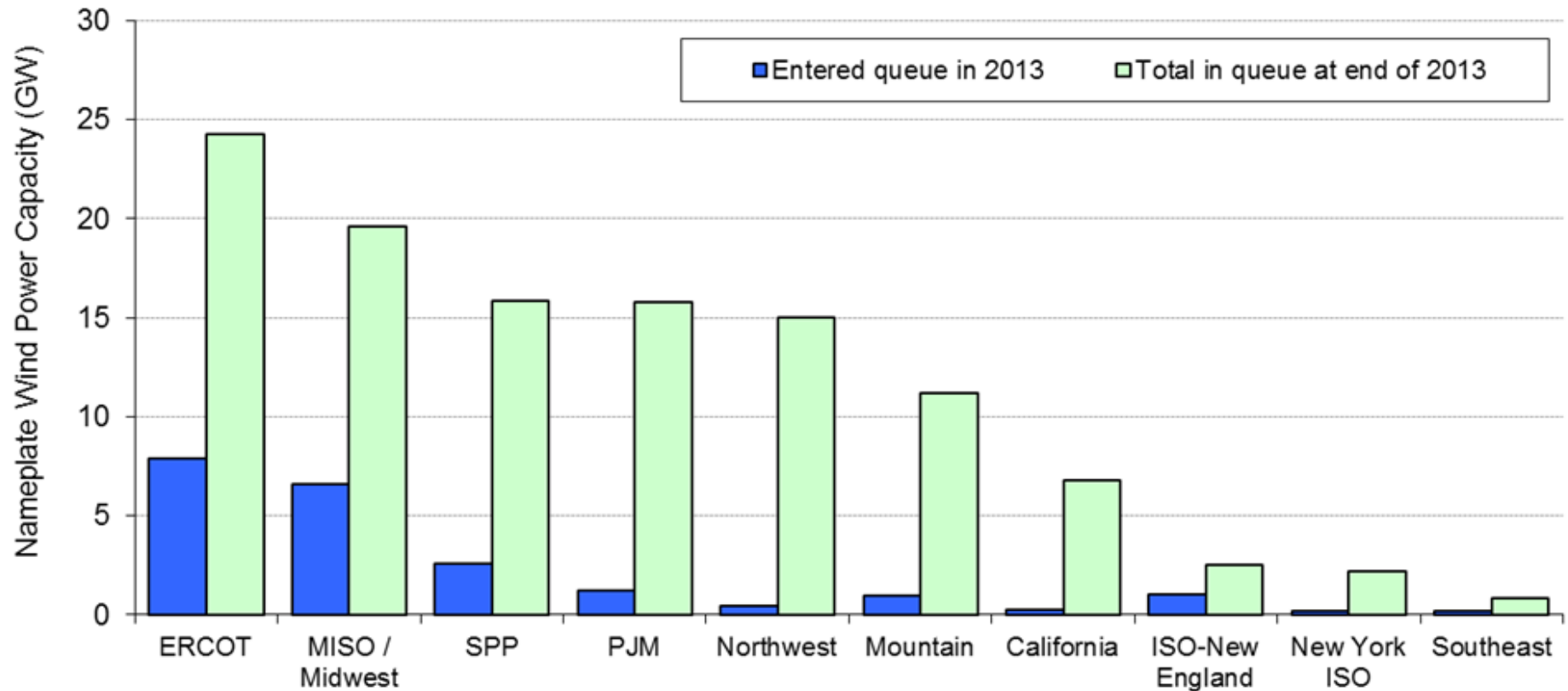
- Two projects have power purchase agreements (PPAs):
  - Cape Wind (MA)
  - Deepwater Wind (RI)
- Three demonstration projects selected for deployment by DOE
- Scale model of floating turbine deployed in ME in June 2013
- MD established offshore wind set-aside within state's RPS
- Fishermen (NJ), Baryonyx (TX) Statoil (ME) faced set-backs

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



- AWEA reports >13 GW of capacity under construction after 1Q2014

# 95% of Wind Capacity Planned for Texas, Midwest, Southwest Power Pool, PJM, Northwest, Mountain Region, and

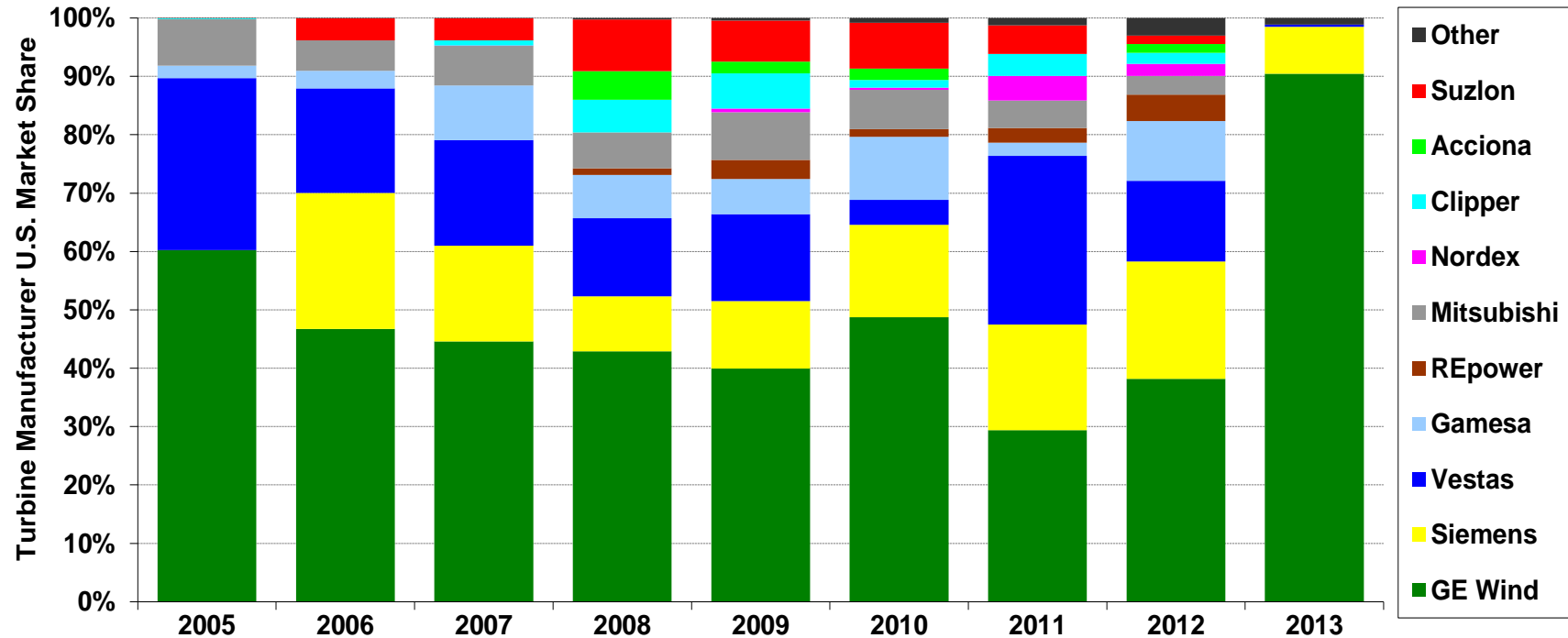


*Not all of this capacity will be built....*

# Industry Trends

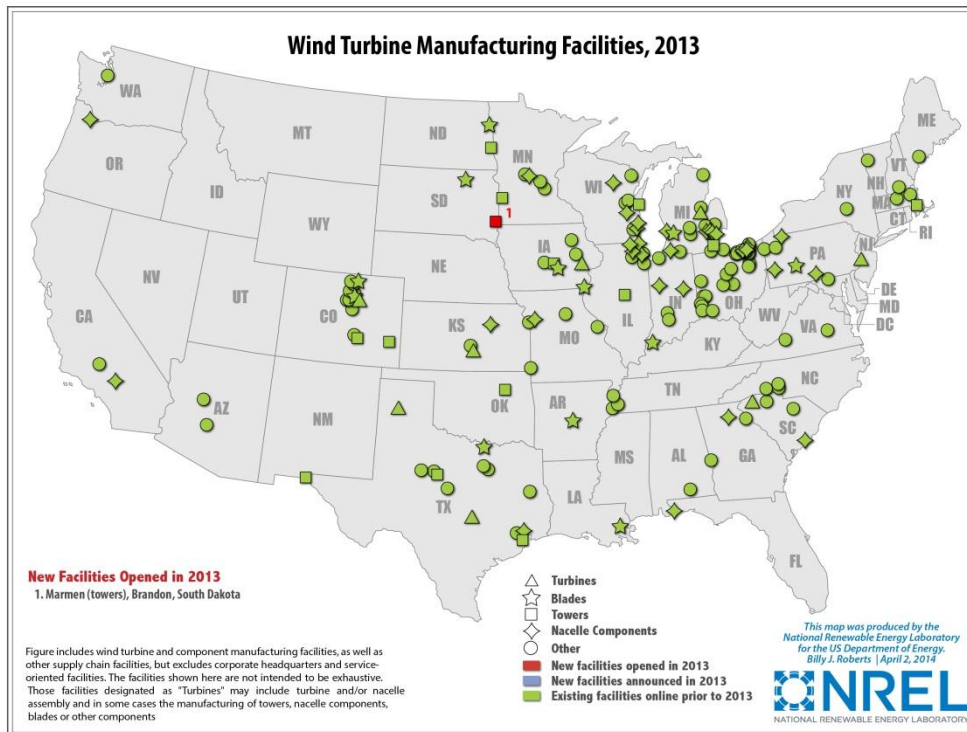


# GE Captured 90% of U.S. Wind Turbine Market Share in a Slow 2013



- Siemens came in a distant second, at 8% market share
- 2013 U.S. installations by Chinese and South Korean manufacturers only included Sany Electric (8 MW)
- Globally, Vestas recaptured the mantle as top supplier, with GE falling to 5th

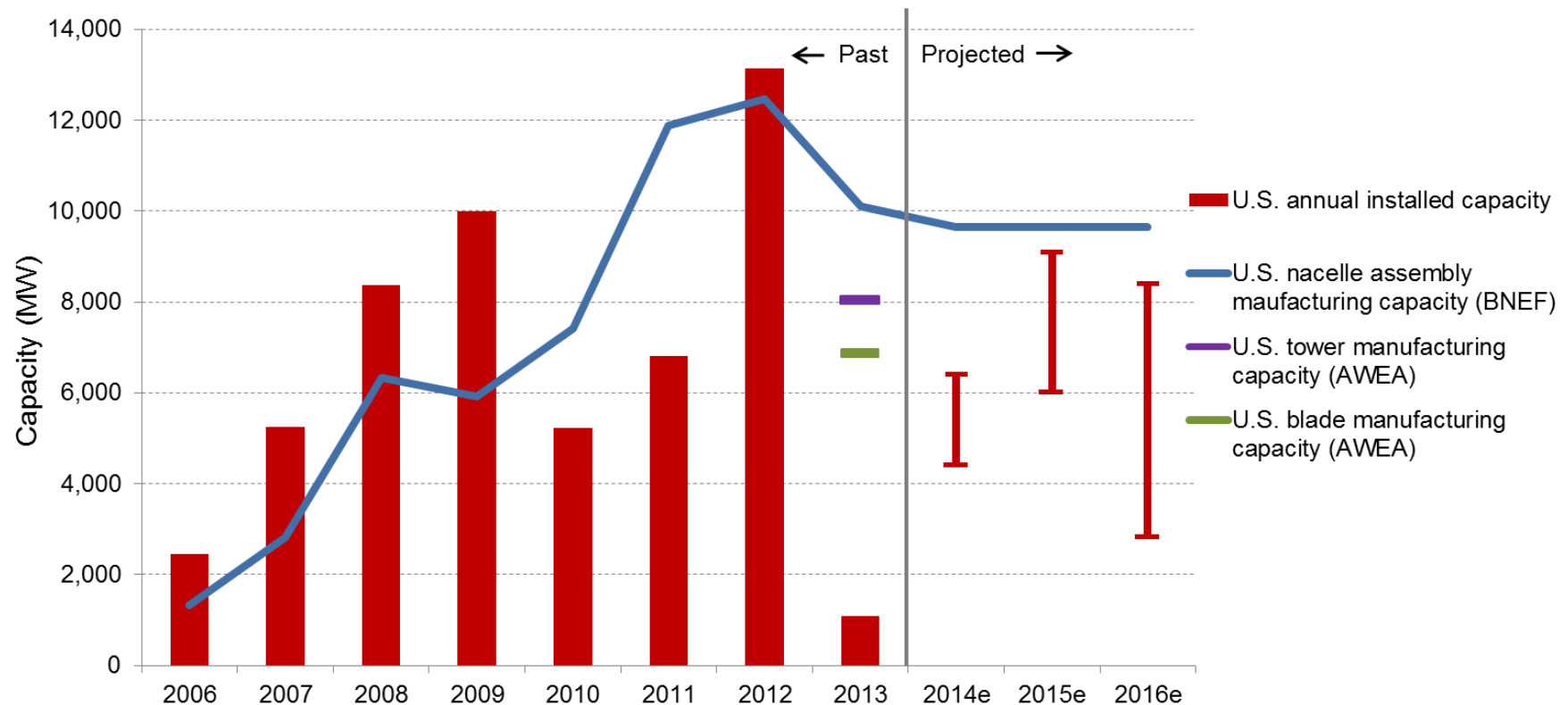
# Manufacturing Supply Chain Experienced Substantial Growing Pains



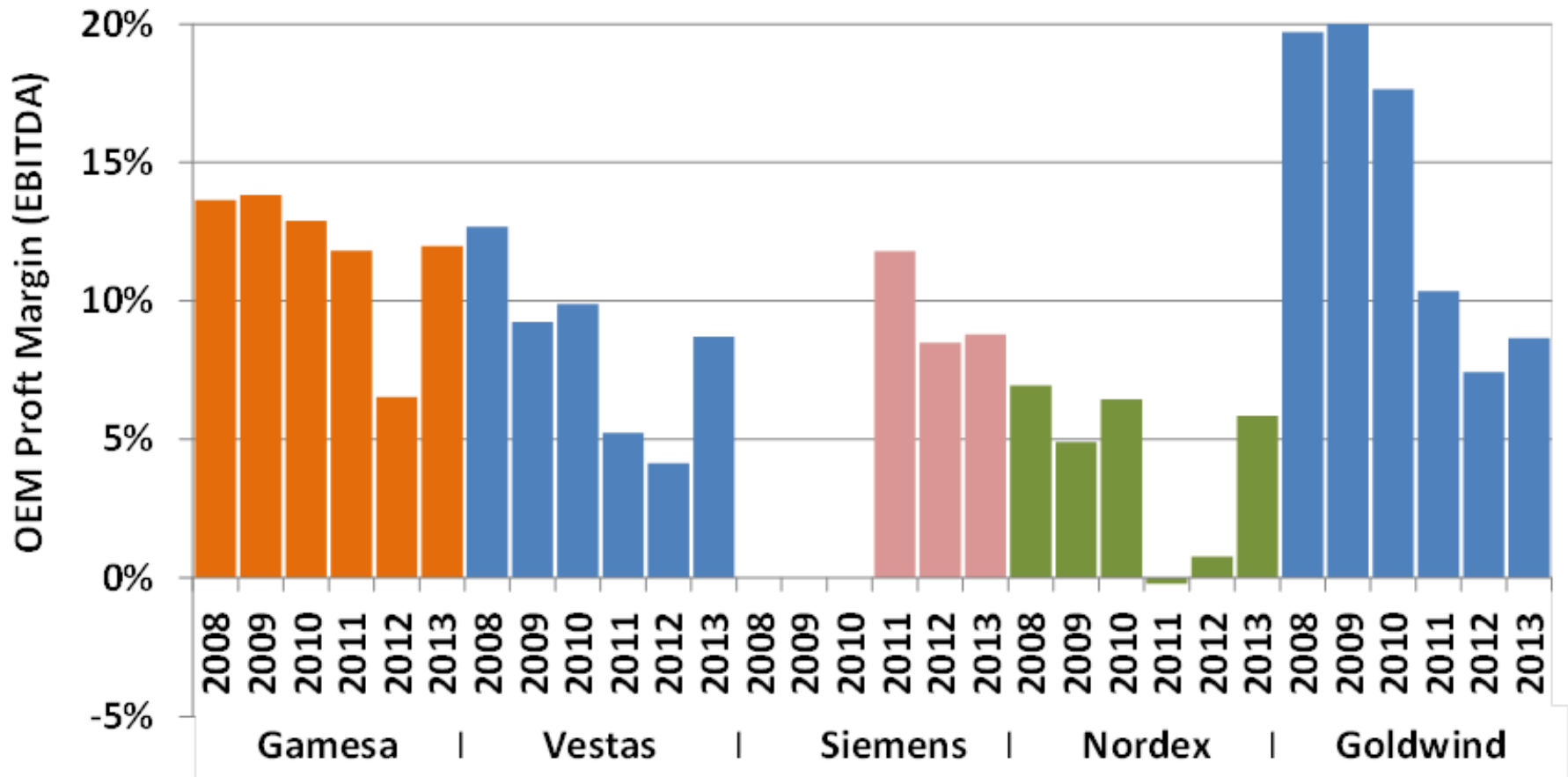
*Note: map is not intended to be exhaustive*

- Over last decade, foreign and domestic manufacturers have localized and expanded U.S. manufacturing presence
- 5 of 10 turbine OEMs with largest share of U.S. market through 2013 had manufacturing facilities in the U.S. at the end of 2013, compared to one in 2004
- Uncertain demand and growing global competition have created strain: general trend in 2013 was towards reduced workforce or closed facilities
- Only one facility opened in 2013, with a larger number closed or dormant
- Wind related jobs declined from 80,700 in 2012 to 50,500 in 2013

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

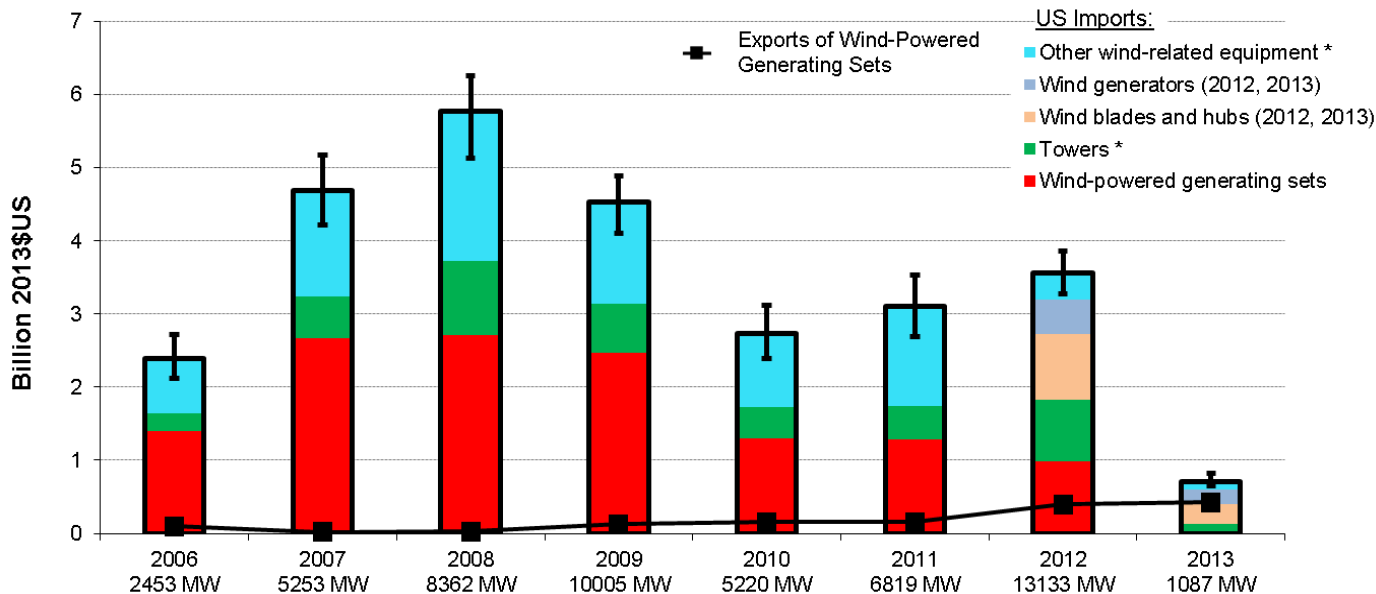


# After a Number of Years in Decline, Turbine OEM Profitability Rebounded in 2013





# Sharp Decline in Wind-Related Imports and Stable Exports in 2013



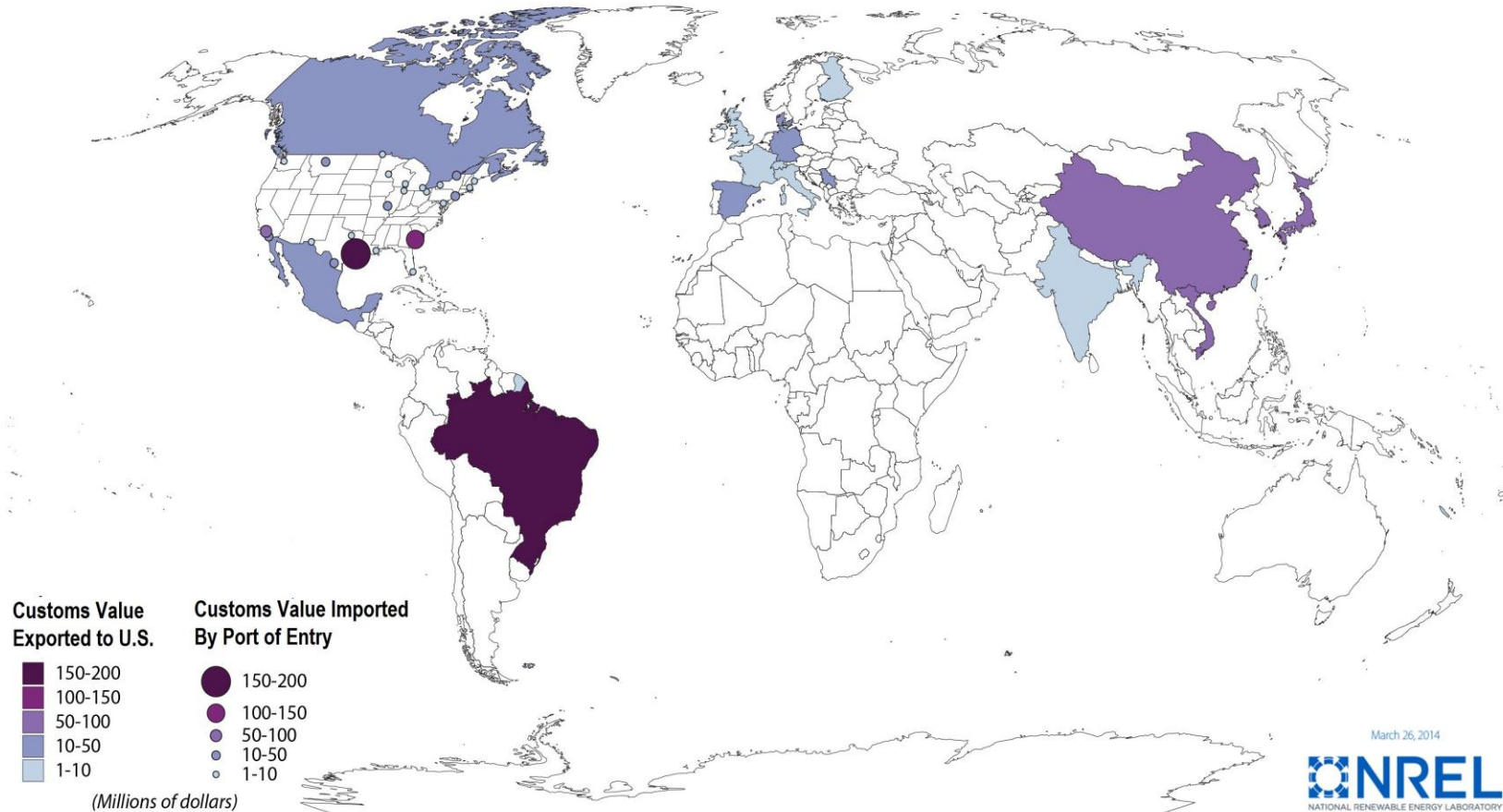
\* estimated imports

U.S. is a net importer of wind equipment

Exports of wind-powered generating sets increased modestly in 2013 to \$421 billion; no ability to track other wind-specific exports, but total tower exports equalled \$129 million

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

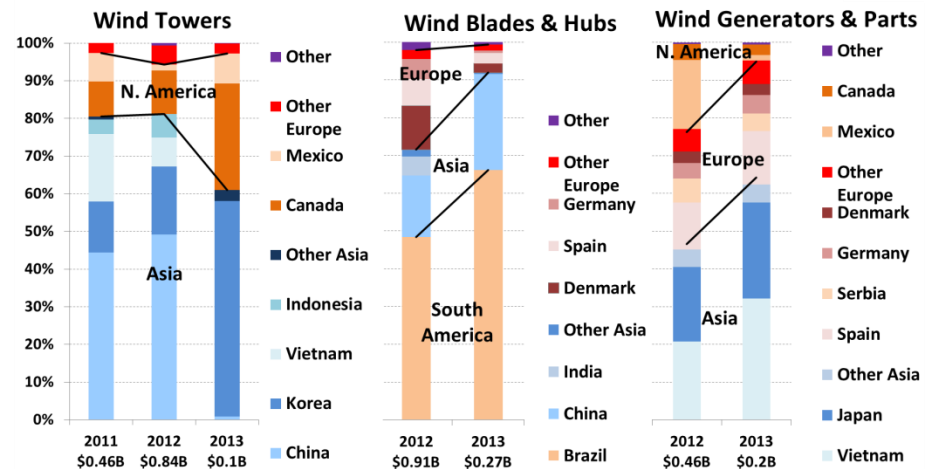
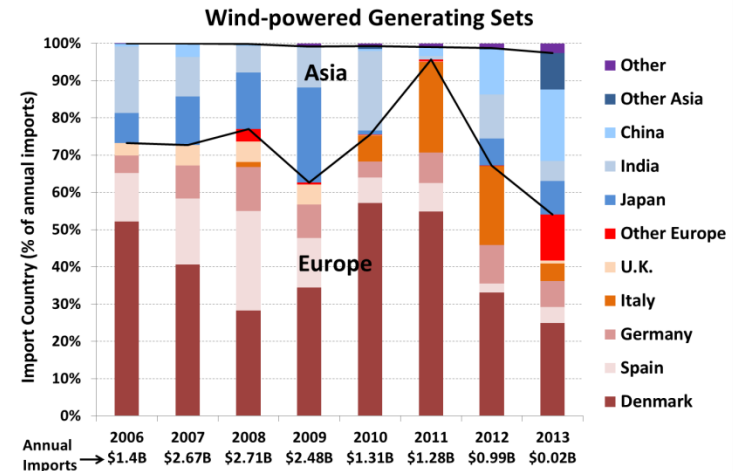
# Tracked Wind Equipment Imports in 2013 Mostly from Asia, the Americas, and



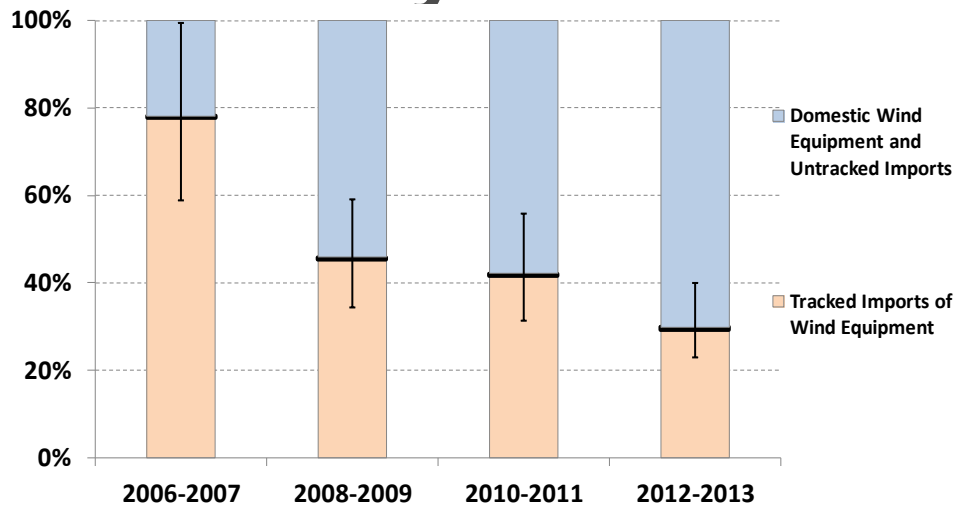
Note: Tracked wind-specific equipment includes: wind-powered generating sets, towers, hubs and blades, wind generators and parts.

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

- Considering total 2013 imports in these selected trade categories: 45% from Asia, 38% Americas, 16% from Europe
- Majority of wind-powered generating sets from home countries of OEMs, but share from Europe in recent decline
- Majority of tower imports from Asia (less from North America), but tariff measures largely stopped imports from China and Vietnam in 2013
- Most imports of blades & hubs from Brazil and China in 2013
- Globally diverse sourcing strategy for generators & parts, with increase from Asia in 2013



# Despite Supply Chain Challenges, a Growing Amount of the Equipment Used in U.S. Wind Projects Has Been Sourced Domestically since 2006-07



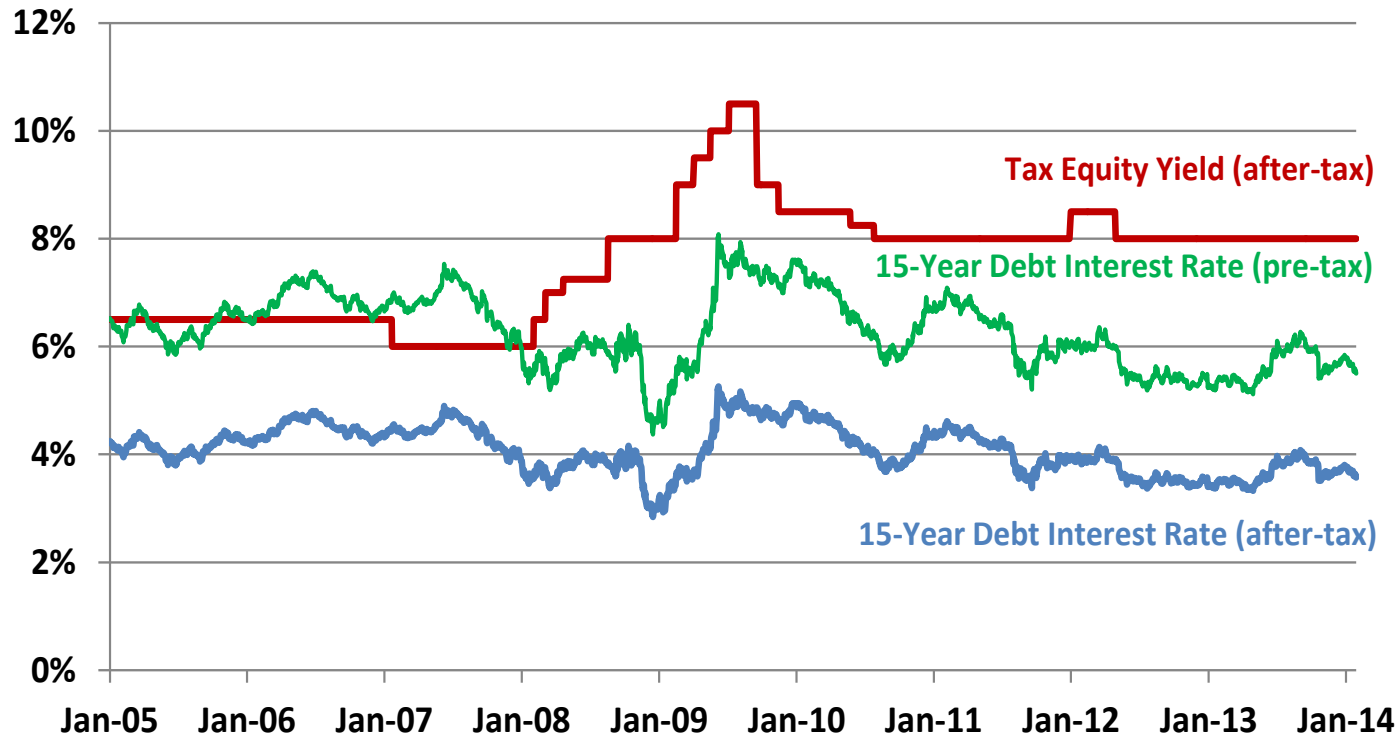
When presented as a fraction of equipment-related turbine costs, the combined import share of *tracked* wind equipment (i.e., blades, towers, generators, gearboxes, and wind-powered generating sets) has declined from nearly 80% in 2006-2007 to ~30% in 2012-2013.

*See report for the assumptions used to generate these figures*

Because imports occur in untracked trade categories, including many nacelle internals, overall import (domestic) content is higher (lower) than suggested here: in 2012, overall domestic content estimated at ~40%

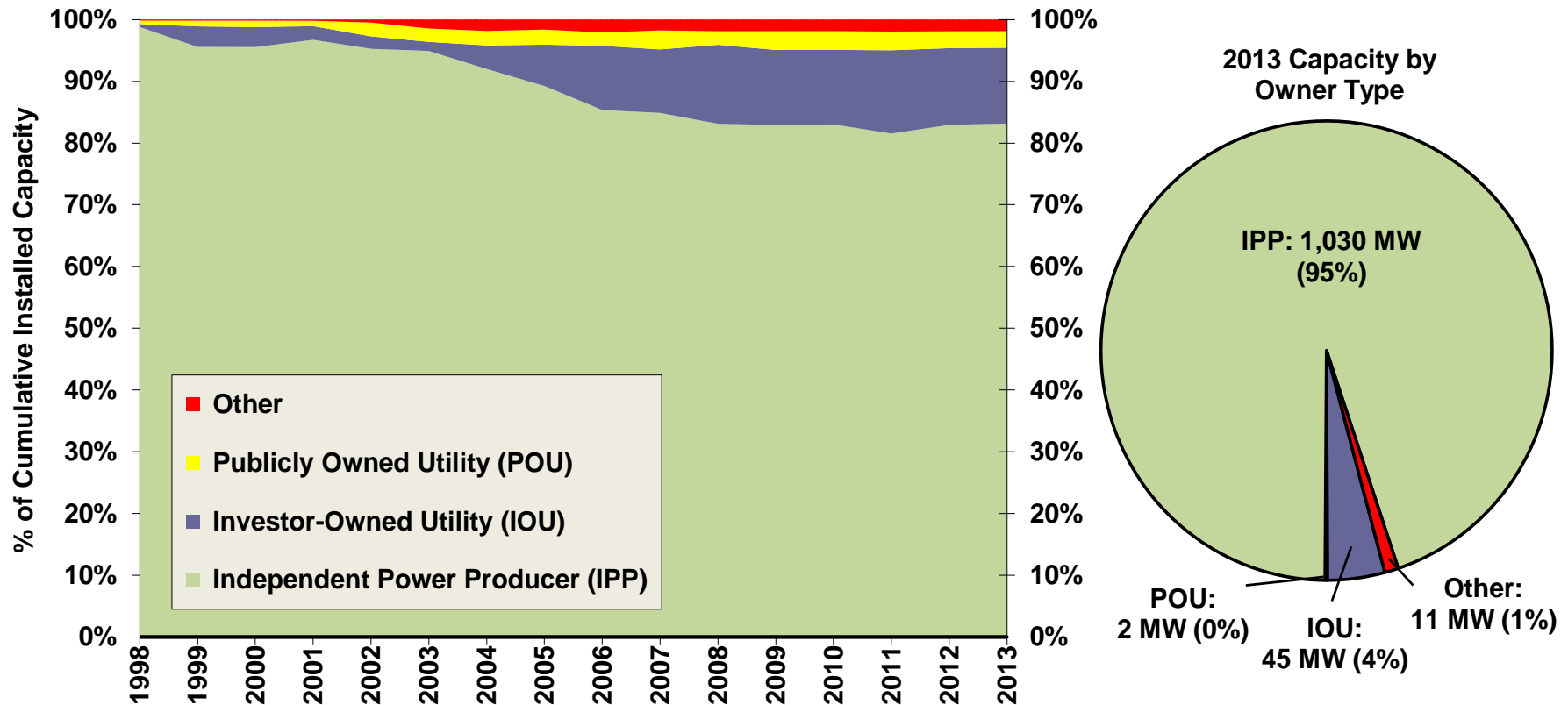


# The Project Finance Environment Held Steady in 2013



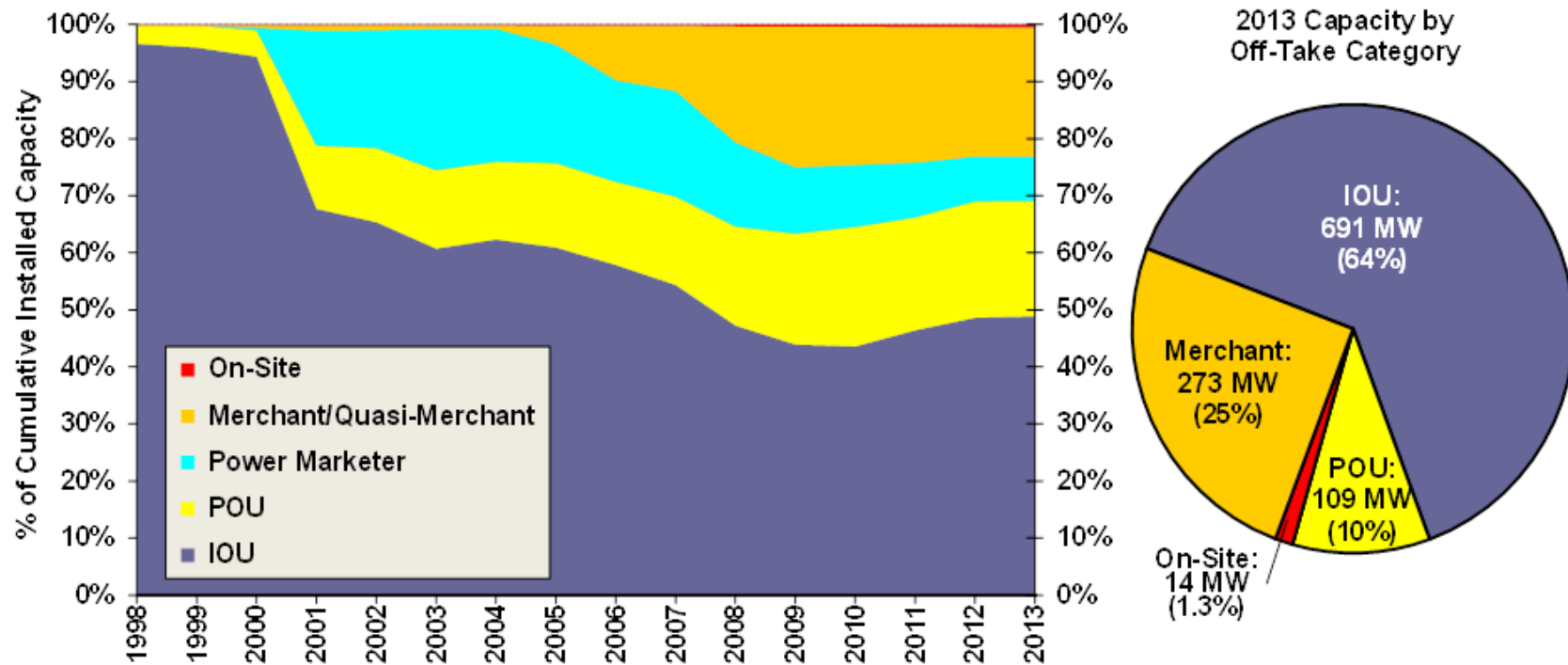
- Notable events included the launch of several renewable energy “yieldcos”
- Tax equity and term debt yields held relatively steady in 2013
- Project sponsors raised \$3.1 billion of tax equity and \$2.4 billion of debt

# IPPs Own 95% of the New Wind Capacity Installed in 2013



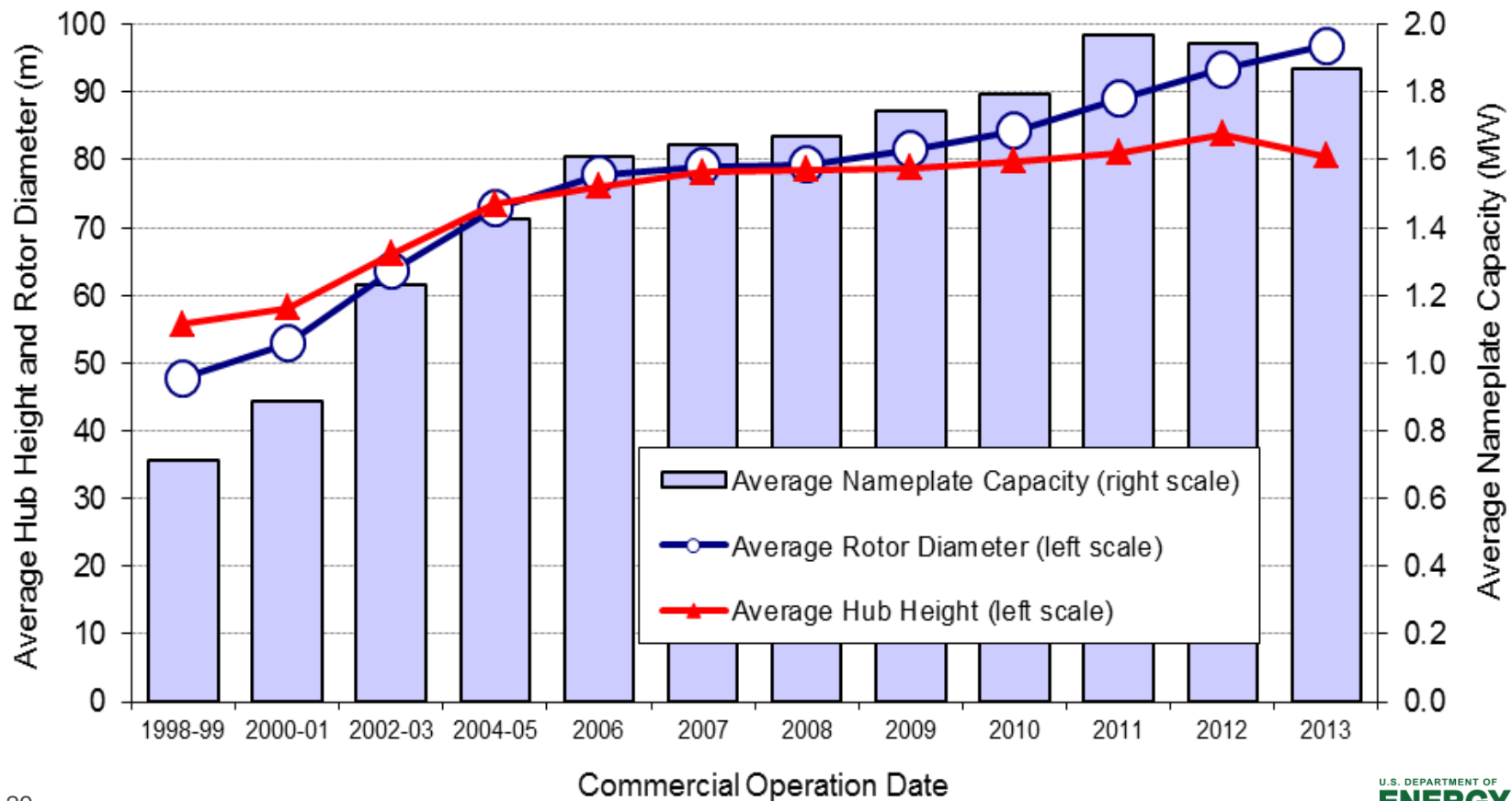
New utility ownership continued to languish for the second year in a row, at just 4% of the 2013 wind capacity additions

# Long-Term Contracted Sales to Utilities Remained the Most Common Off-Take Arrangement, but Merchant Projects Have Regained some Favor, at Least in Texas



# Technology Trends

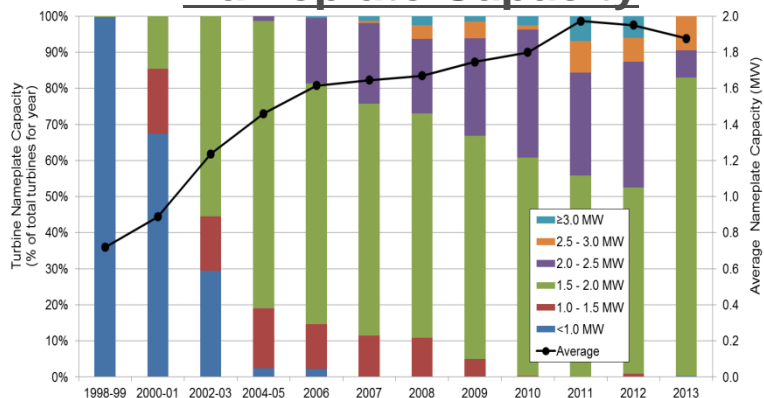
# Turbine Nameplate Capacity, Hub Height, and Rotor Diameter Have All Increased Significantly Over the Long Term



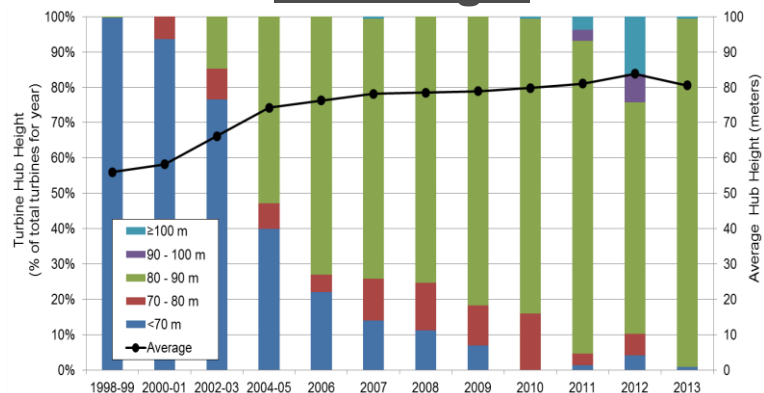


# Growth in Rotor Diameter Has Outpaced Growth in Nameplate Capacity and Hub Height in Recent Years

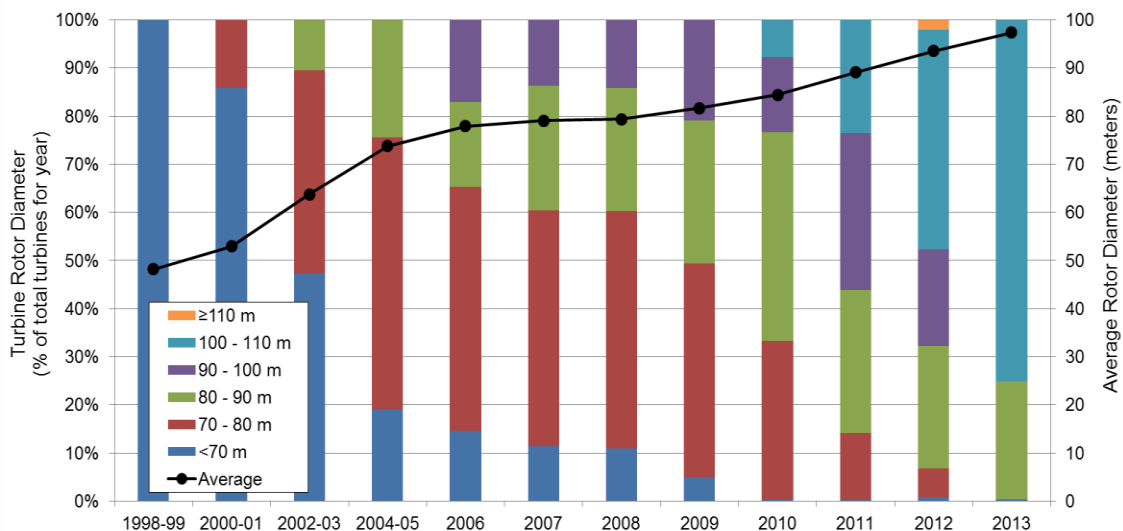
## Nameplate Capacity



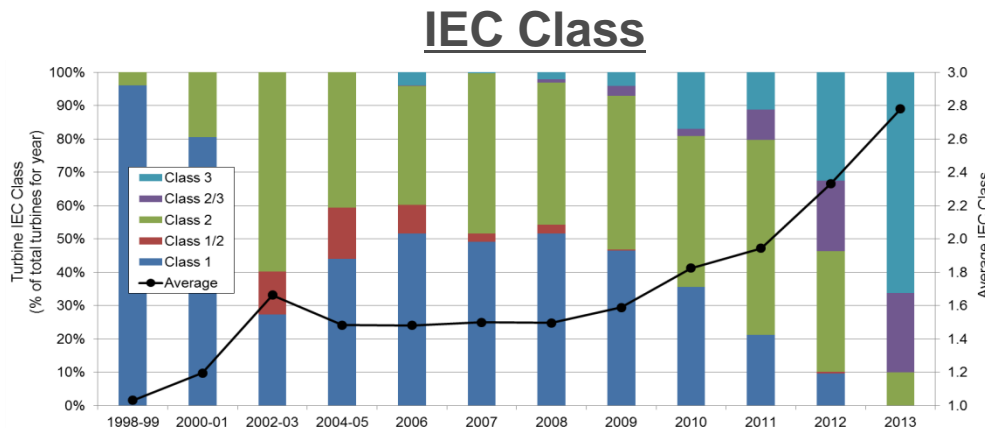
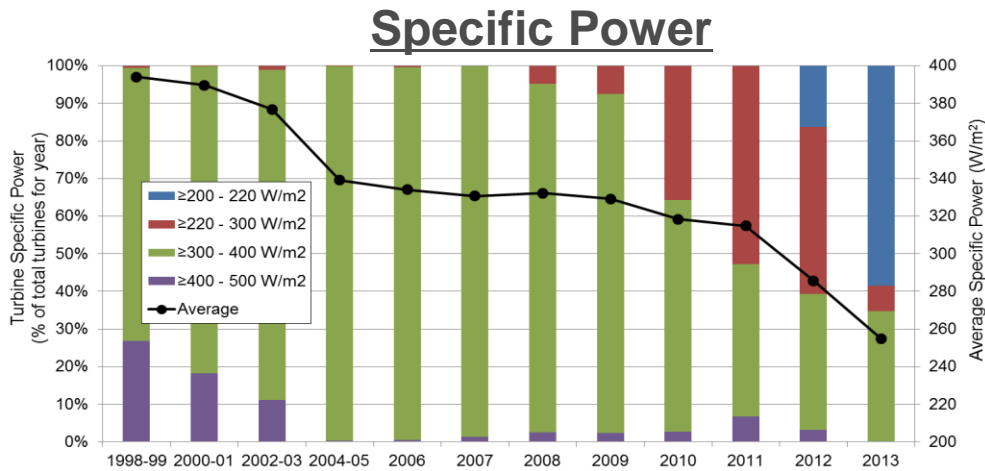
## Hub Height



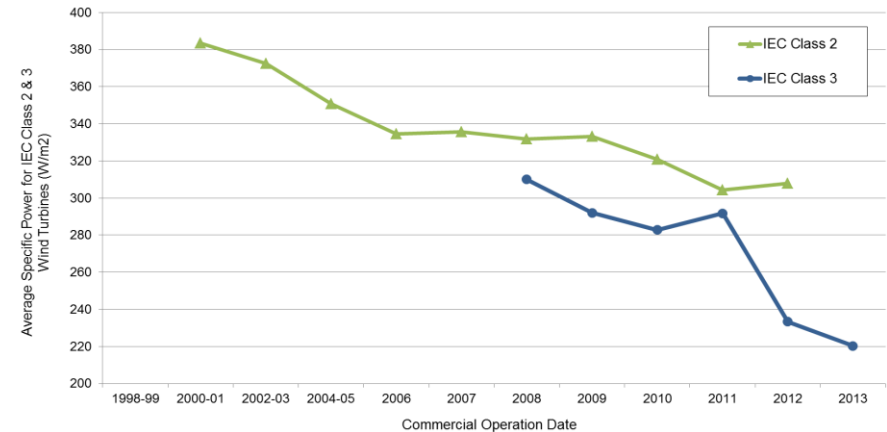
## Rotor Diameter



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

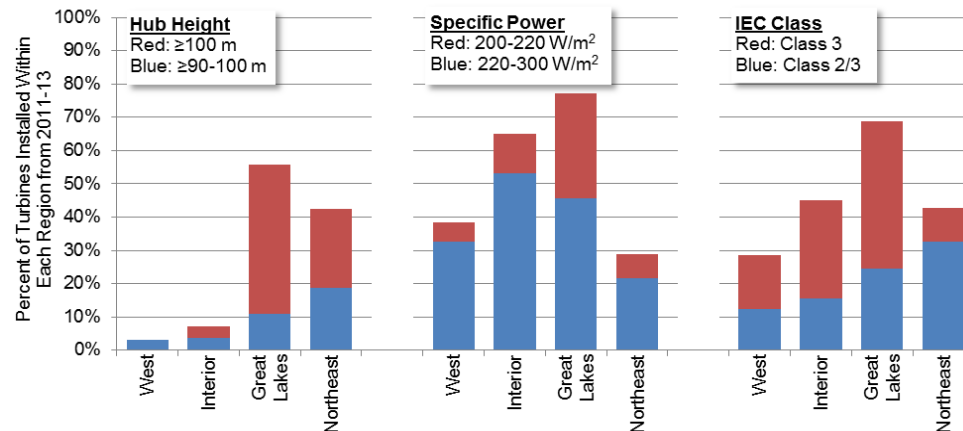


## Specific Power by IEC Class 2 & 3

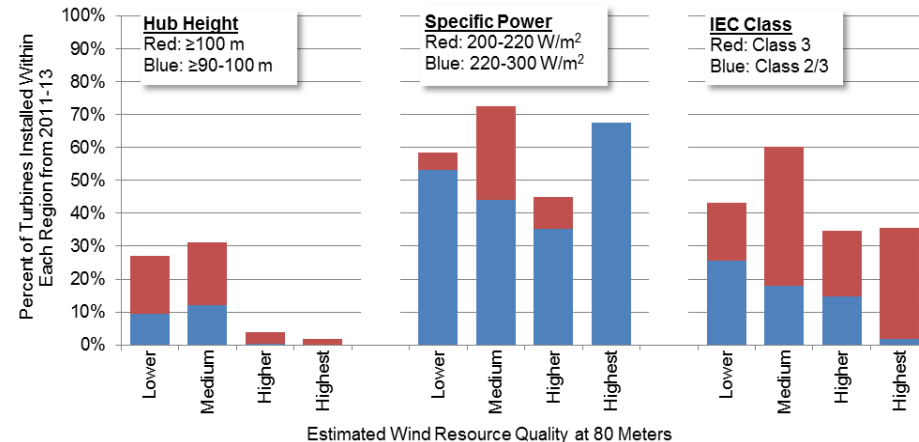


# Turbines Originally Designed for Lower Wind Speeds Are Now Regularly Employed in Both Lower and Higher Wind Speed Sites, Whereas Taller Towers Predominate in Lower Wind Speed Sites

## By Region

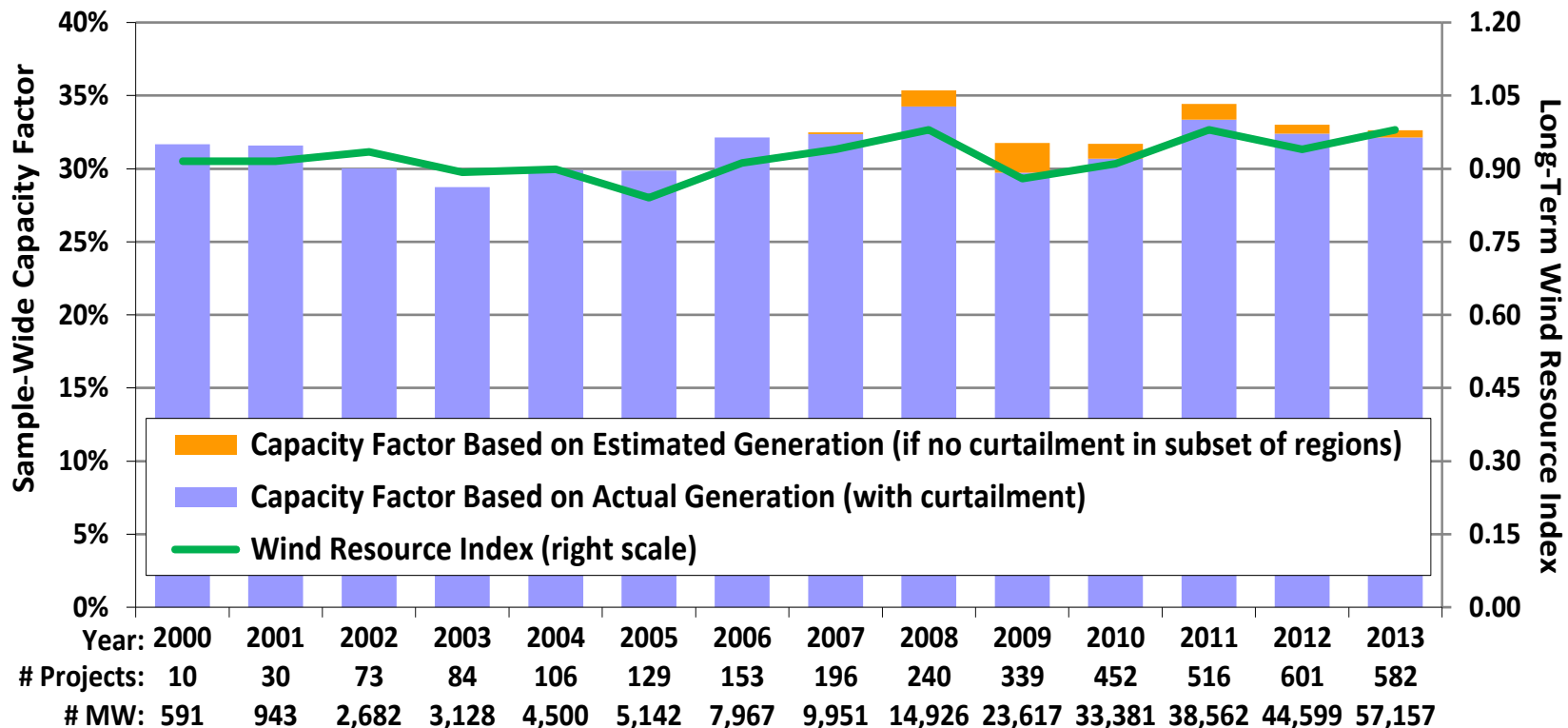


## By Wind Resource Quality



## Performance Trends

# Trends in Sample-Wide Capacity Factors Have Been Impacted by Curtailment and Inter-Year Wind Resource Variability



The wind resource index is compiled from NextEra Energy Resources reports. The pre-2007 portion of the index is adjusted to approximate the conversion from wind speed to generation (this adjustment is unnecessary starting in 2007).



# Wind Curtailment Is Substantial, but Has Generally Declined in Recent Years

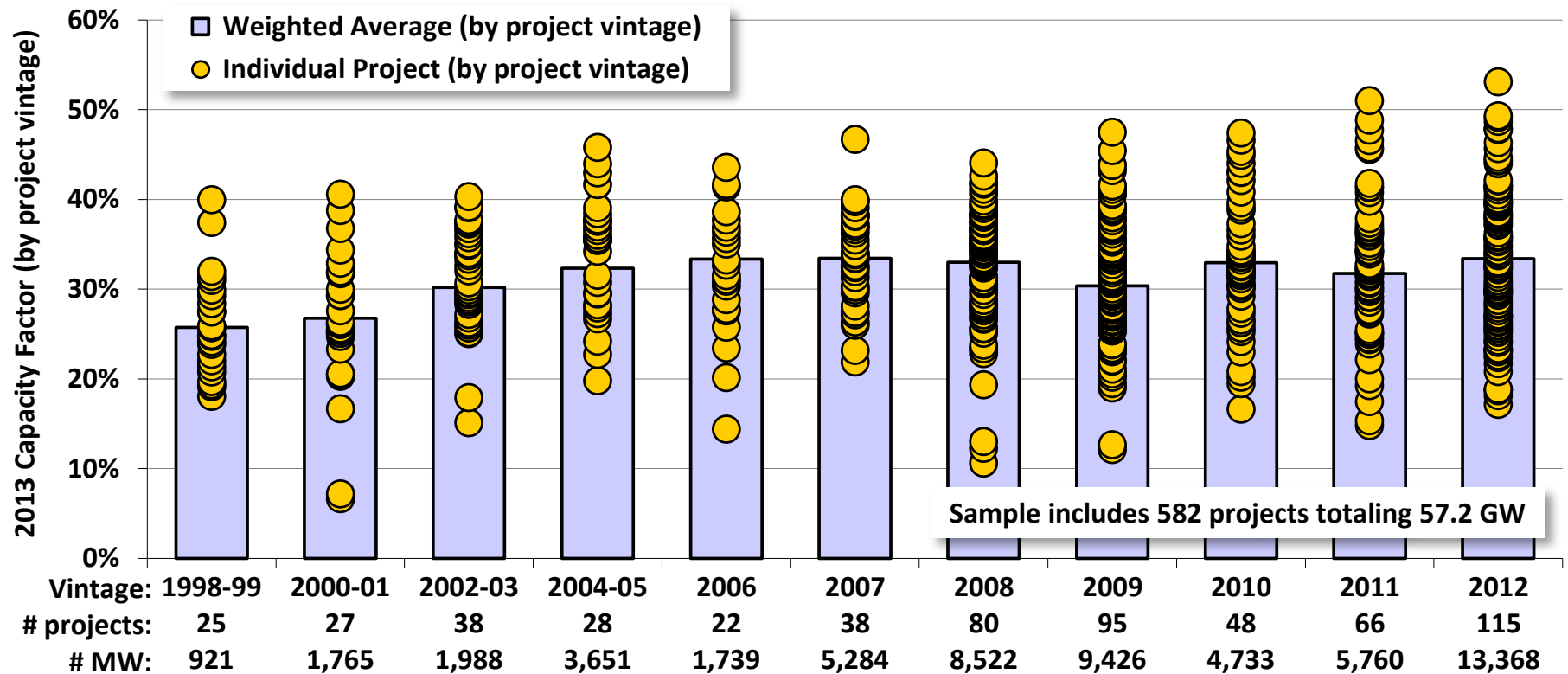
Estimated Wind Curtailment (GWh and % of potential wind generation)

	2007	2008	2009	2010	2011	2012	2013
Electric Reliability Council of Texas (ERCOT)	109 (1.2%)	1,417 (8.4%)	3,872 (17.1%)	2,067 (7.7%)	2,622 (8.5%)	1,175 (3.8%)	363 (1.2%)
Southwestern Public Service Company (SPS)	N/A	0 (0.0%)	0 (0.0%)	0.9 (0.0%)	0.5 (0.0%)	N/A**	N/A**
Public Service Company of Colorado (PSCo)	N/A	2 (0.1%)	19 (0.6%)	82 (2.2%)	64 (1.4%)	115(e) (2.0%)	112(e) (1.7%)
Northern States Power Company (NSP)	N/A	25 (0.9%)	42 (1.7%)	44 (1.7%)	59 (1.6%)	125 (3.0%)	284 (5.9%)
Midwest Independent System Operator (MISO), less NSP	N/A	N/A	250 (2.0%)	780 (4.2%)	792 (3.4%)	724 (2.5%)	1,470 (4.6%)
Bonneville Power Administration (BPA)	N/A	N/A	N/A	5* (0.1%)	129* (1.4%)	71* (0.7%)	6* (0.1%)
New York Independent System Operator (NYISO)	N/A	N/A	N/A	N/A	N/A	9 (0.3%)	50 (1.4%)
PJM	N/A	N/A	N/A	N/A	N/A	125 <sup>#</sup> (2.0%) <sup>#</sup>	284 (1.9%)
<b>Total Across These Eight Areas:</b>	<b>109 (1.2%)</b>	<b>1,444 (5.7%)</b>	<b>4,183 (9.7%)</b>	<b>2,978 (4.9%)</b>	<b>3,665 (5.0%)</b>	<b>2,345 (2.6%)</b>	<b>2,569 (2.5%)</b>

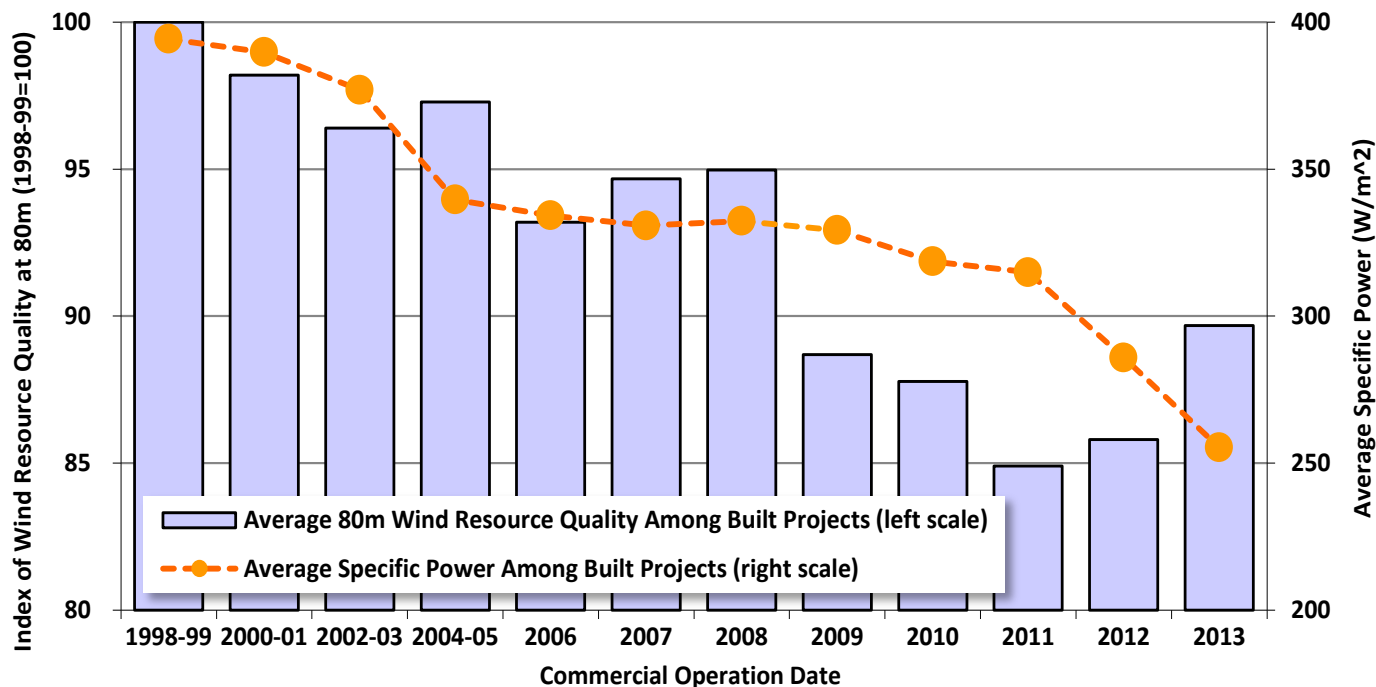
*MISO, ERCOT, NYISO, and PJM track both forced and economic curtailment, while BPA, NSP, PSCo, and SPS likely only capture forced curtailment*

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



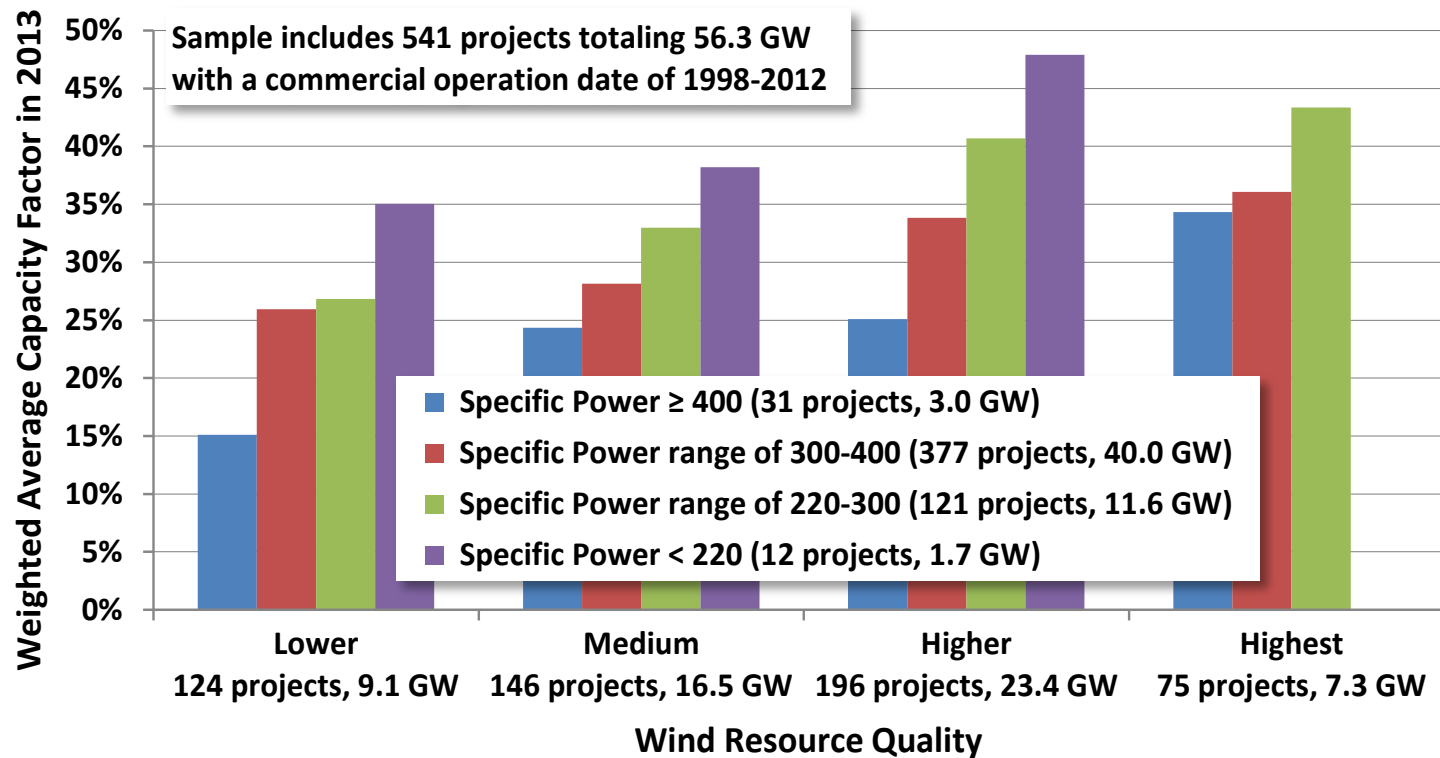
# Trends Explained by Competing Influence of Lower Specific Power and Build-Out of Lower Quality Wind Resource Sites



## All else equal:

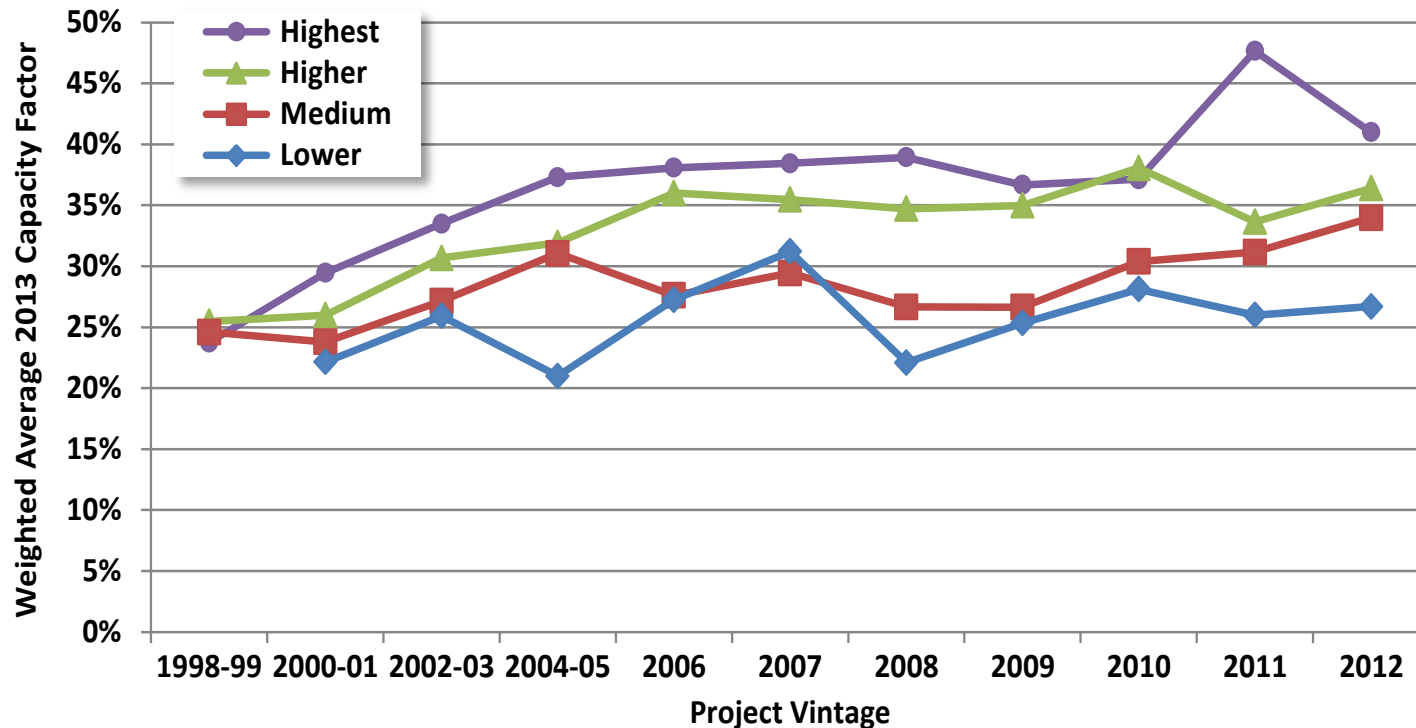
- Drop in average specific power will boost capacity factors
- Building projects in lower wind resource sites will hurt capacity factors

# 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

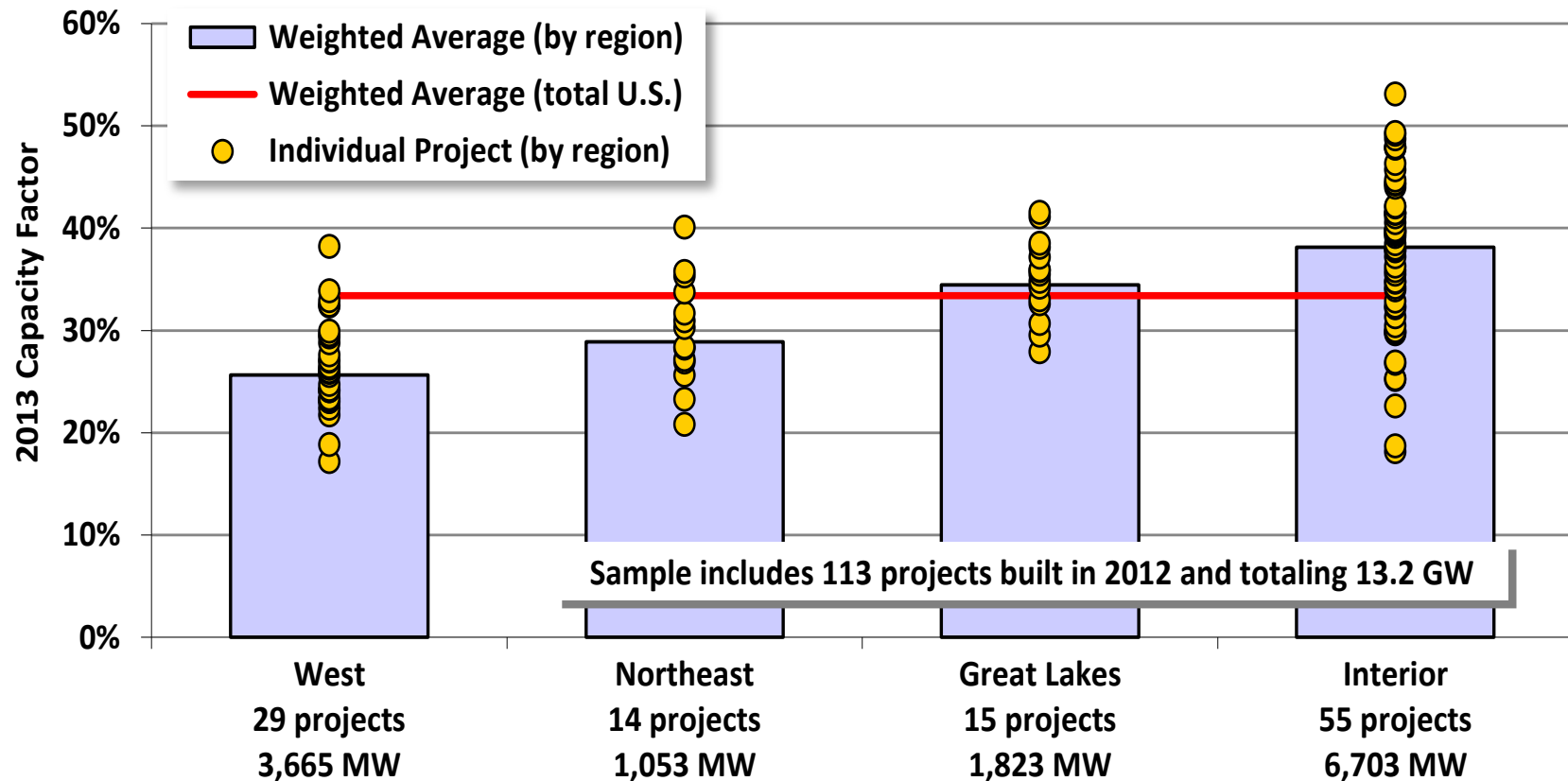
# Controlling for Wind Resource Quality and Commercial Operation Date Demonstrates Impact of Turbine Evolution



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

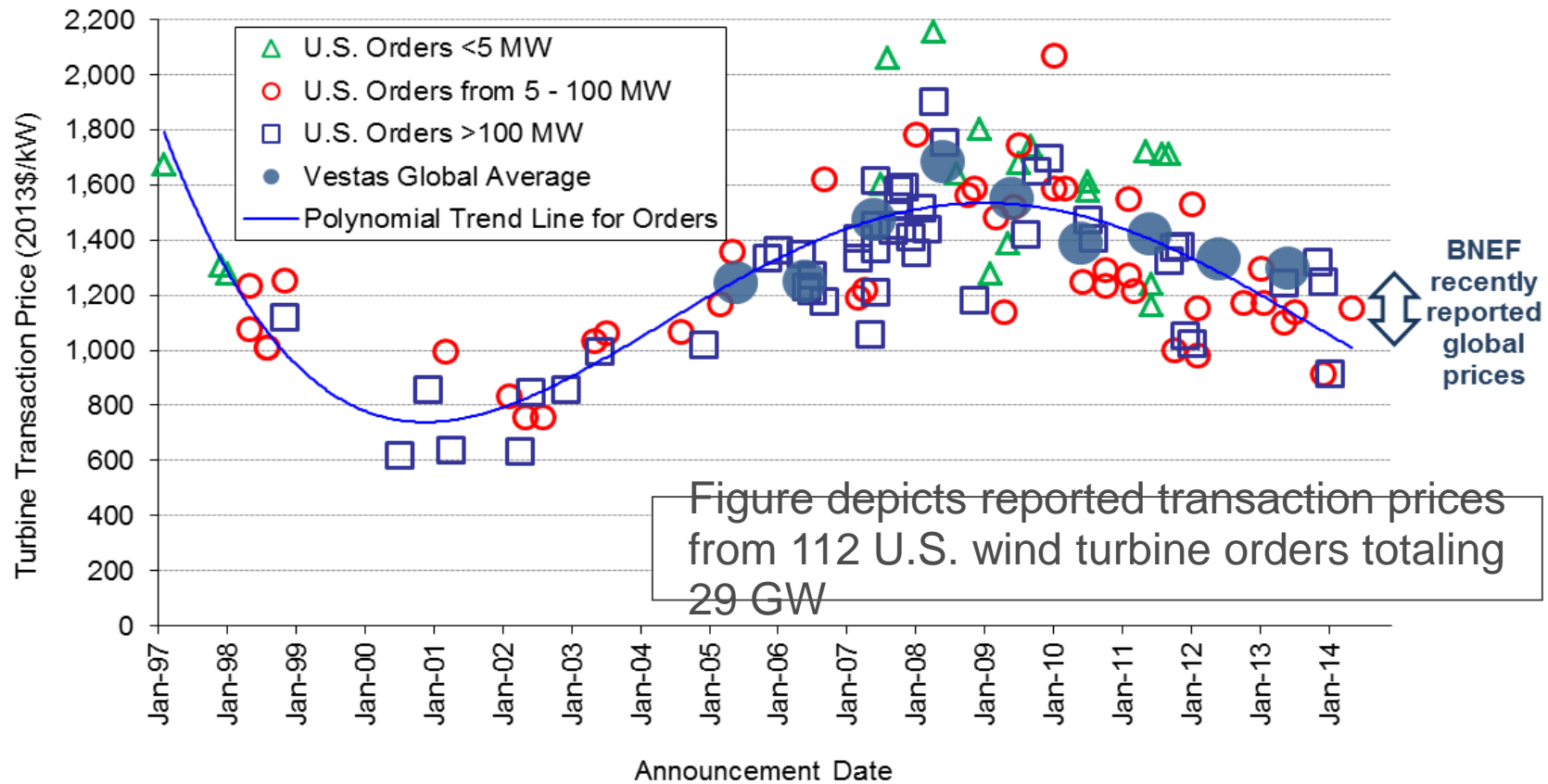


# Regional Variations in Capacity Factors Reflect the Strength of the Wind Resource and Adoption of New Turbine Technology



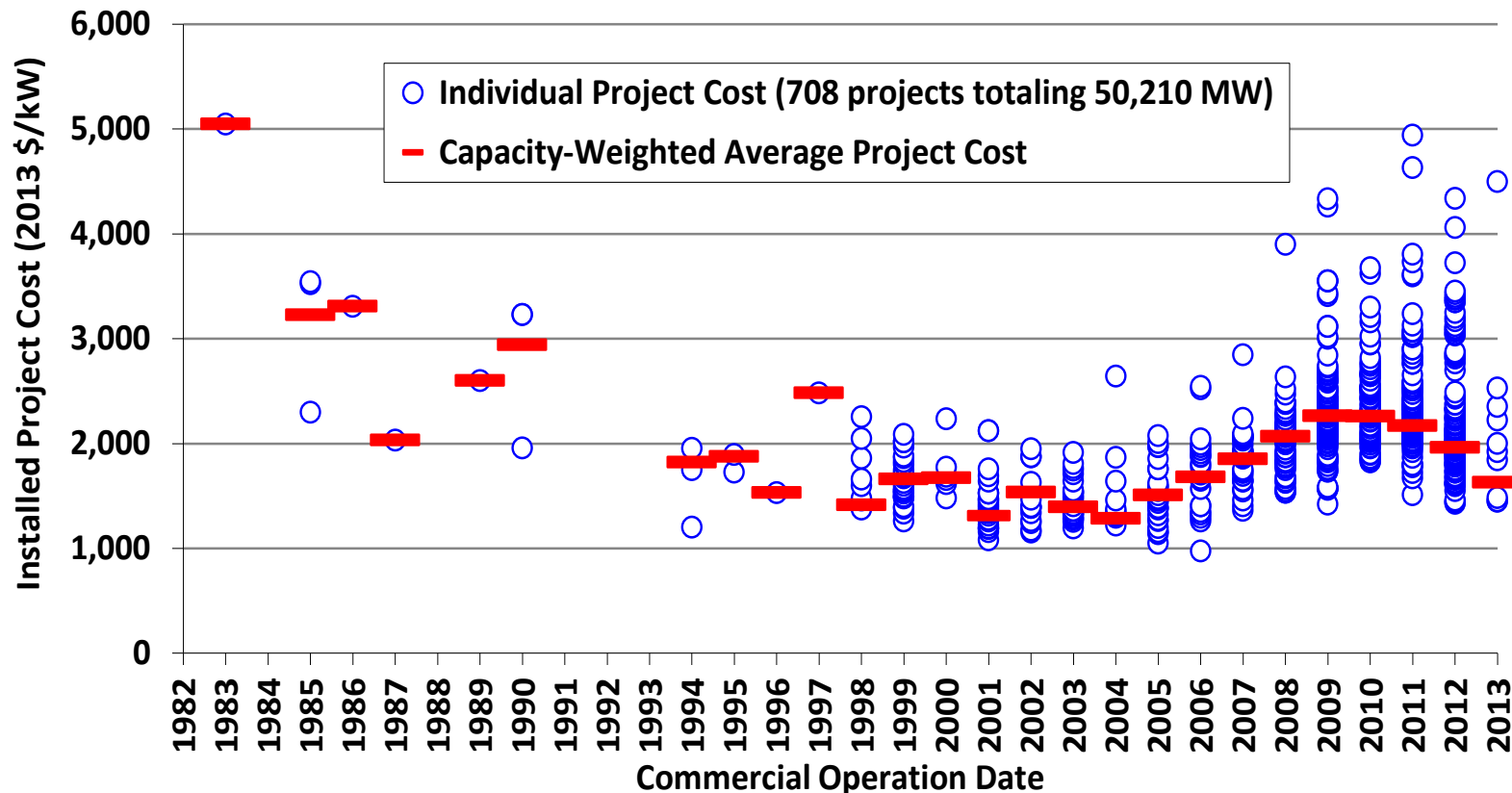
## Cost Trends

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



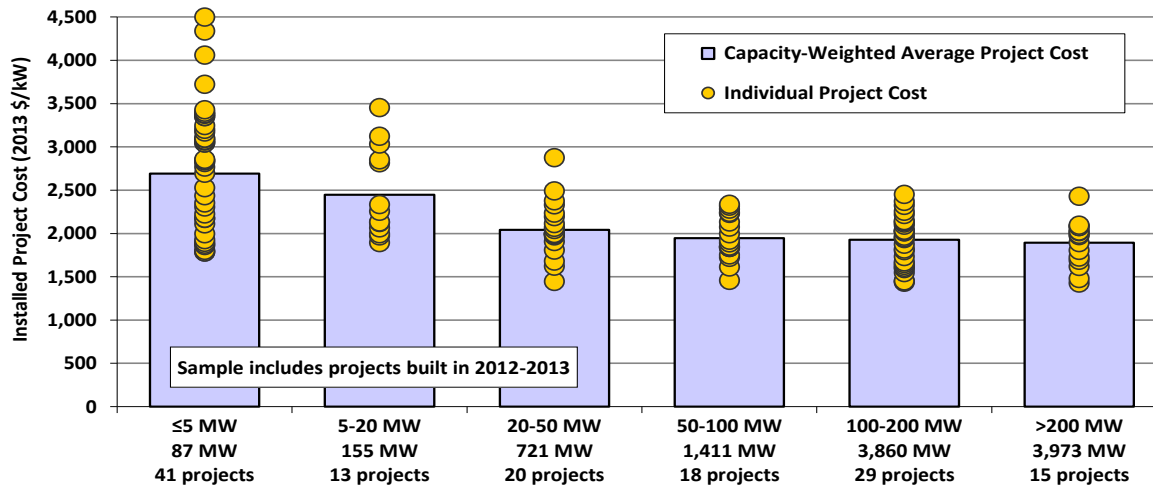
- Recent turbine orders reportedly in the range of \$900-1,300/kW, with more-favorable terms for buyers and improved technology

# Reported Installed Project Costs Continued to Trend Lower in 2013

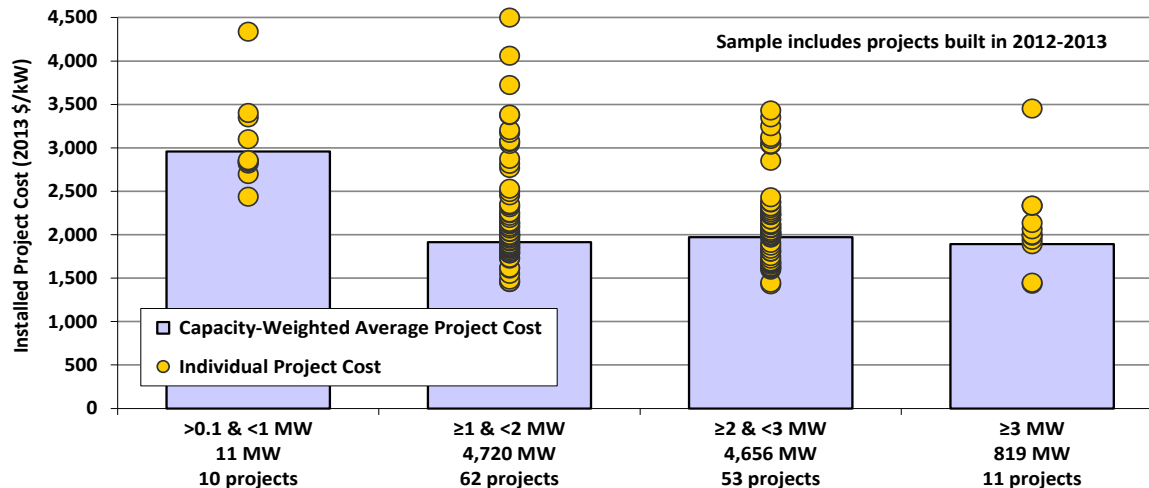


- The limited sample of 2013 projects had an average cost of \$1,630/kW, down substantially from previous years
- Larger sample of under-construction projects average \$1,750/kW

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



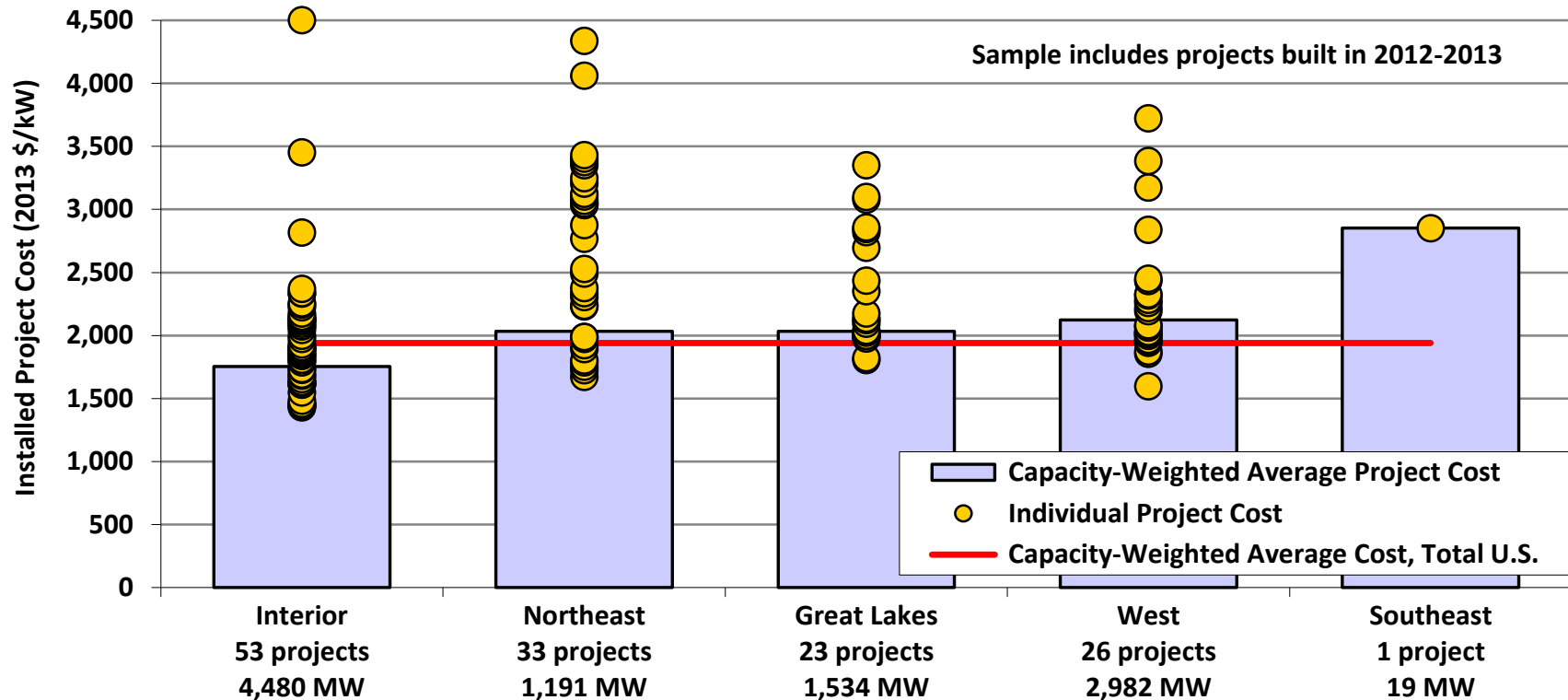
Project Size



Turbine Size

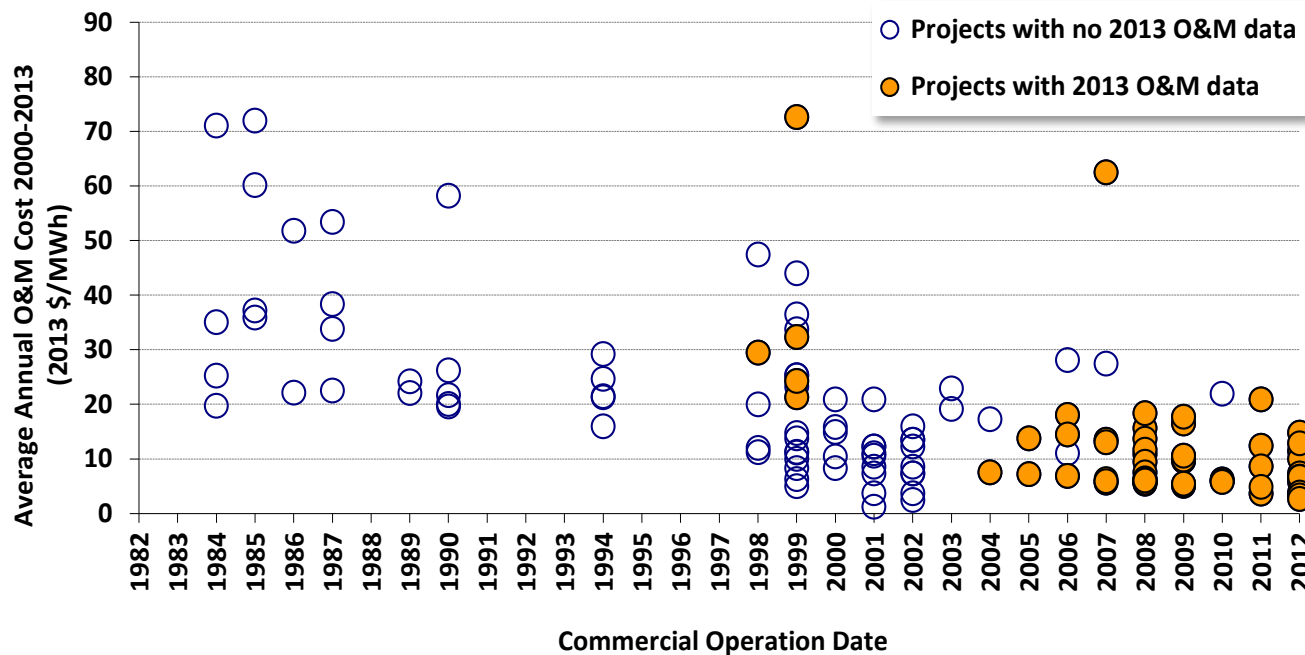


# Some Regional Differences in Average Wind Power Project Costs Are Apparent



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

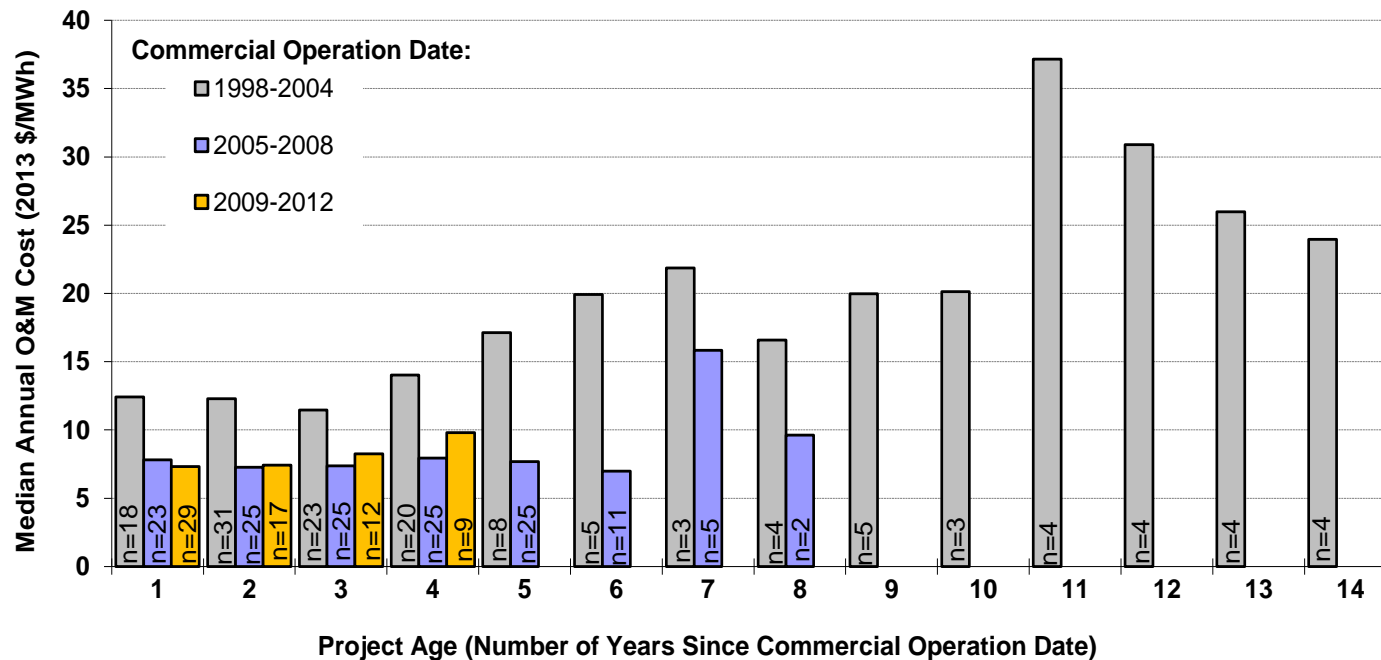
# Operations and Maintenance Costs Varied By Project Age and Commercial Operations Date



Capacity-weighted average 2000-13 O&M costs for projects built in the 1980s equal **\$34/MWh**, dropping to **\$23/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 152 wind projects totaling 10,679 MW; few projects in sample have complete records of O&M costs from 2000-13; 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 extremely 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 2013 for projects built in the 2000s of ~\$24/MWh

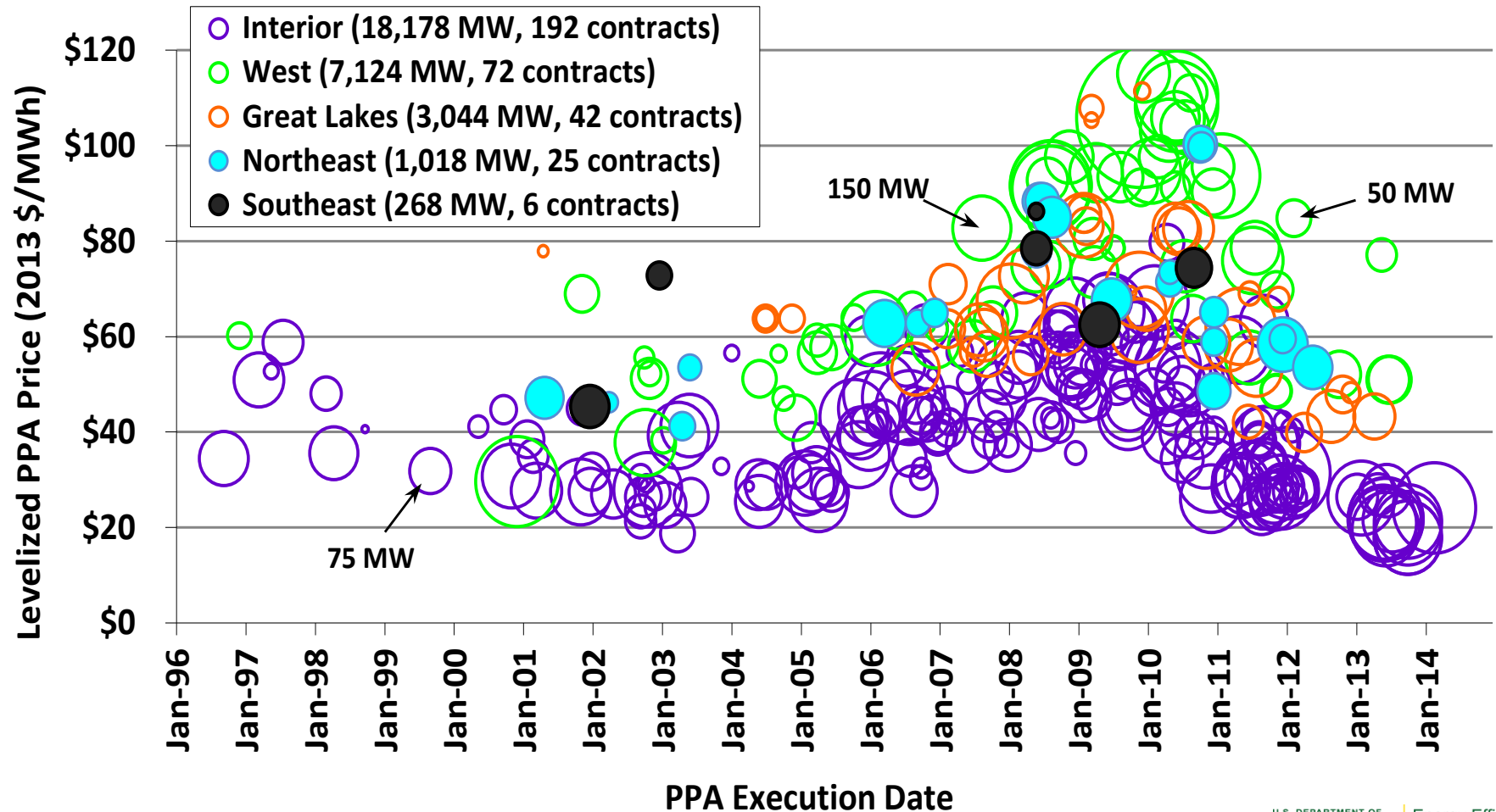
## Wind Power Price Trends

# Sample of Wind Power Prices

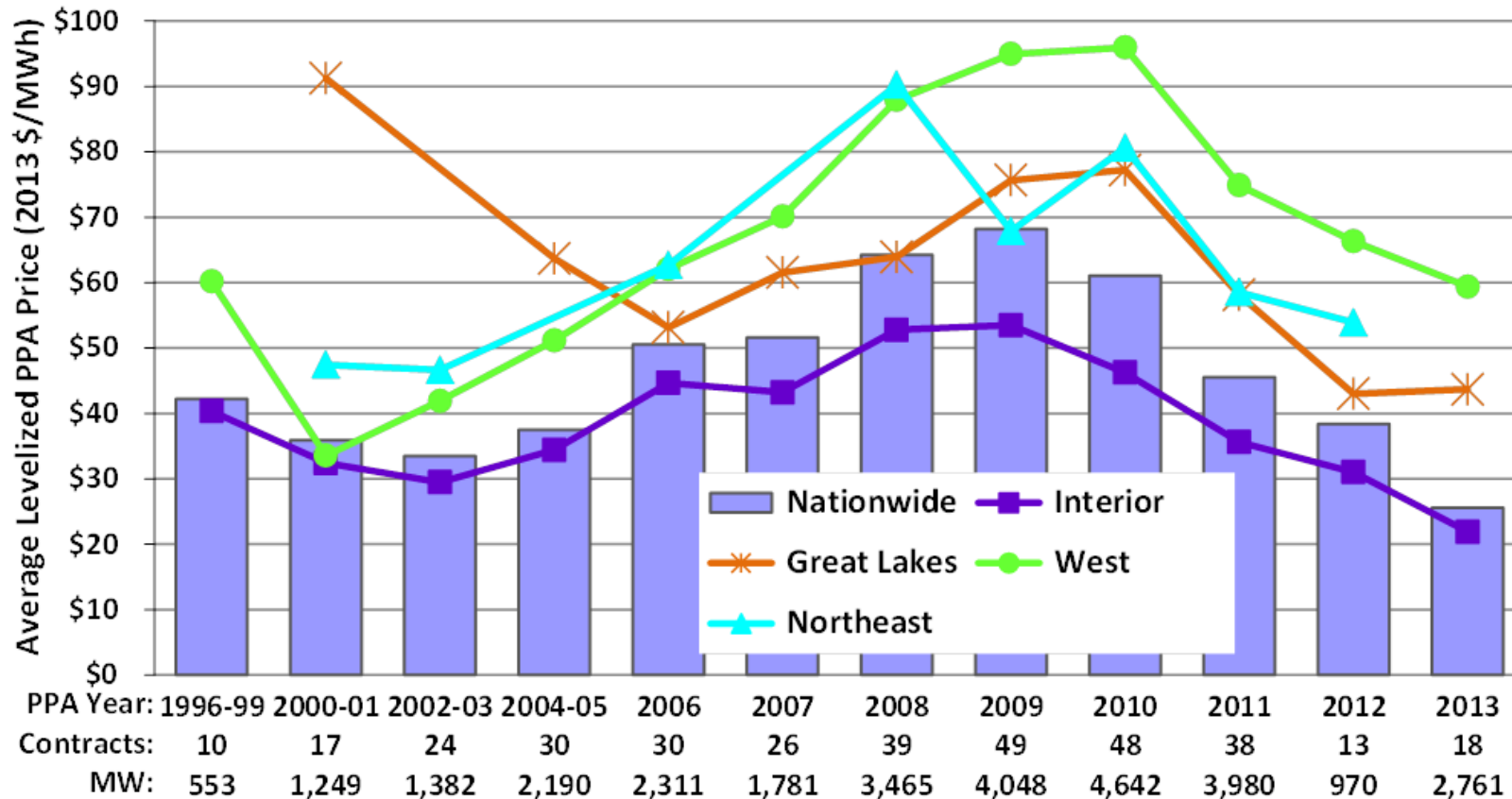
- Berkeley Lab collects data on historical wind power sales prices, and long-term PPA prices
- PPA sample includes 343 contracts totaling 29,632 MW from projects built from 1998-2013, or planned for installation in 2014 or 2015
- Prices reflect the bundled price of electricity and RECs as sold by the 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



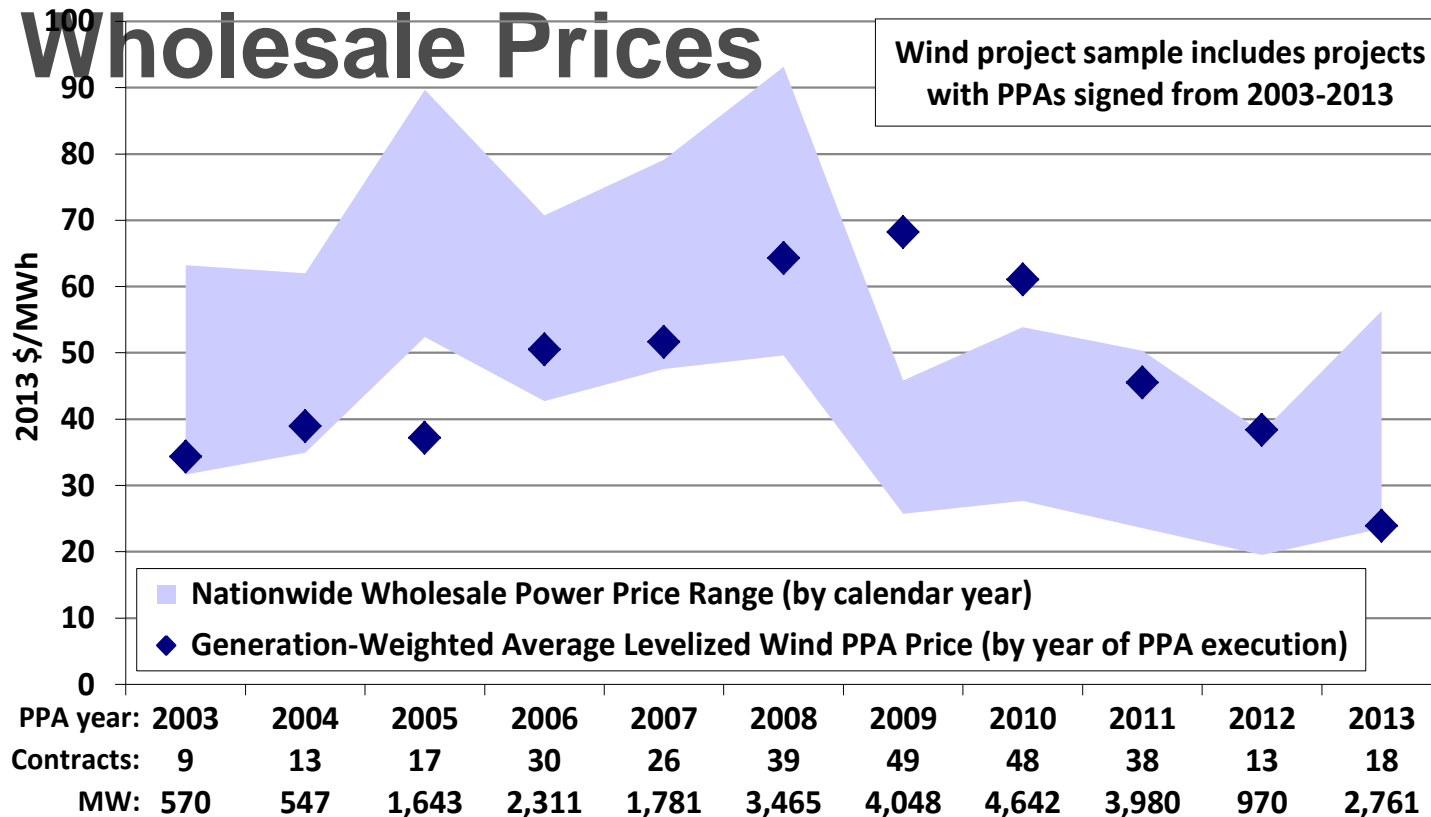
# Wind PPA Prices Have Reached All-Time Lows



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

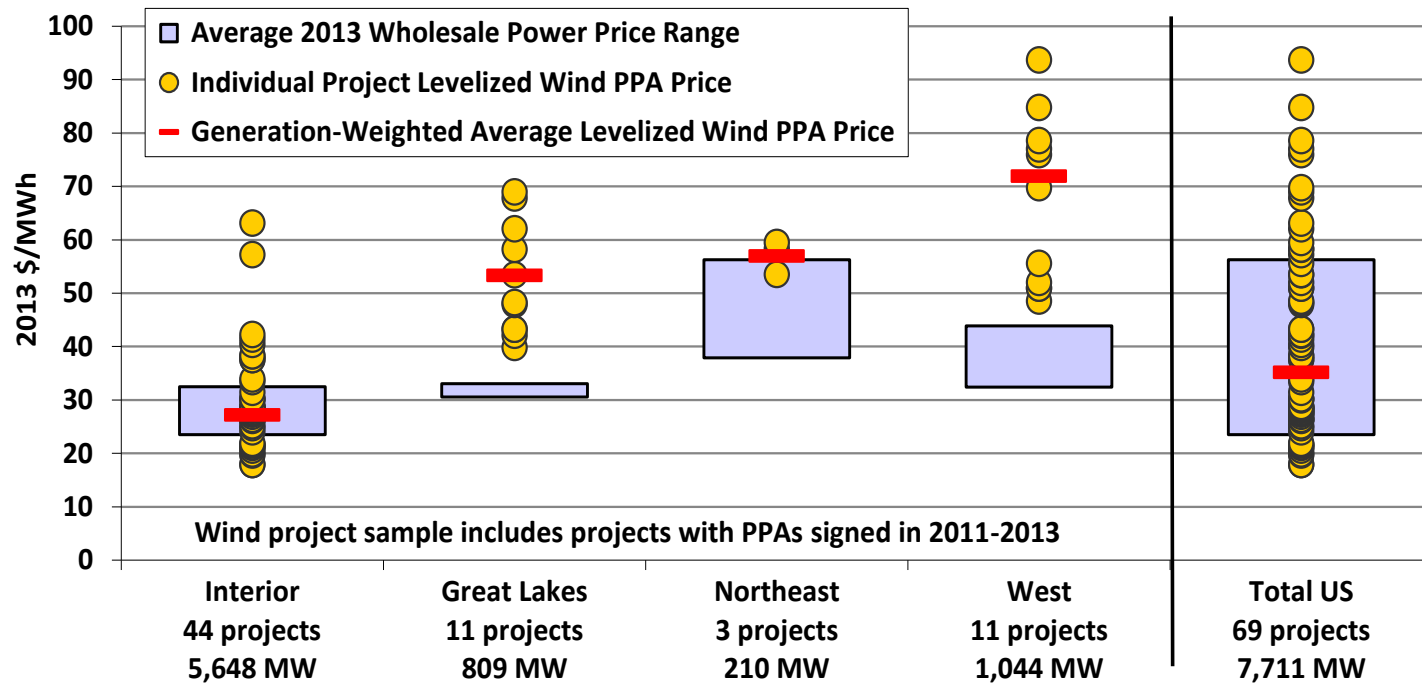


# Relative Competitiveness of Wind Improved in 2013: Comparison to Wholesale Prices



- Wholesale price range reflects flat block of power across 23 pricing nodes across the U.S.
- Recent wholesale prices reflect low natural gas prices, driven by weak economy and shale gas
- Price comparison shown here is far from perfect – ***see full report for caveats***

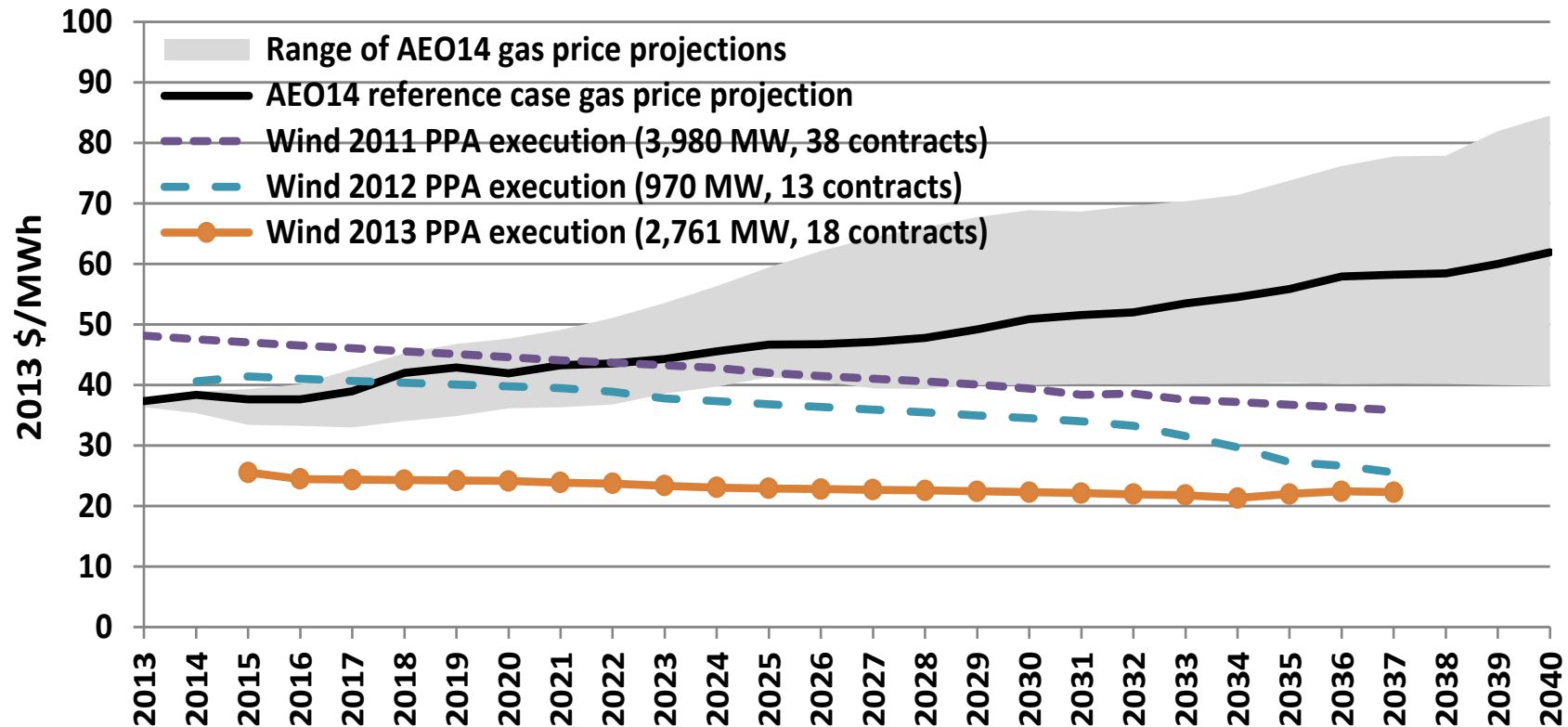
# Comparison Between Wholesale Prices and Wind PPA Prices Varies by Region



*Notes: Wind PPAs included are those signed from 2011-2013. 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

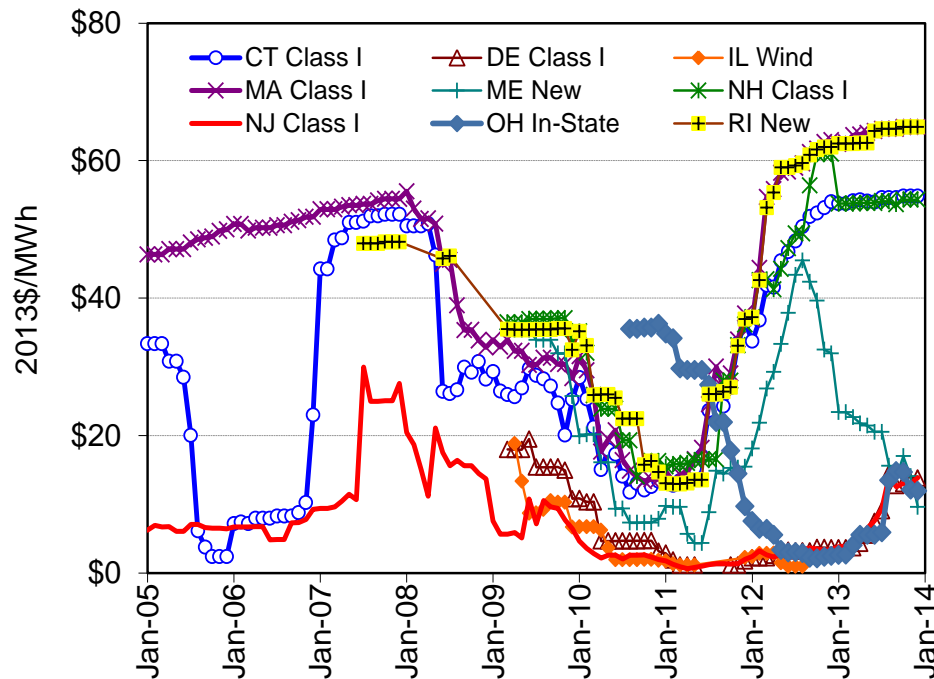
# Recent Wind Prices Are Hard to Beat: Competitive with Expected Future Cost of Burning Fuel in Natural Gas Plants



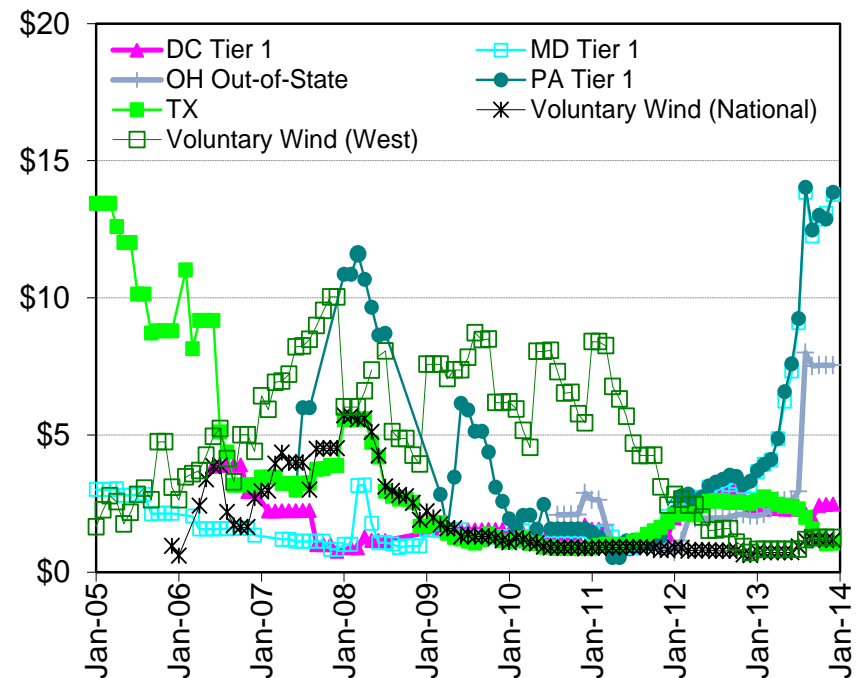
*Price comparison shown here is far from perfect – see full report for caveats*

# Renewable Energy Certificate (REC) Prices Remain High in Northeast

## High-Price REC Markets



## Low-Price REC Markets



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

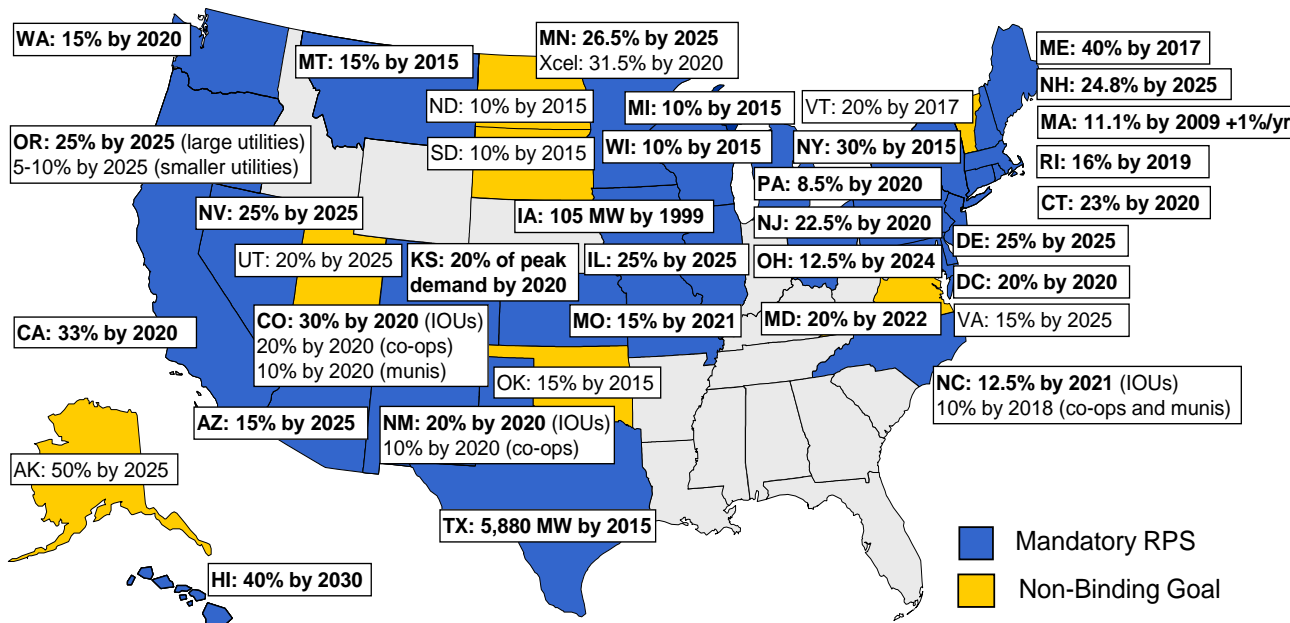


# Policy and Market Drivers

# Availability of Federal Incentives for Wind Projects Built in the Near Term Has Helped Restart the Domestic Market, but Policy Uncertainty Persists

- Near-term availability of the PTC/ITC for those projects that reached the “under construction” milestone by the end of 2013 has helped restart the domestic market and should enable solid growth at least through 2015
- Little action in 2013 on what are among the wind industry’s two highest priorities: a longer-term extension of federal tax incentives and passage of a federal renewable or clean energy portfolio standard
- 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

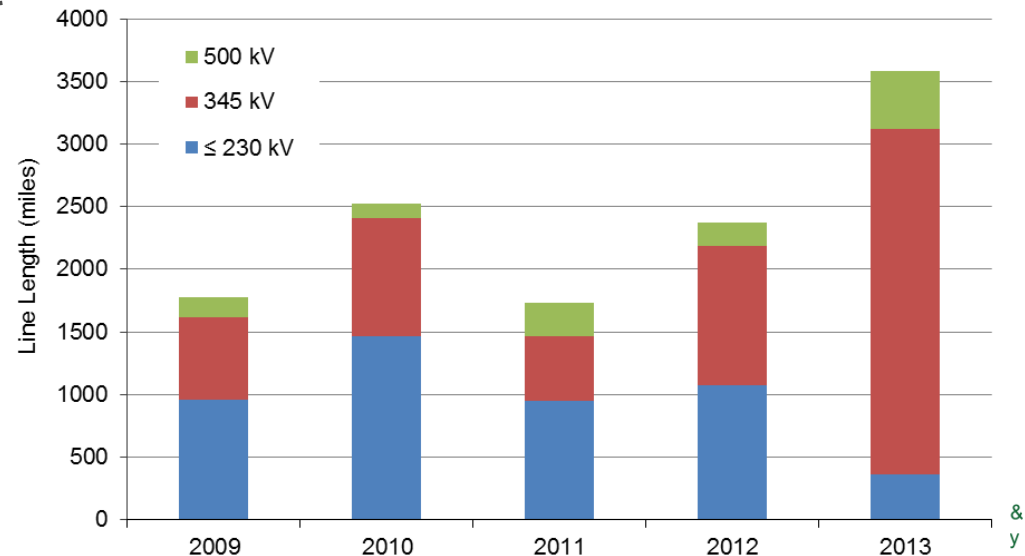


Source: Berkeley Lab

- 29 states and D.C. have mandatory RPS
- State RPS' can support ~3-4 GW/yr of renewable energy additions on average through 2025 (less for wind specifically)

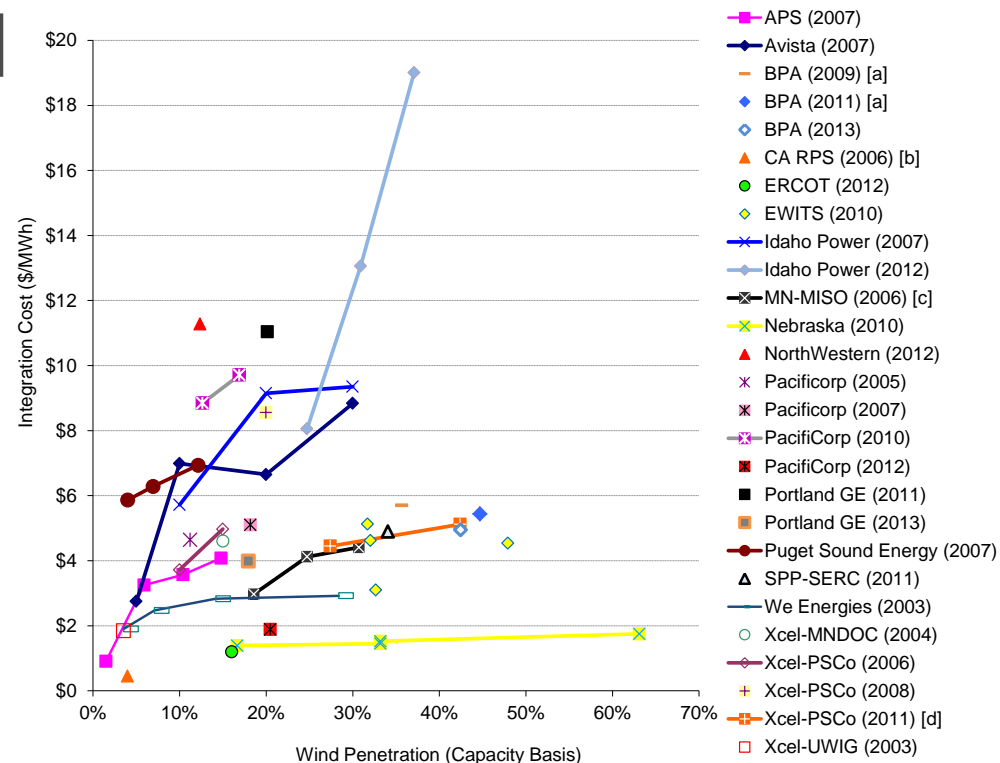
# Solid Progress on Overcoming Transmission Barriers Continued

- 3,500 circuit miles of new transmission built in 2013; completion of the Competitive Renewable Energy Zones project in Texas
- EEI has identified over 170 transmission projects in development, 76% of which would – at least in part – support the integration of renewable energy
- AWEA has identified 15 near-term transmission projects that – if all were completed – could carry almost 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 to electricity systems*

## Future Outlook



# Relatively Strong Wind Power Capacity Additions Anticipated for 2014 and 2015, then Uncertainty in 2016 and Beyond

## Forecasts for Annual U.S. Wind Additions (MW)

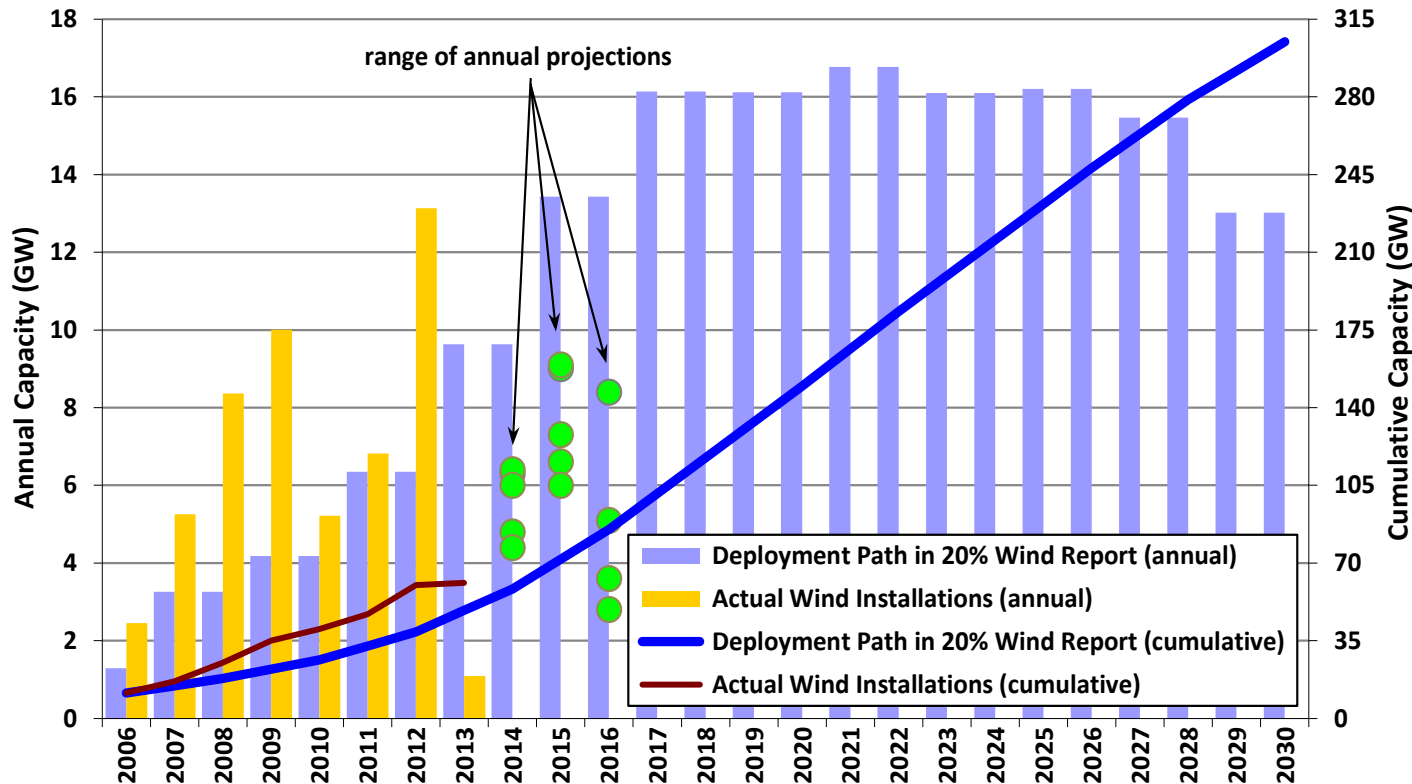
Source	2014	2015	2016	Notes
Bloomberg NEF (2014c)	6,000	9,000	3,600	Assumes no PTC extension beyond current law
IHS EER (2014)	4,800	7,300	8,400	Assumes one PTC extension for 2016
Navigant (2014)	6,300	6,000	2,800	Presumably assumes no PTC in 2016
MAKE Consulting (2014)	6,400	6,600	5,100	Assumes one PTC extension for 2016
EIA (2014b)	4,400	9,100	na	Assumes no PTC extension beyond current law

The upper end of the forecast range for 2014 and for 2015 does not approach the record build level achieved in 2012

# Current Low Prices for Wind Energy, 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

# U.S. Is on Early Trajectory that May Lead to 20% Wind; Projections for 2014-2016, However, Fall Short of Annual Growth Envisioned in 2008 20% Wind Report



# Conclusions

- Annual wind additions were modest in 2013, but signals point to more-robust growth in 2014/15
- Notwithstanding 2013, wind has been a significant source of new generation in the U.S. since 2007
- 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 is on the decline
- Trends are enabling very aggressive wind power pricing and solid economics in many regions despite low natural gas prices
- Growth after 2015 remains uncertain, dictated in part by future natural gas prices, fossil plant retirements, and policy decisions, though technological advancements and recent declines in the price of wind energy have boosted 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/wind-program>

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