NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Offshore Wind Energy Market Overview

BOEM Offshore Renewable Energy Workshop

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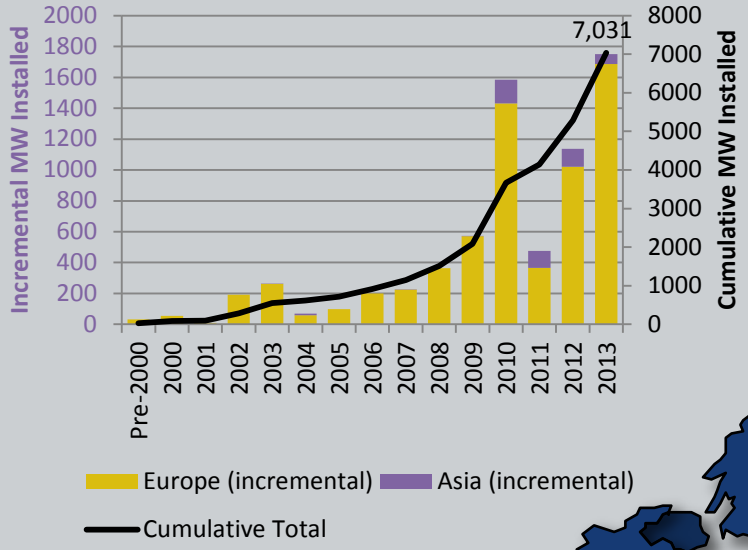
Support from Navigant Consulting, Inc., Bruce Hamilton

All Offshore Wind Projects are in Europe and Asia, with European Nations Leading Deployment



Offshore Wind Drivers & Developments in Asia

China – 404 MW installed. Issued *12th Five-Year Development Plan for Renewable Energy* (2012) targeting 5 GW installed by 2015 and 30 GW installed by 2020

Japan – 50 MW installed. 2 operating 2MW floating turbines, larger OSW specific turbine under development, the government plans to phase out nuclear power by 2040, which previously provided over 30% of the country's electricity. New feed-in tariffs for wind announced in 2012 ~25 cents/kWh and indications that the domestic market for floating OSW may be as high as 1,000 MW

South Korea – 5 MW offshore demonstration project (Jeju Island) in operation, plus a government target of 2 GW in operation by 2019

Taiwan – Launched the *Thousand Wind Turbines Promotion* program, targeting 3 GW installed by 2030

Reported Capital Costs for Global OSW

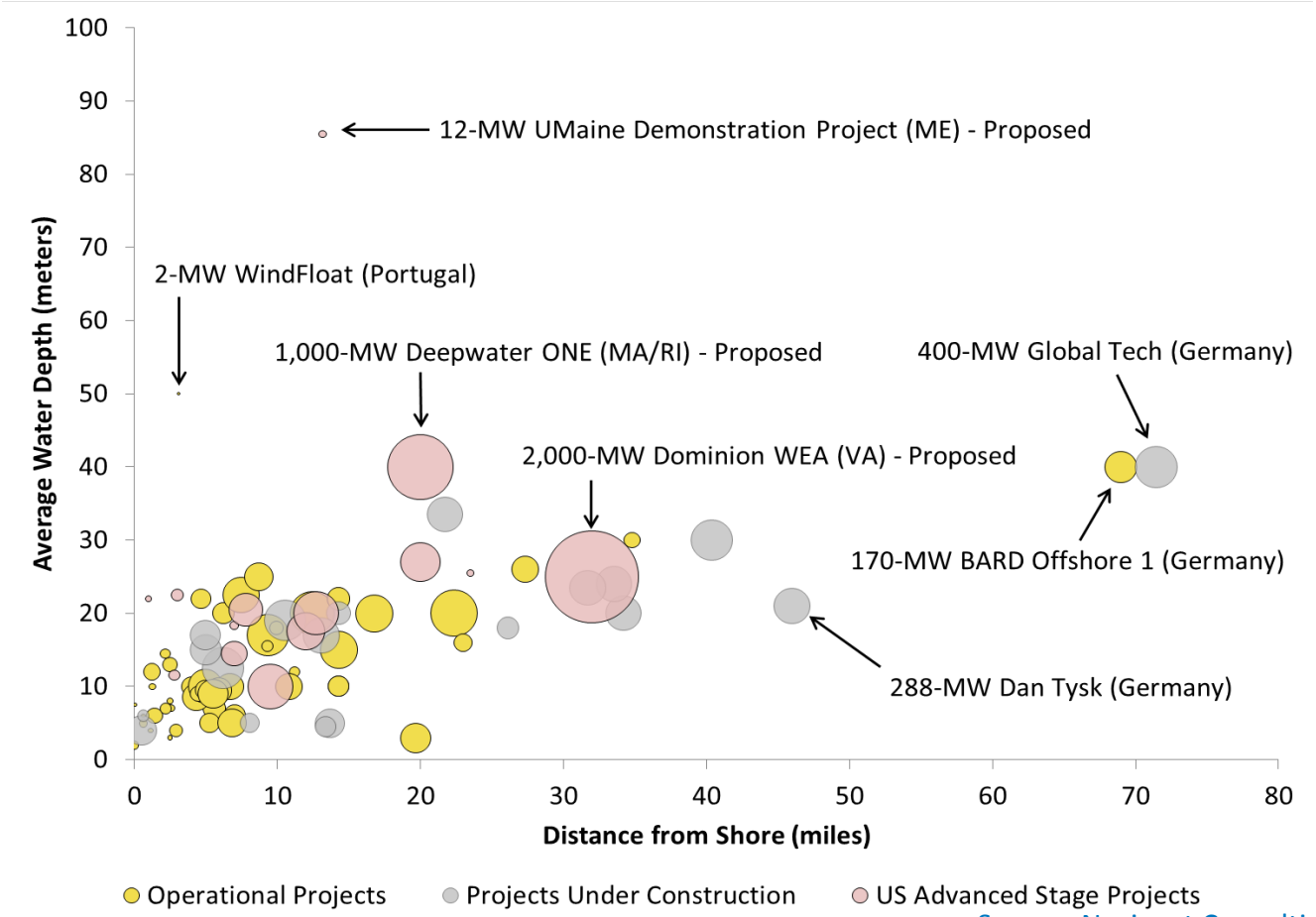
Source: Navigant Consulting, Inc

Costs have risen but seems to have stabilized

Physical Siting Considerations / Cost Drivers

- Water depth
- Distance to shore
- Wind resource and losses
- Project size
- Geotechnical / geophysical soil conditions
- Wave climate – sheltered vs. open ocean
- Extreme climate conditions – e.g. tropical storms, installation windows
- Environmental impacts and long term mitigation
- Availability of grid connections/load proximity
- Supply chain – where the equipment comes from and how this changes over time
- Turbine reliability and repair timelines
- …

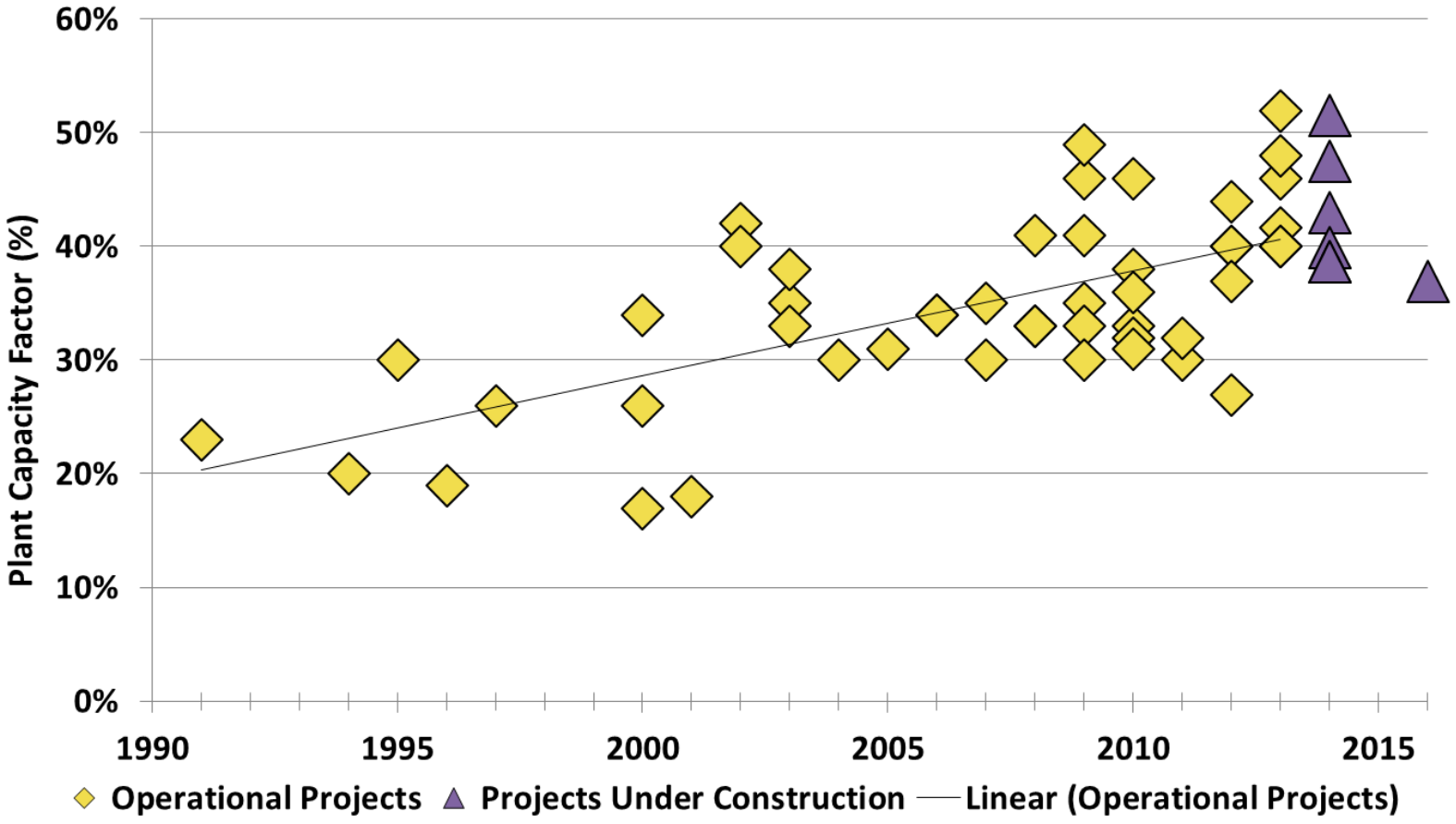
Wide Distance and Water Depth Deployments



Source: Navigant Consulting, Inc

Clearly the close, shallow sites are the first to go.. Deeper projects farther from sure will then be developed and resulting in higher cost

OSW Plant Capacity Factors Increasing



Source: Navigant Consulting, Inc

Expected plant capacity factors (efficiency of the turbines) has steadily increased – more experience, better wind resource, more reliable operation and maintenance

Expected Costs

	Land-Based	Offshore
Installed capital cost	$1,400–$2,900/kW	$4,500–$6,500/kW
Annual operating expenses	$9–$18/MWh	$15–$55/MWh
Capacity factor	18%–53%	30%–55%
Discount rate	6%–13%	8%–15%
Operational life	20–30 years	20–30 years
Range of LCOE	<$60–>$100/MWh	<$168–>$292/MWh

Source: NREL Cost of Energy Report – 2011 - NREL 56266

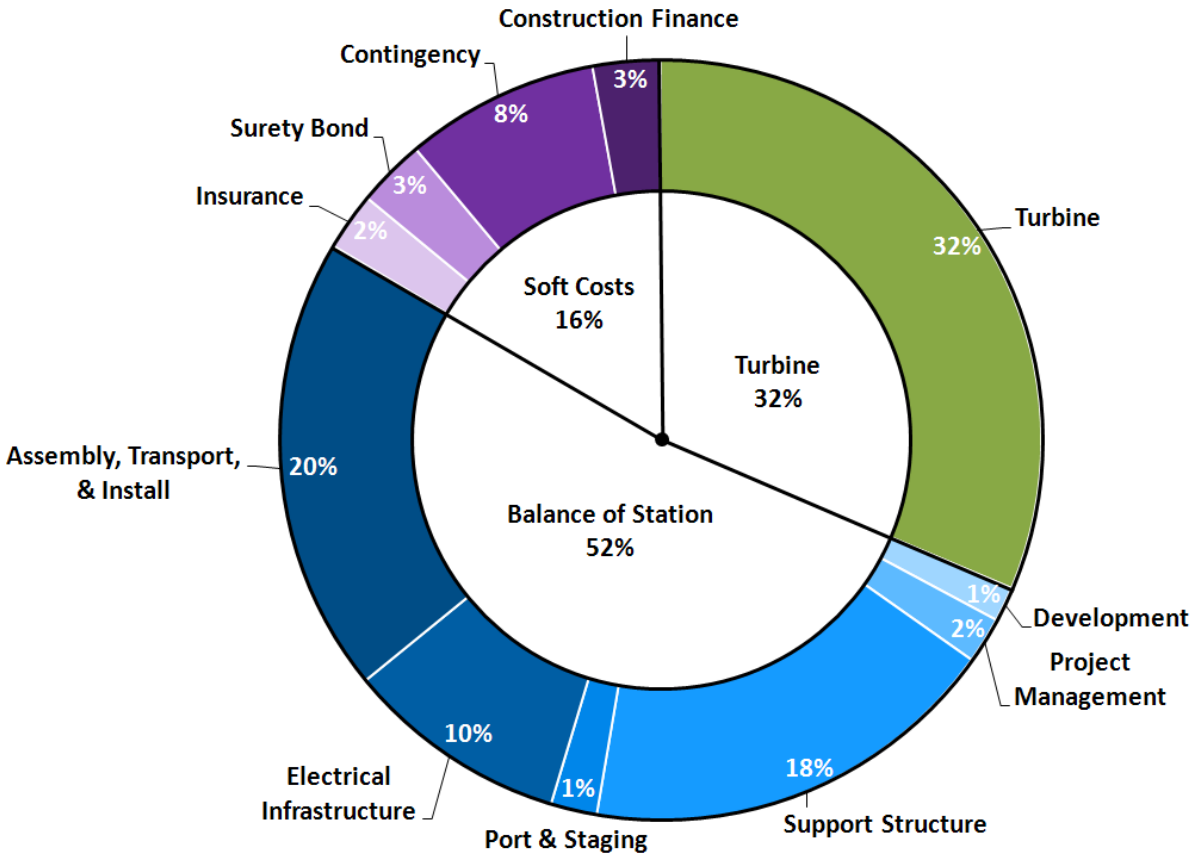
Installed Capital Costs (ICC)

Balance-of-station (BOS) costs dominate ICC for offshore wind projects

There are three primary BOS contributors:

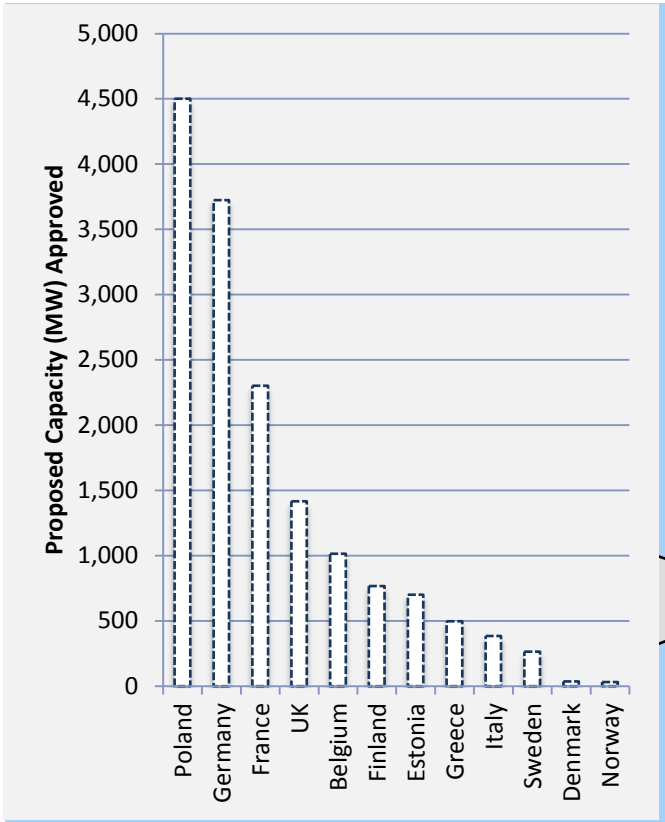
- *Support structure*
- *Electrical infrastructure*
- *Assembly, transport, and install*

Component contribution can vary significantly from one project to another



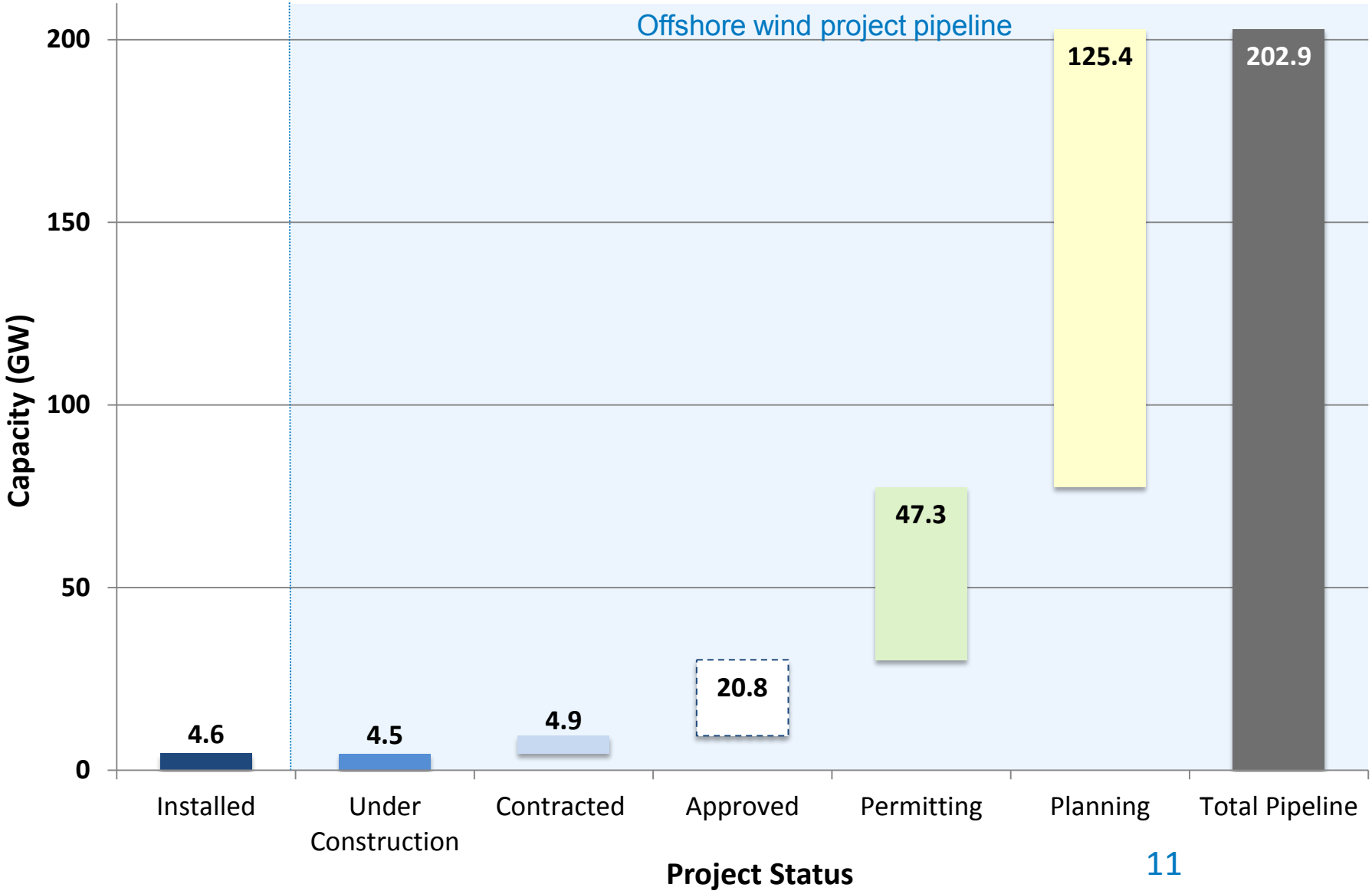
Source: Tegen, S.; Hand, M.; Maples, B.; Lantz, E.; Schwabe, P.; Smith, A. (2012). 2010 Cost of Wind Energy Review. 111 pp.; NREL Report No. TP-5000-52920.

Majority of Global Offshore Wind Developments are in Europe

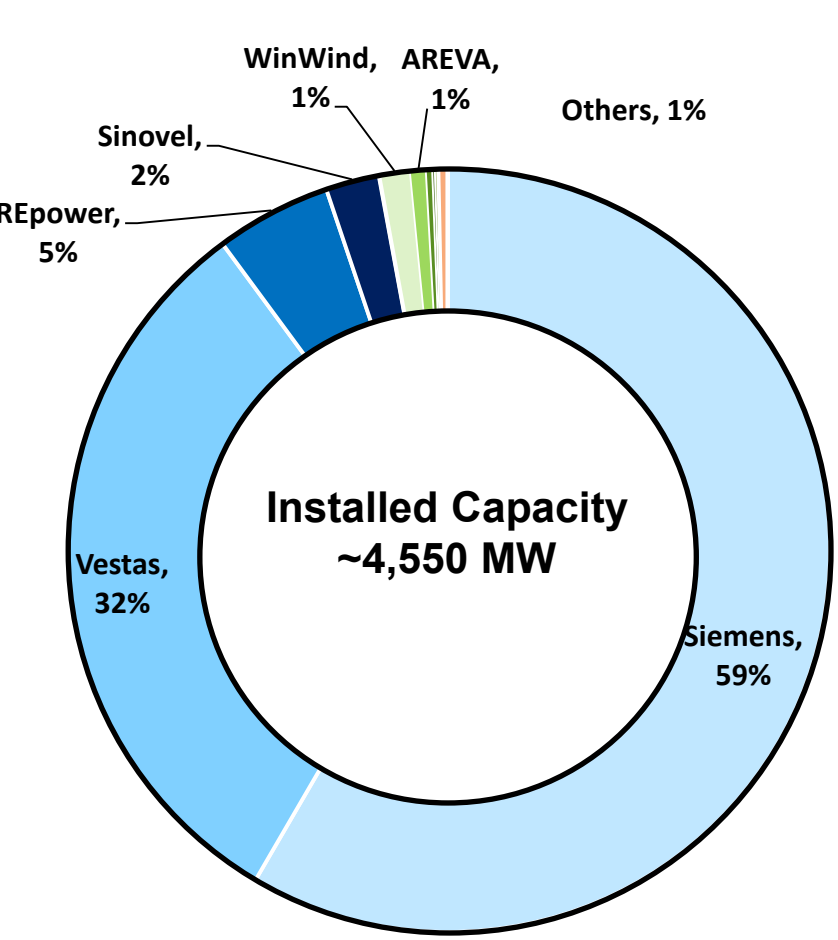


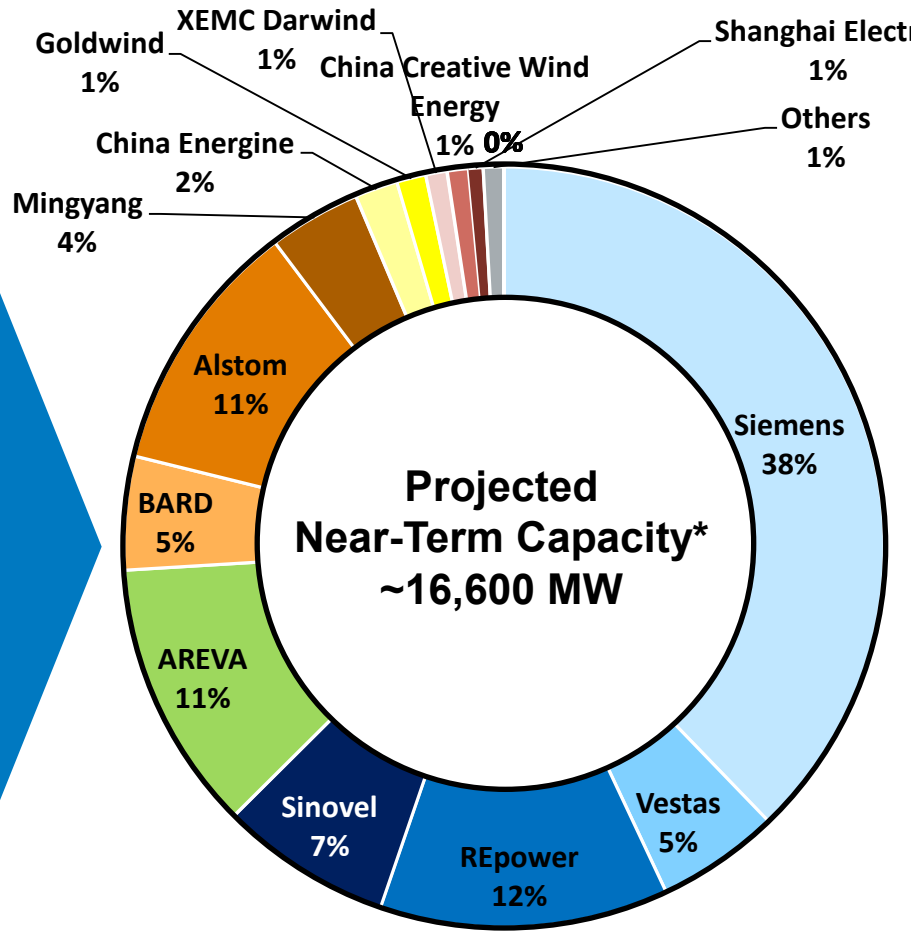
The total global offshore wind project pipeline exceeds 200 GWs

(Total US Generating capacity is about 1000 GW)



The global market for offshore wind turbines is expected to become increasingly fragmented





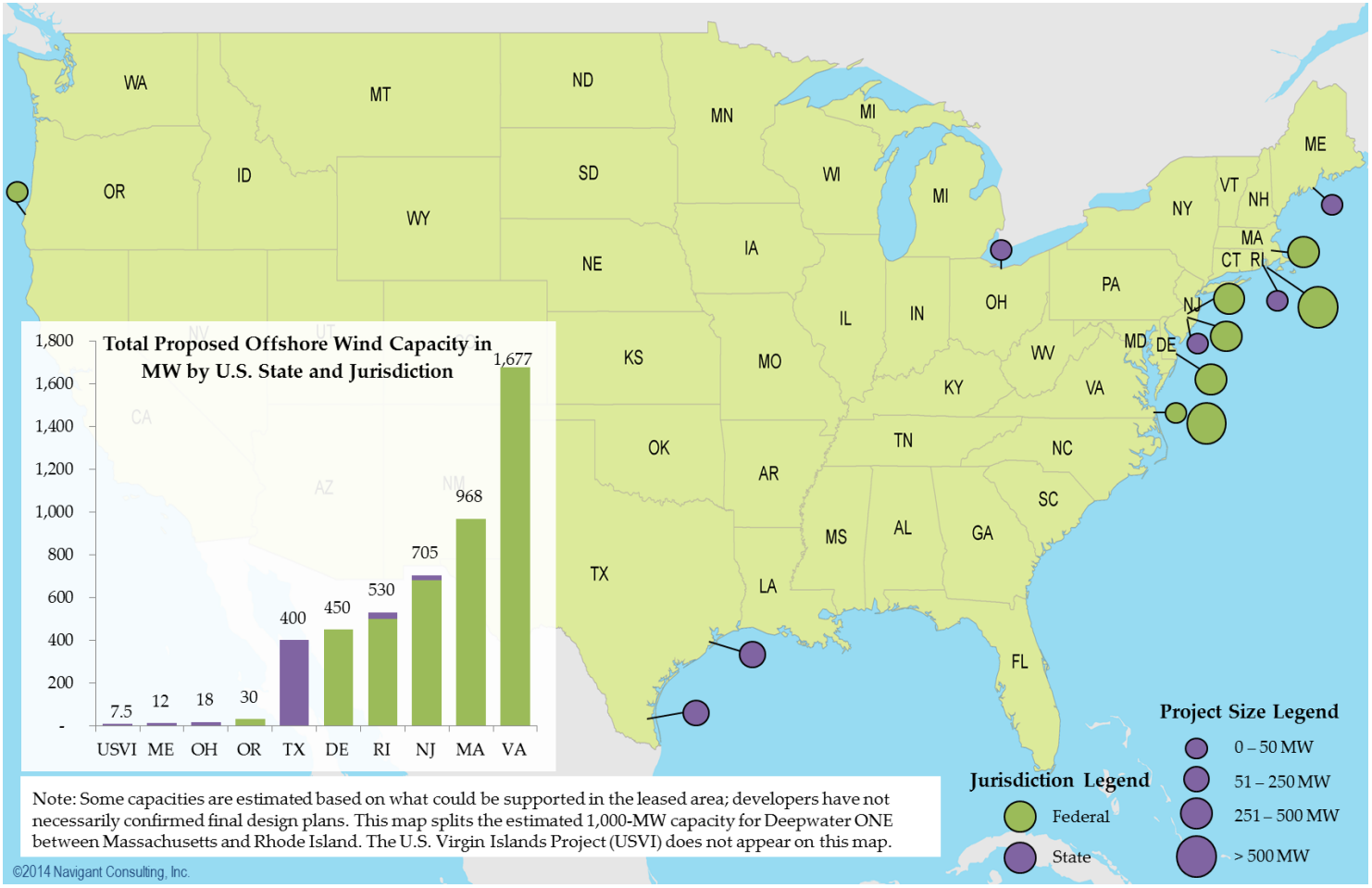
Turbines from Siemens and Vestas represent a combined 91% of capacity installed to date

A number of OEMs have developed strong pipelines, reducing projected Siemens/Vestas share to 43% of near term market

OEMs gaining share tend to be either 1) offering turbine models in the 5 MW+ class or 2) are well positioned to take advantage of growth in the Chinese market

* Includes projects under construction and approved projects that have announced a turbine manufacturer.

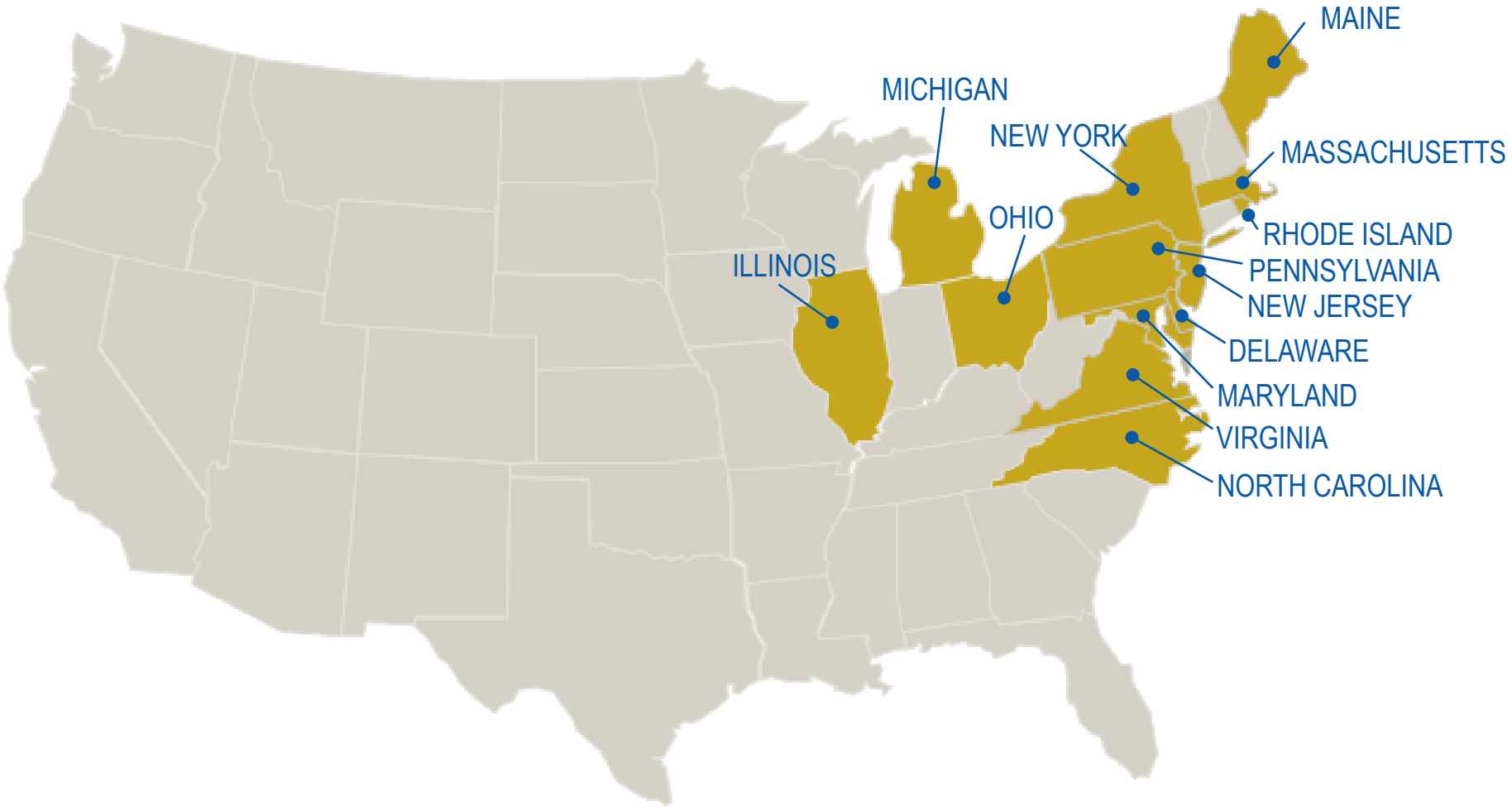
Current, Proposed, and Lease Projects



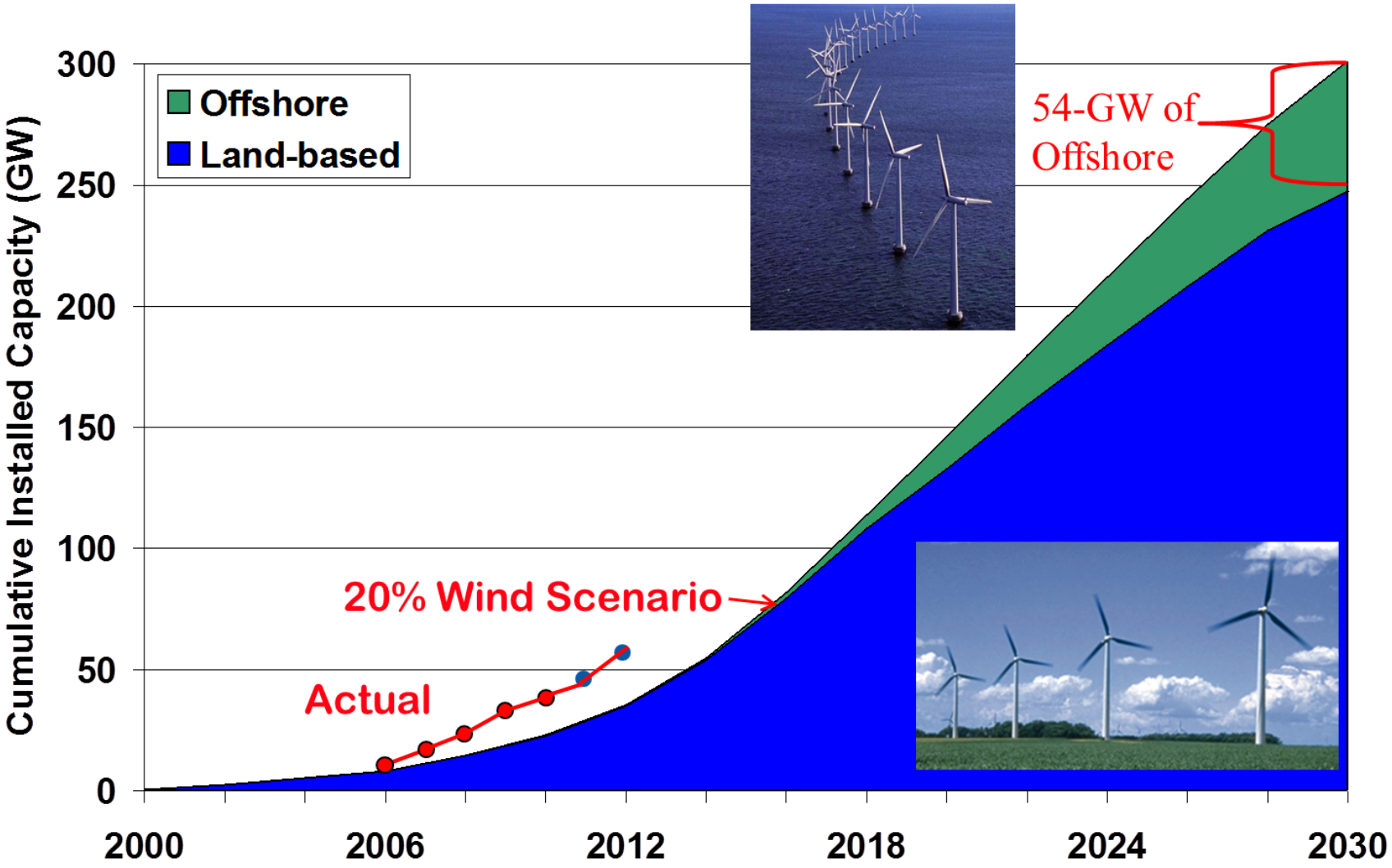
Source: Navigant Consulting, Inc

Proposed U.S. Offshore Wind Energy Projects in Advanced Development Stages by Jurisdiction and Project Size

State Offshore Wind Policies & Development Process

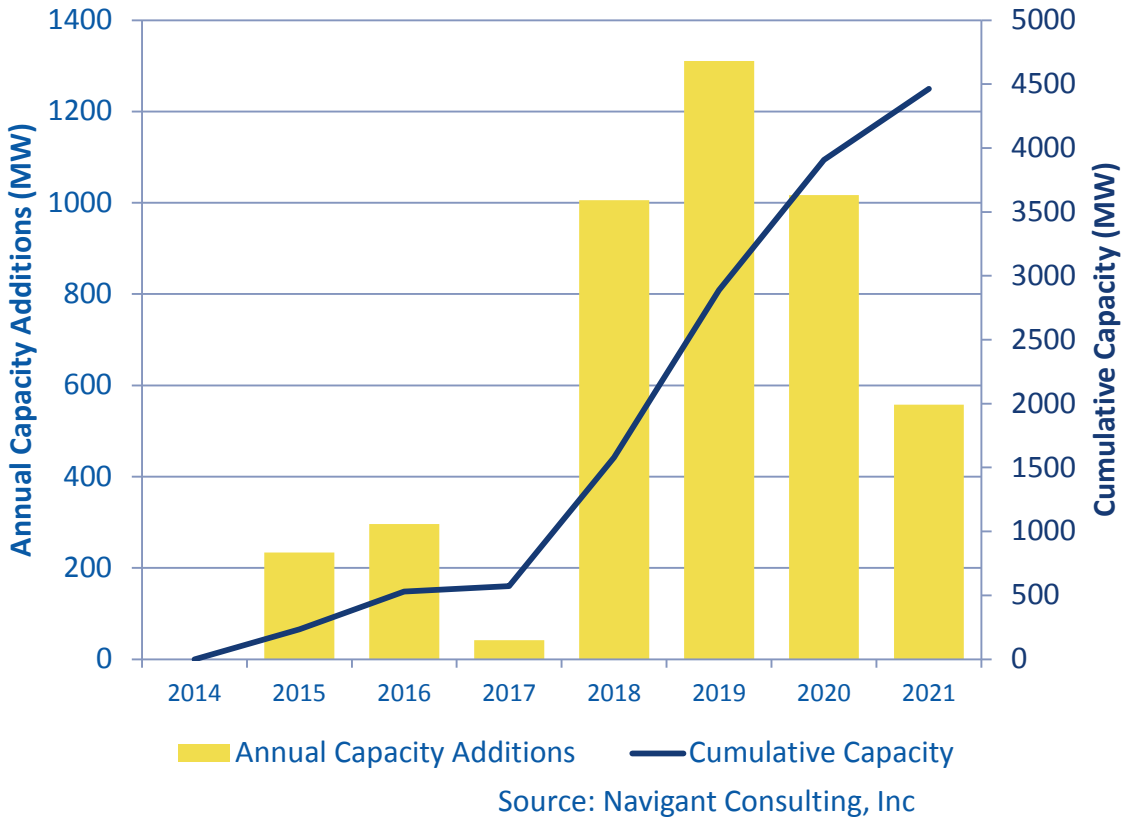


20% Wind Study OSW Estimates



Current wind vision has estimates of ~20 GW by 2030, 80 GW by 2050

Growth Trajectory for U.S. Offshore Wind Markets

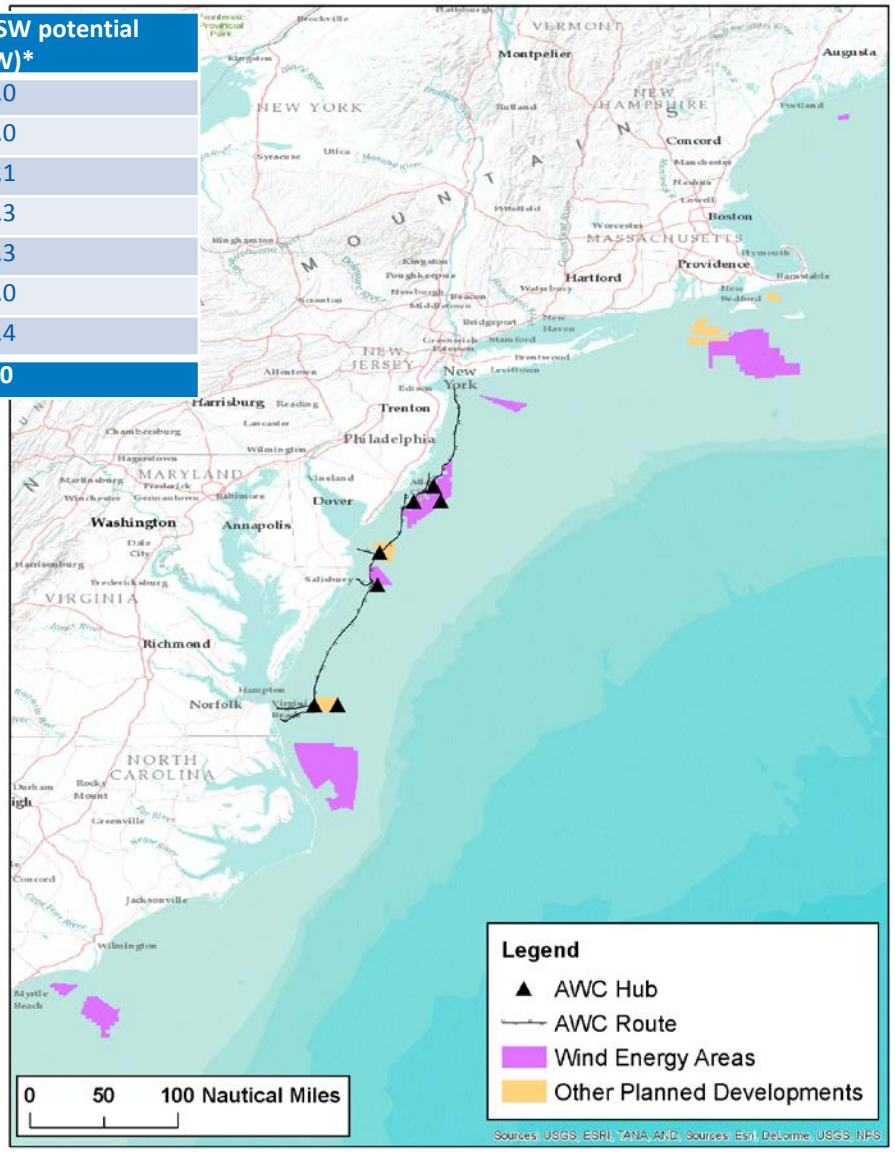


- Represent 15 defined projects totaling 4.5 GW with others still possible
- Unlikely all of these will be completed within this time horizon

US Off Shore Lease Zones and Markets

WEA	Status	Area (sq. km)	Estimated OSW potential (GW)*
MA	Announced	3,007	9.0
RI-MA	Awarded	667	2.0
NY	Scoping	329	1.1
NJ	Announced	1,434	4.3
DE	Scoping	418	1.3
MD	Announced	323	1.0
VA	Awarded	457	1.4
Total (GW)			**20**

[1] Assumes an average capacity density of 3 MW per square kilometer based on standard spacing metrics developed in Musial et al. 2013a and Musial et al. 2013b

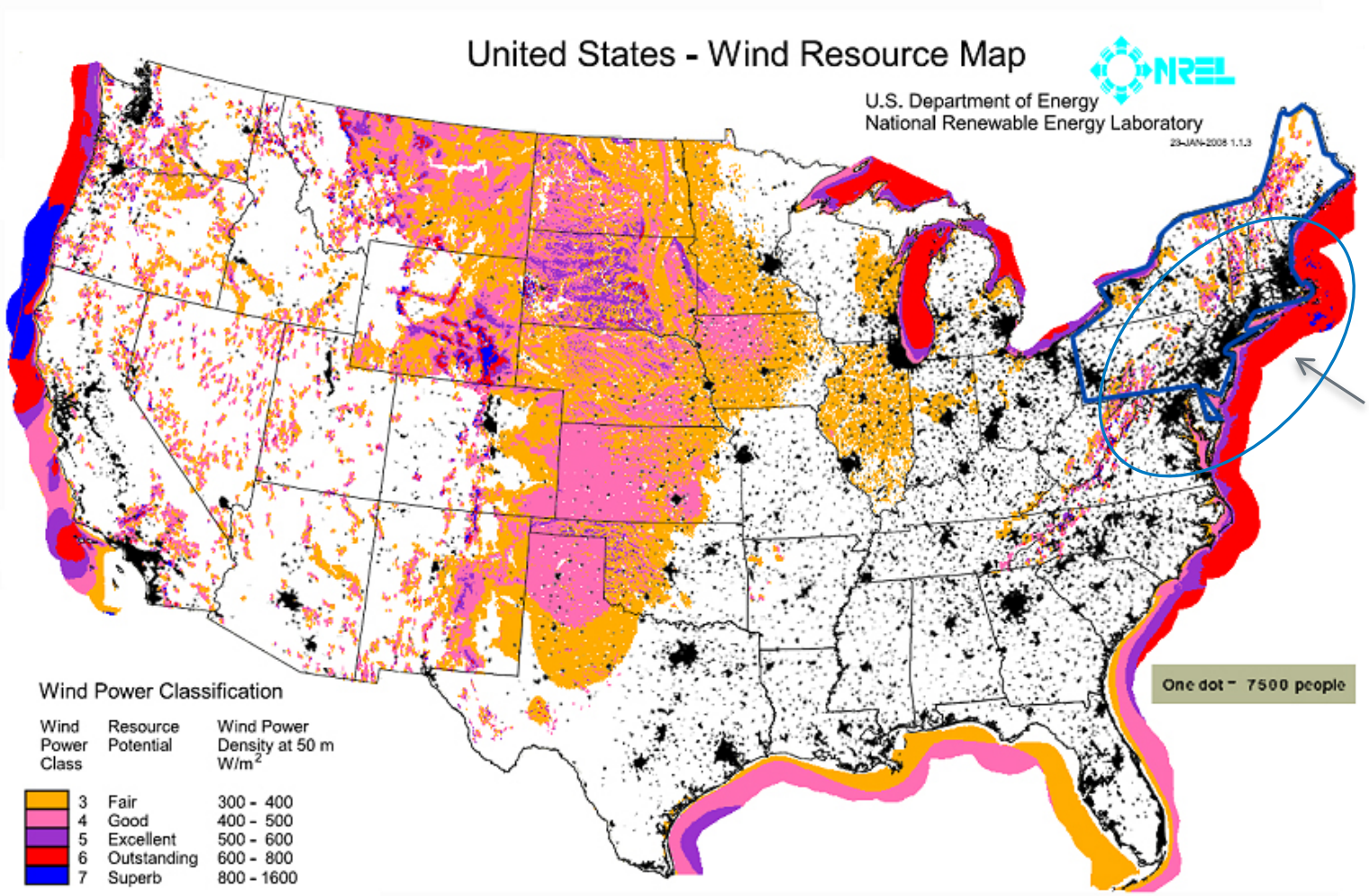


~20 MW of potential capacity in identified lease areas

Other lease areas under consideration, including west coast

Offshore Wind Resource is Near Population Centers

Map of Annual Average Wind at 80-m



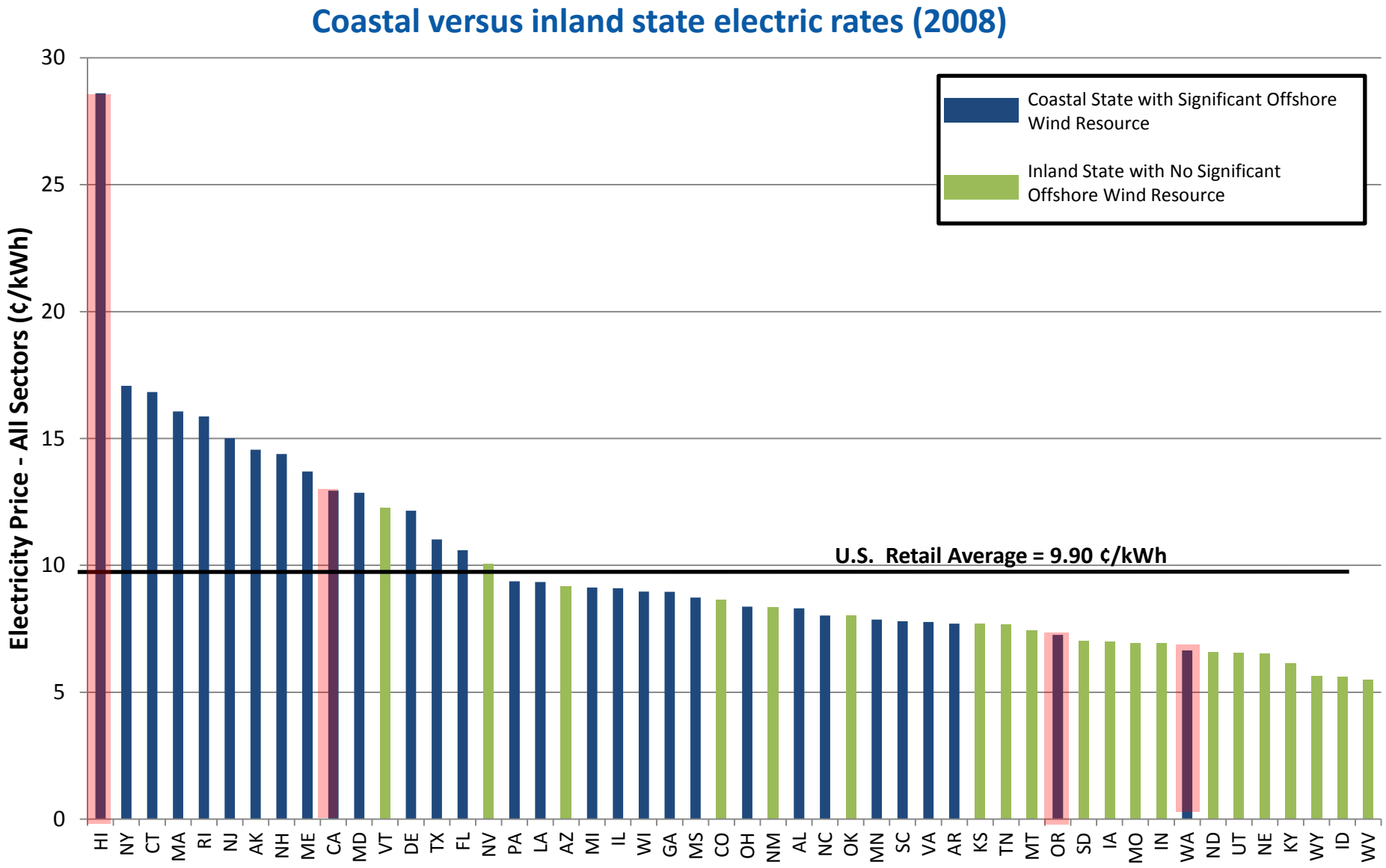
55 million people in NE

18% of US population

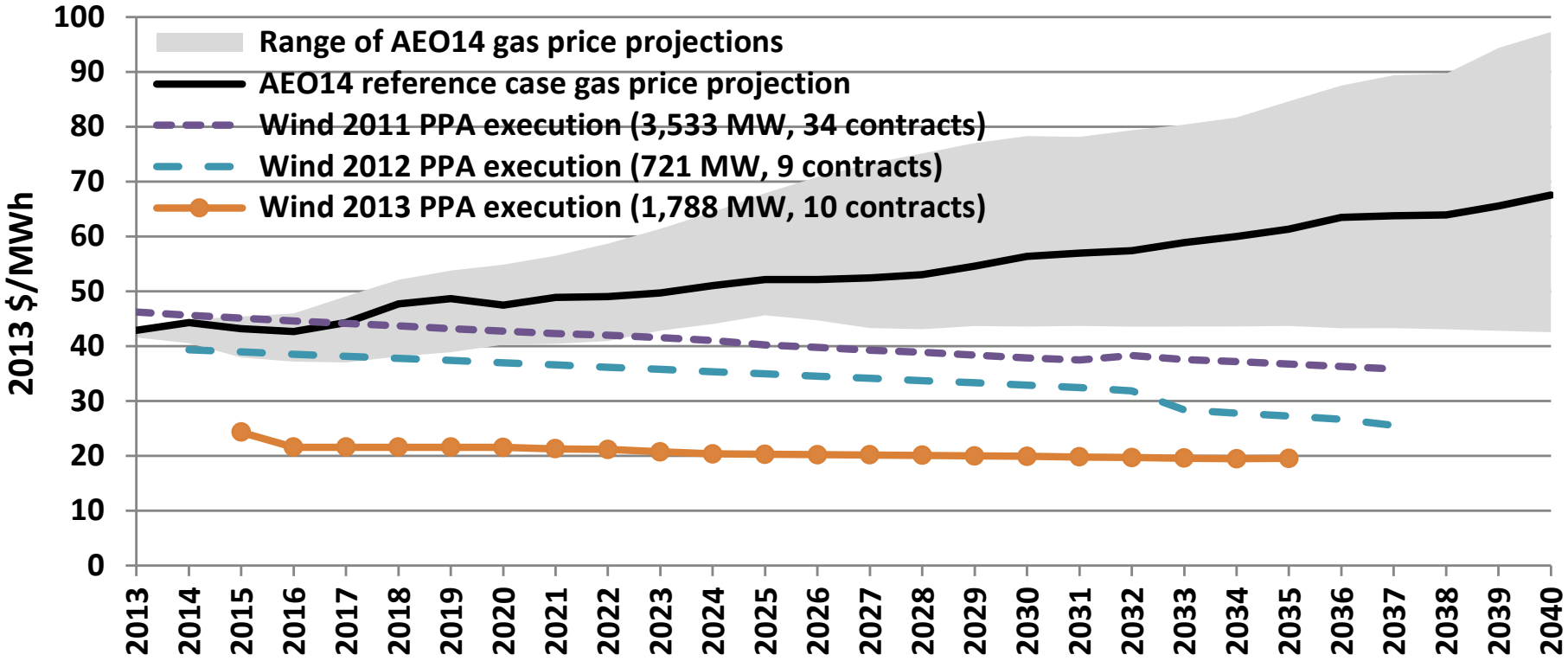
Highest electricity costs

Credit: Dr. H. J. Dagher

Coastal states generally have high electricity prices, making offshore wind more competitive



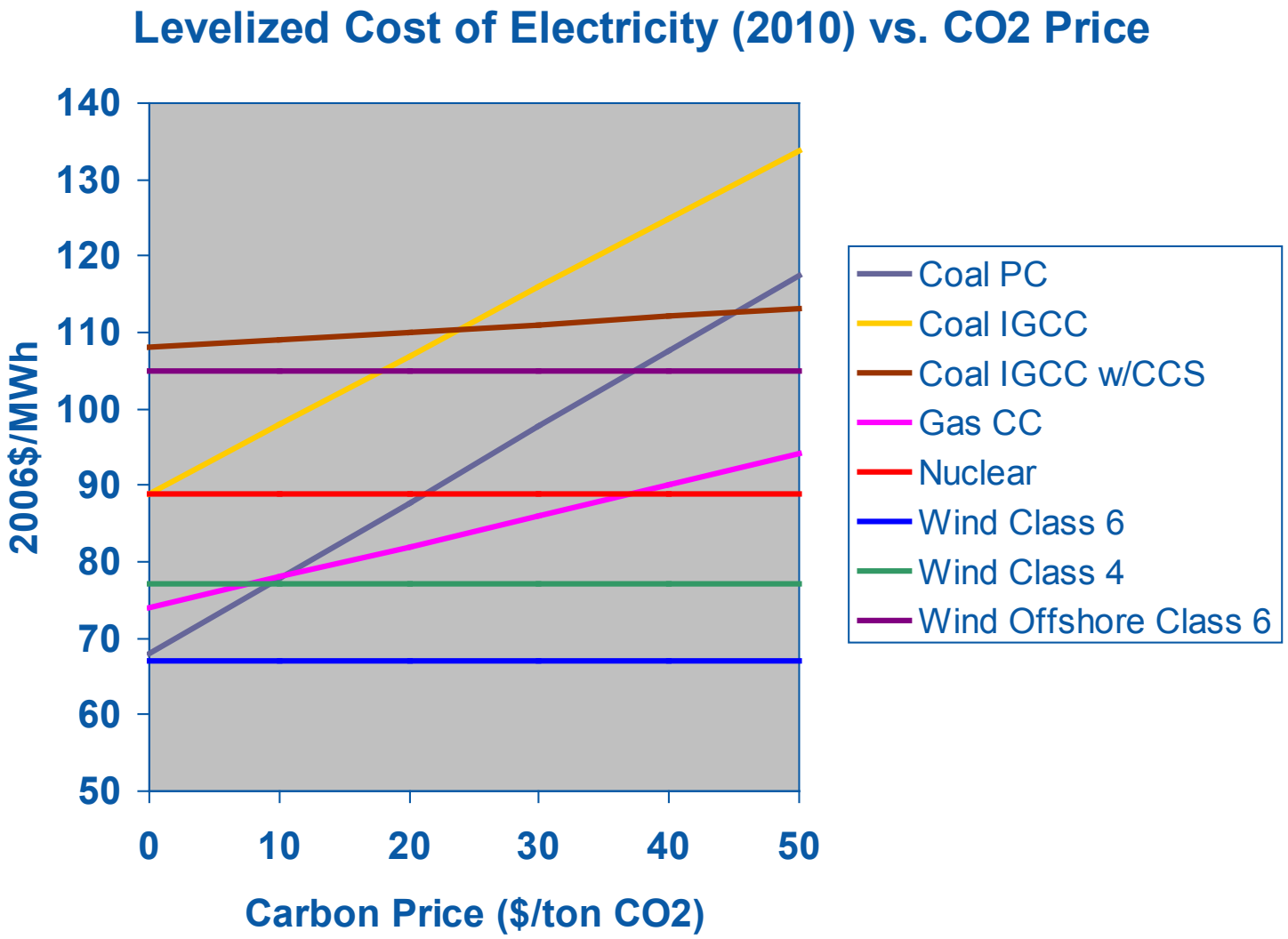
Long Term – Price Certainty is a Real Issue



Source: Laurence Berkeley National Laboratory

- Over the long term, wind can compete head to head in a subsidized energy market
- In the near term wind costs competitive with future cost of natural gas
- Even without the subsidies (PTC), wind still competes quite well against the subsidized NG and provides huge hedge against NG price volatility

Externalities can Significantly Impact Costs



U.S. Federal Policy to Support OSW

DOE National Offshore Wind Strategy	• DOE Offshore Wind Initiative • Advanced Technology Program & Grants • DOE Guaranteed Loan Program
Federal Tax Credits & Deductions	• Production Tax Credit • Investment Tax Credit • Accelerated Depreciation Deduction
Bureau of Ocean Energy Management Initiatives	• Smart from the Start • Rules Revisions • Research Studies • Competitive Auction Lease Process

State Policy to Support OSW

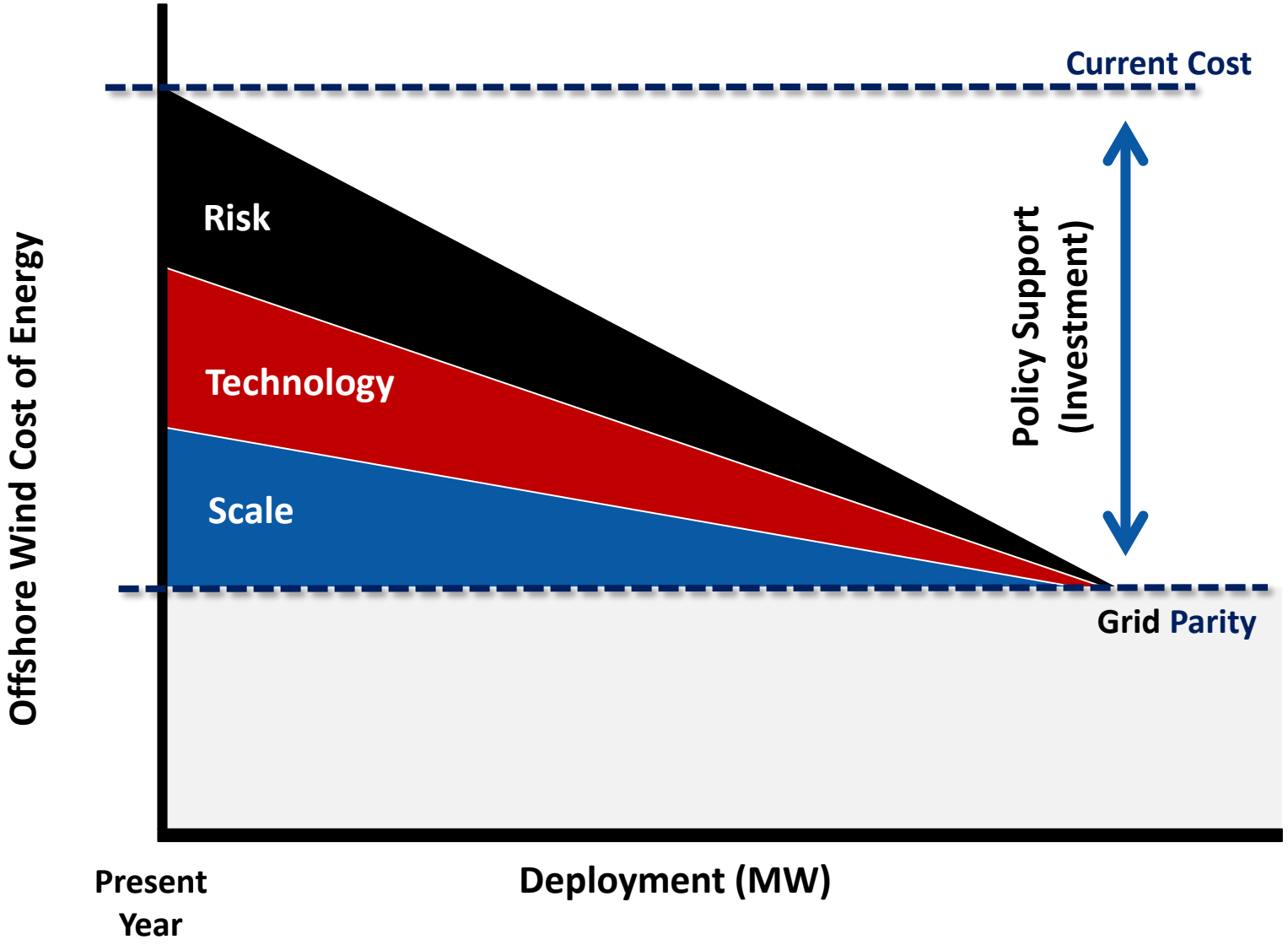
Policy Options *Barrier: High Cost*	Jurisdictions where Used						
	Delaware	Maine	Maryland	Massachusetts	New Jersey	New York	Rhode Island
Renewable Portfolio Standard (RPS)	✓	✓	✓	✓	✓	✓	✓
Incorporate PPAs into competitive situations	✓1	✓3		✓5		✓7	✓8
RPS with offshore carve out			✓4		✓6		
Green certificates with premium prices for offshore installations	✓2						

(1) Delaware statute directed all-resource competitive bid & Delmarva to negotiate a PPA with Bluewater Wind approved by four Delaware state agencies in 2009 (~$14/MWh).
(2) DE offshore wind RECs count 3.5 times in meeting Delmarva's renewable energy purchase requirements.
(3) Maine legislation authorized bidding process for pilot offshore projects and PPAs; U.Maine team signed term sheet with PUC.
(4) The Maryland Offshore Wind Energy Act of 2013 established Offshore Wind Renewable Energy Credits (ORECs) for up to 200 MW and requires consideration of broad range of economic and ratepayer benefits.
(5) Massachusetts statute requires PPAs for 7% of load and approved Cape Wind PPA for $18.70/MWh with a 3.5%/year escalator
(6) NJ statute requires 1100 MW Ocean RECs at a cost-effective rate based on a comprehensive net benefits analysis.
(7) LIPA conducted competitive bid in 2005 and ended in 2008 due to high prices. NYPA conducted competitive bid in Great Lakes in 2009 and ended in 2011 due to high prices. NYPA, LIPA & Con Edison submitted application for BOEM lease for a 350 -700 MW offshore wind project to meet NY's 700 MW offshore wind target.
(8) Rhode Island issued an RFP for an offshore wind project to produce 15% of the state's electricity demand and subsequently signed a Joint Development Agreement with Deepwater Wind. Approved initial 30MW Pilot PPA for $24.40/MWh.

Source: Navigant Consulting, Inc

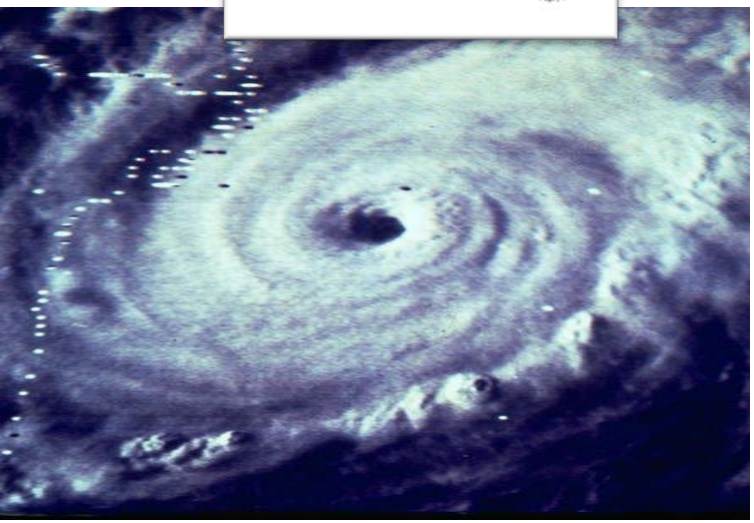
Where is the industry going?

…however, speed of cost reduction will be determined by deployment rate



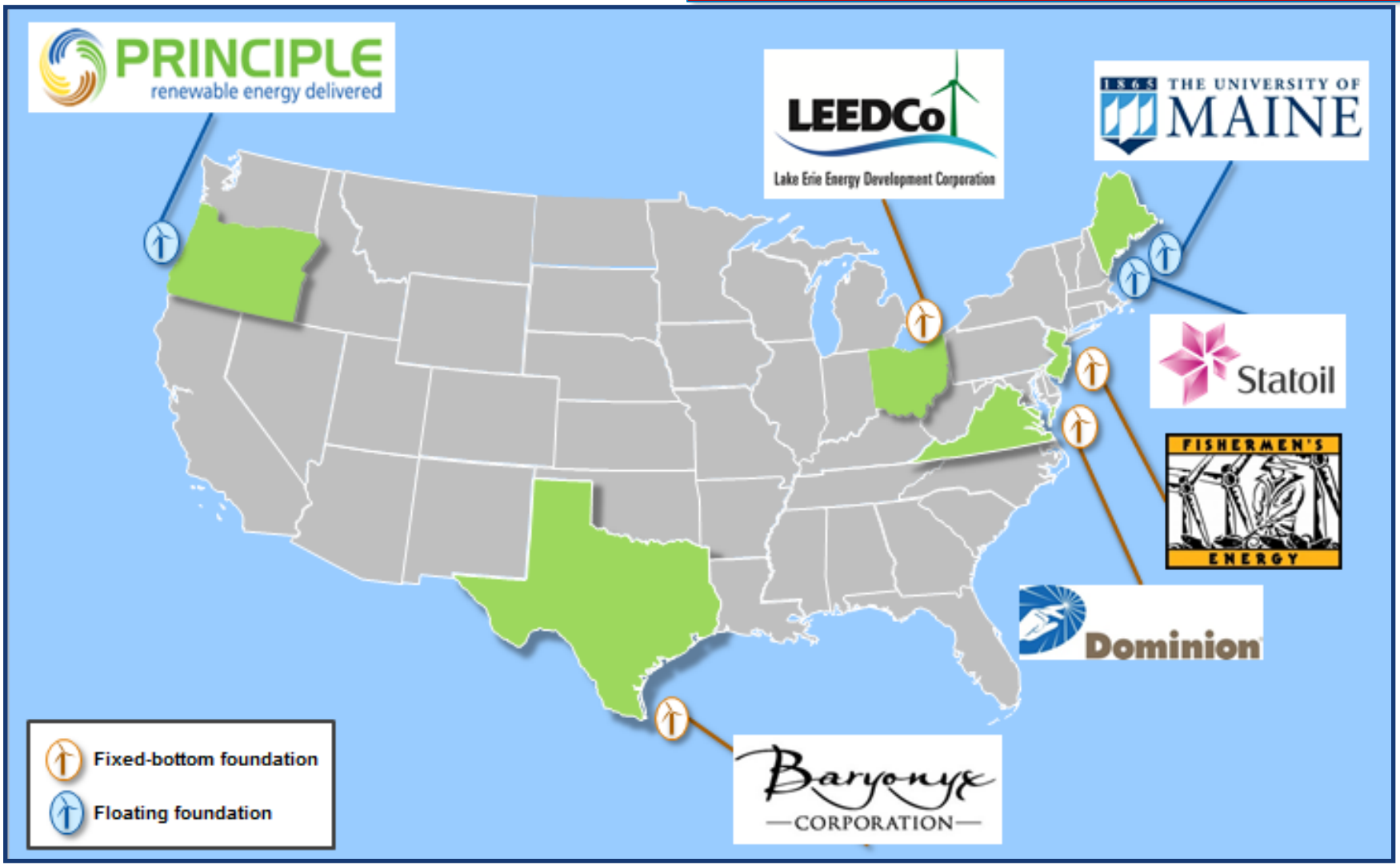
How do we reduce costs?

Risk Reduction



- Increase demand side market certainty through consistent long-term policy
- Increase regulatory certainty
- Get steel in the water to help develop investor confidence
- Mature design tools, practices, and standards through IEC, API, AWEA and class societies for U.S. Specific conditions
- Industry-wide focus on risk identification and management
- Improve understanding of metocean conditions and develop forecasting methods to provide

How do we reduce costs? Technology Innovation



DOE's ATD FOAs will bring next generation of technology to U.S

Projects announced in Dec 2012 will receive $4M for initial planning and design phases. Three will be selected to complete the follow-on design and deployment phases by 2017.

How do we reduce costs?

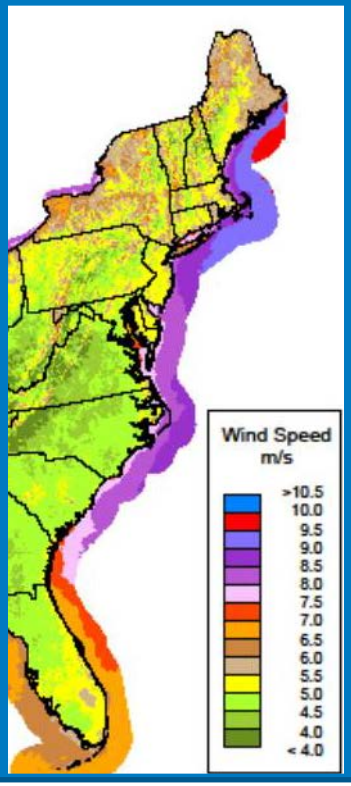
Scale

Increase

Turbine Capacity

Wind Plant Size

National and Global Deployment



Economies of scale, local manufacturing and installation expertise, stable market, and streamline projects.

Marketing Summary

- European markets dominate so far.
- Asian markets promise lower costs; but yet undemonstrated
- The U.S. offshore wind industry is ready to begin deployment
- Stable, coordinated policy is needed to offset high initial costs and drive deployment
- A robust project pipeline is needed to encourage investment in technologies and infrastructure that will lower cost of energy
- Cost are high for first adopters and must be reduced through risk reduction, new technology, and increasing scale (turbine, project, and national deployment)
- Expanded market reports starting to be produced – DOE funded, Navigant Consulting Offshore Wind Market Report due out in September.

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