

Tracking the Cost of Wind Energy



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Overview

- **The offshore wind industry is expanding into deeper waters farther from shore contributing to a wide range of the cost of energy**
- **U.S. land-based wind plant cost of energy may be returning to a historical low as a result, in part, of new wind turbine options**
- **Projections for future wind plant cost of energy anticipate reductions for both land-based and offshore wind plants**

Levelized Cost of Energy (LCOE)

The diagram shows the LCOE formula with arrows indicating the relationship between labels and terms:

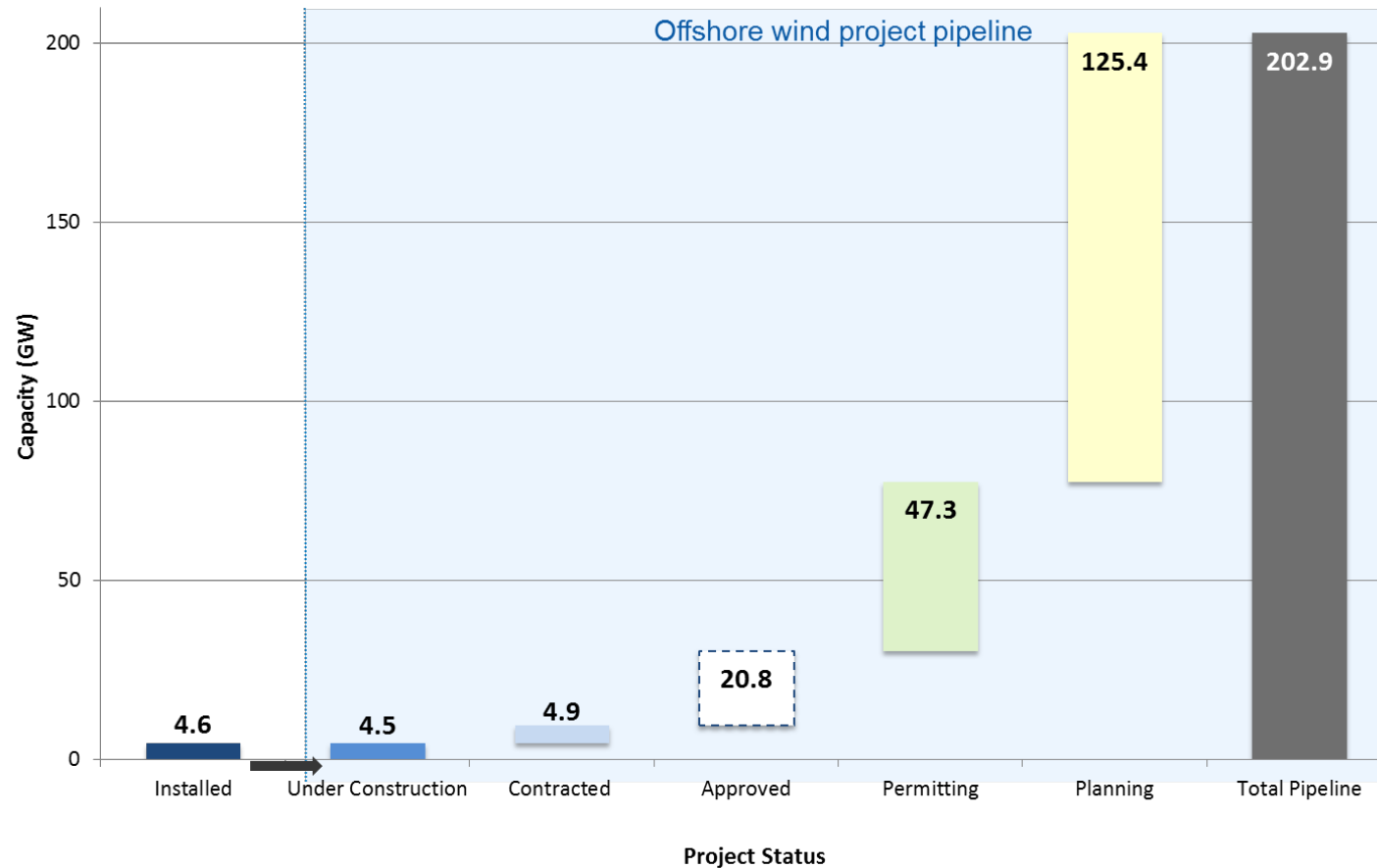
- Capital Investment** points to ICC in the numerator of the first fraction.
- Financing** points to FCR in the numerator of the first fraction.
- Operating Expense** points to AOE in the numerator of the second fraction.
- Annual Energy Production** points to AEP_{net} in the denominator of both fractions.

$$LCOE = \frac{(FCR \times ICC)}{AEP_{net}} + \frac{AOE}{AEP_{net}}$$

Source: Short et al. 1995

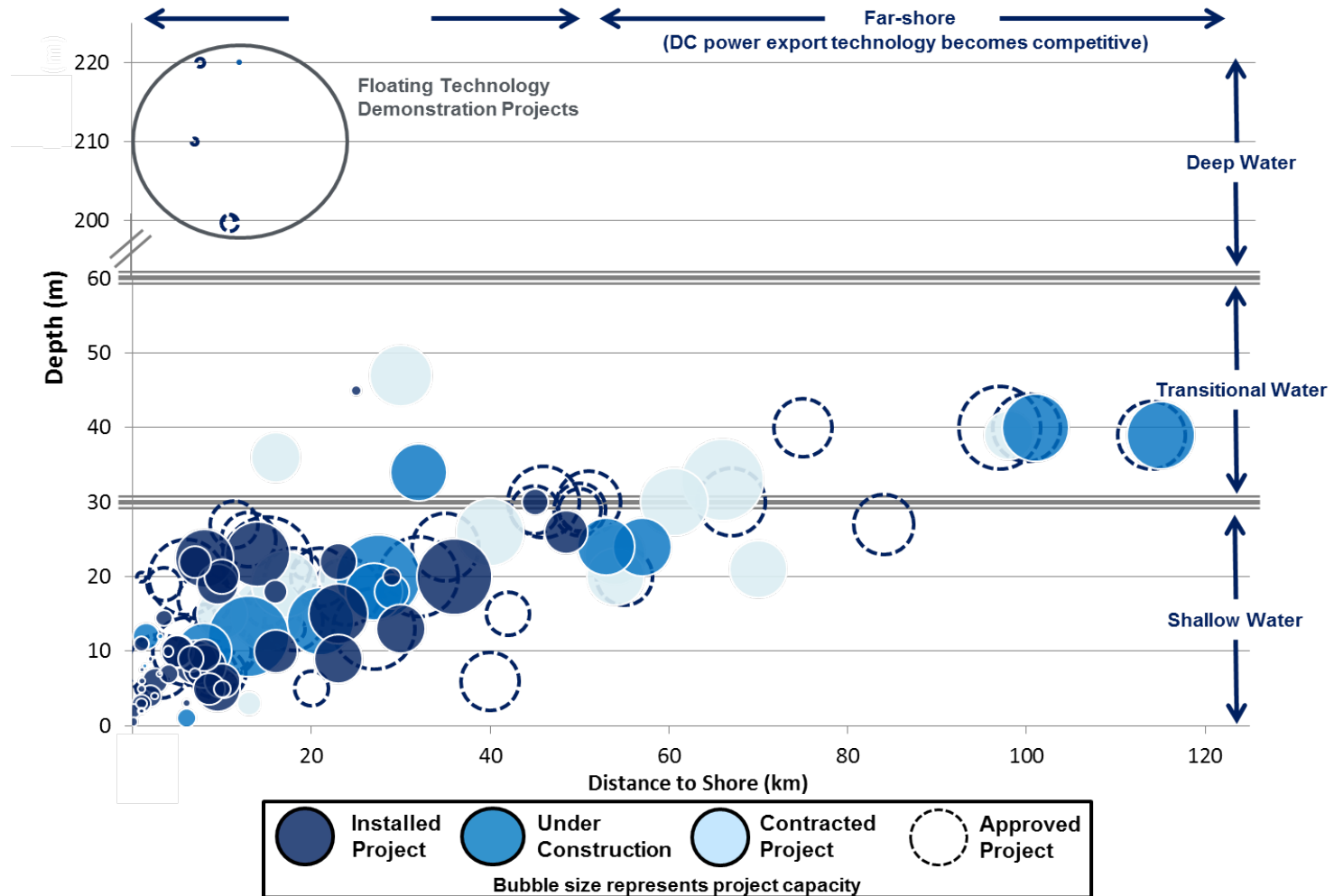
- **Four basic parameters**
 - Initial Capital Cost (ICC), Annual Operating Expenses (AOE), finance parameters (Fixed Charge Rate (FCR)), and net Annual Energy Production (AEP)
- **Metric is useful to explore**
 - Long-term trends or projections
 - Relative differences in resource quality, geographic locations, or technology options

Globally, There are Over 200 GW of Offshore Wind Plants in Various Stages of Planning In Addition to Nearly 5 GW in Operation



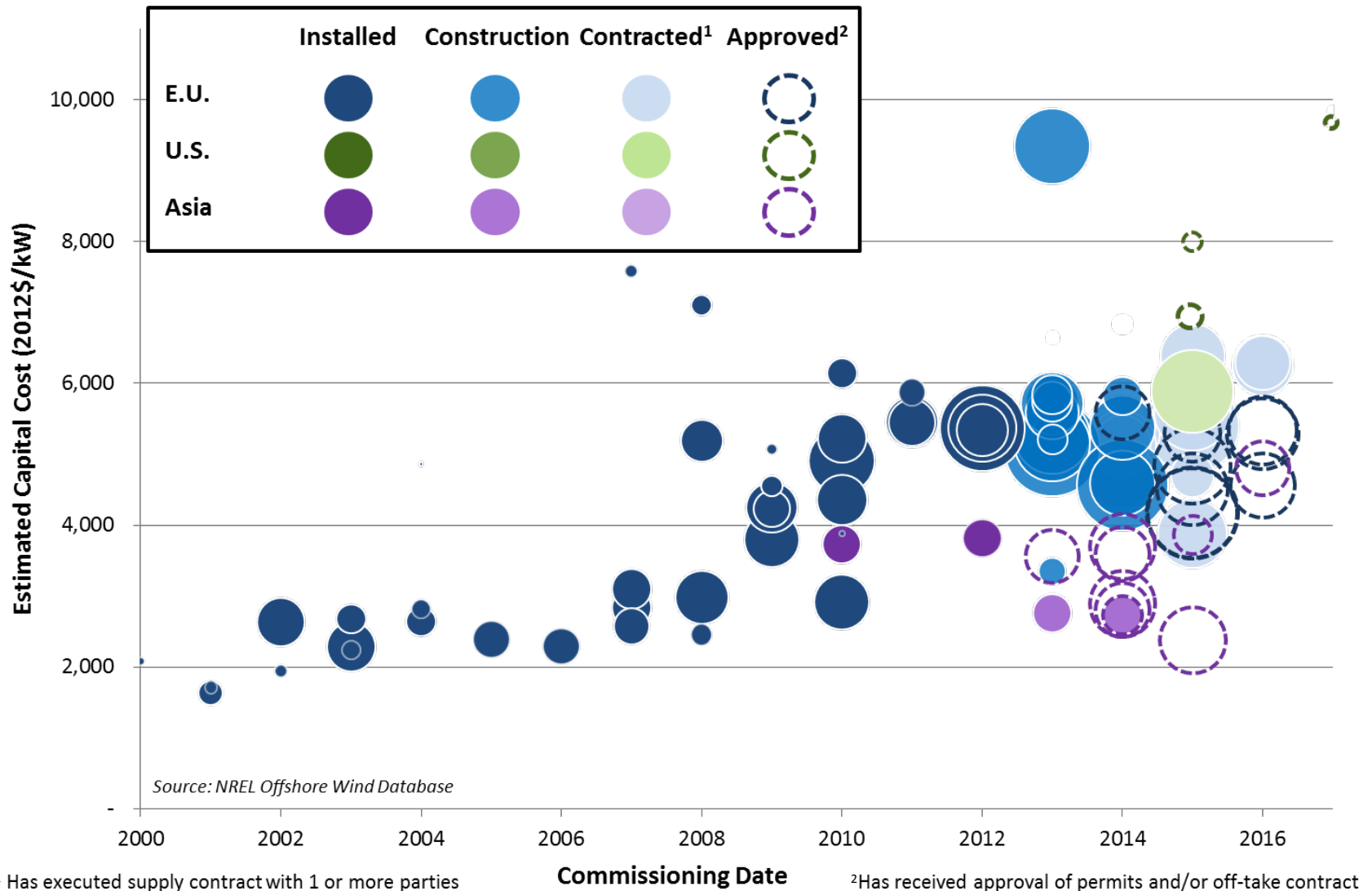
Source: NREL Offshore Wind Database

Installed Offshore Wind Projects Have Typically Been Sited In Shallow Water and Close to Shore, But New Projects are Exploring Deeper Water Farther From Shore

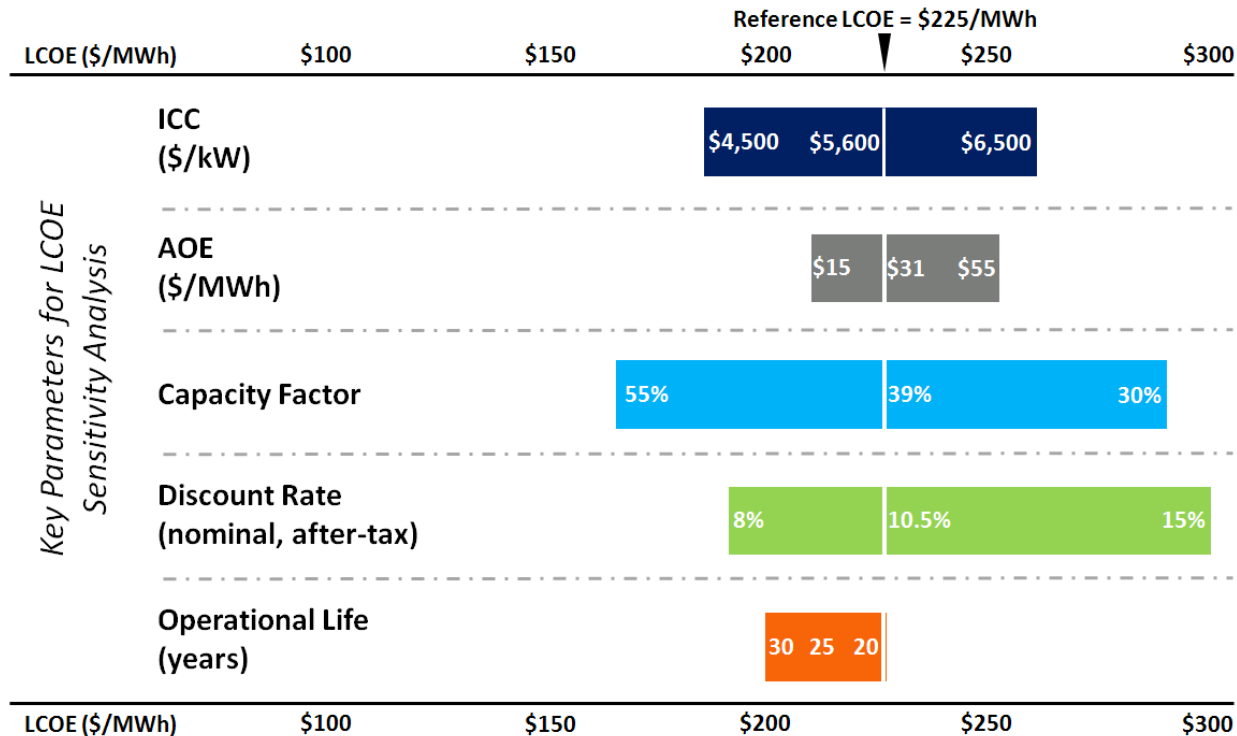


Source: NREL Offshore Wind Database

Offshore Wind Plant Capital Costs Have Increased Over the Past Decade Partly Due to the Rapid Expansion to Deeper Water Farther From Shore



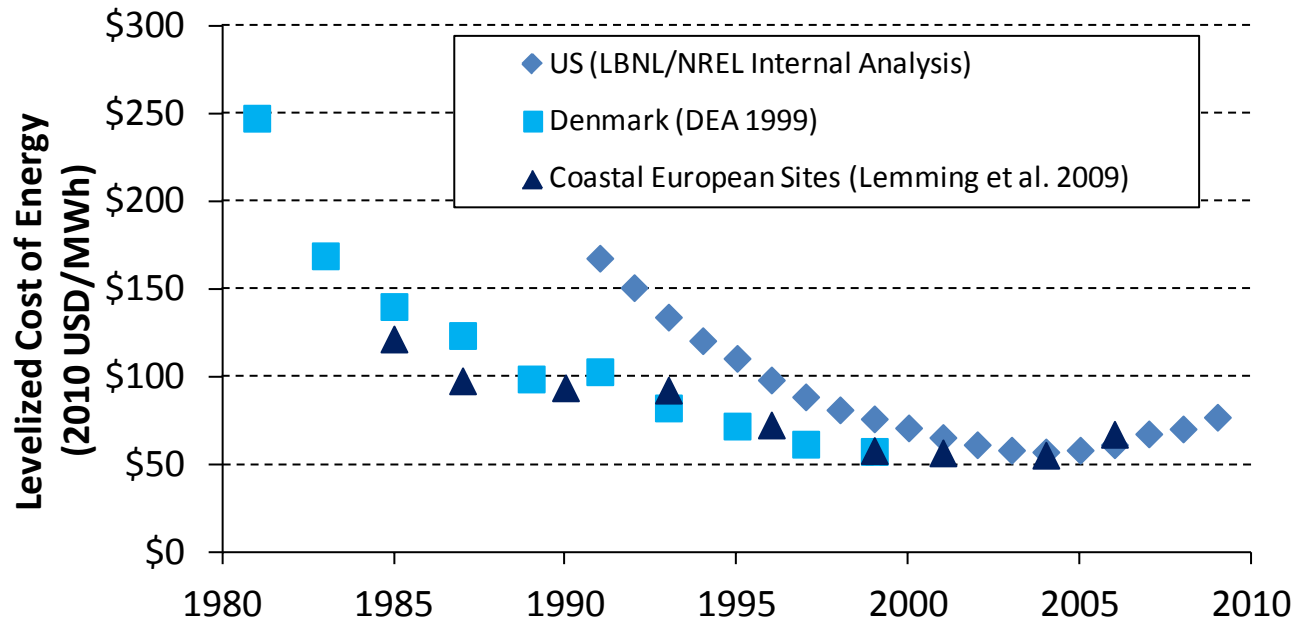
Potential U.S. Offshore Wind Plant LCOE Ranges From \$168/MWh to \$292/MWh



Source: Tegen et al. 2013

- The offshore wind industry is evolving with a variety of foundation types designed for a number of site conditions contributing to a range of cost estimates
- Lack of experience in project planning, construction and operation also introduces uncertainty that results in varied cost estimates

Land-Based Wind Plant LCOE Declined by More Than 2/3 Between the Early 1980s and 2000s

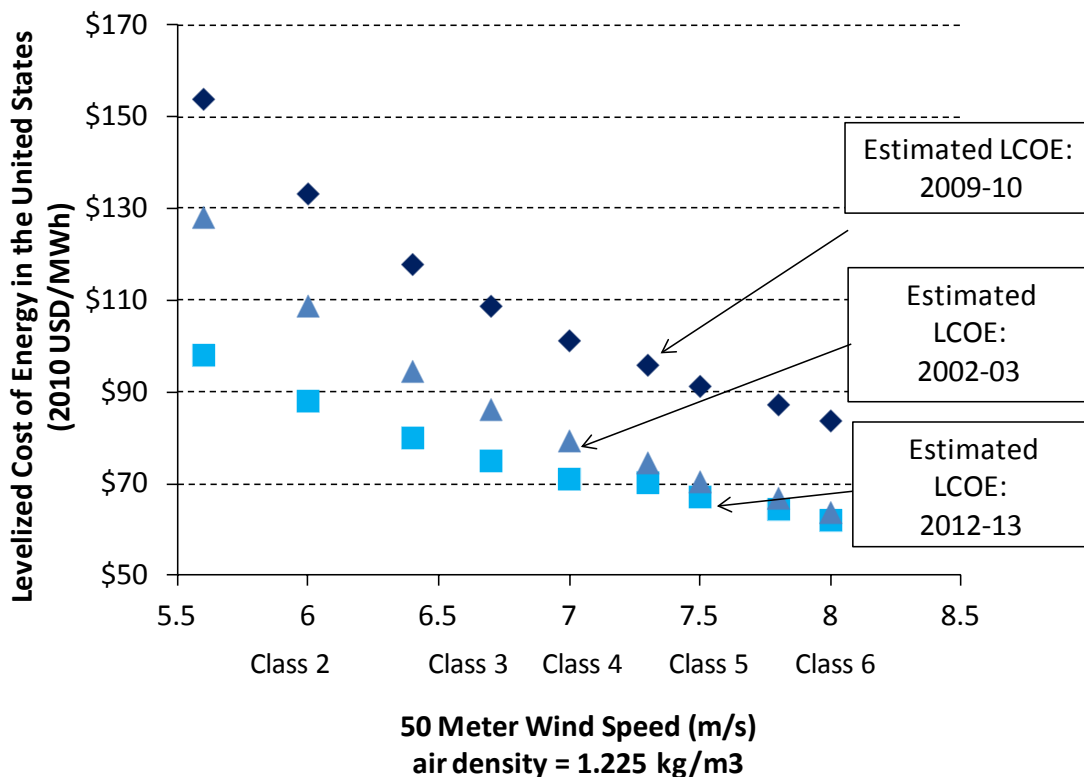


Source: Lantz et al. 2012

Escalation in wind power capital costs since 2003 resulted from:

- Rising commodity and raw material prices
- Increased labor costs
- Improved manufacturer profitability
- Turbine upscaling.

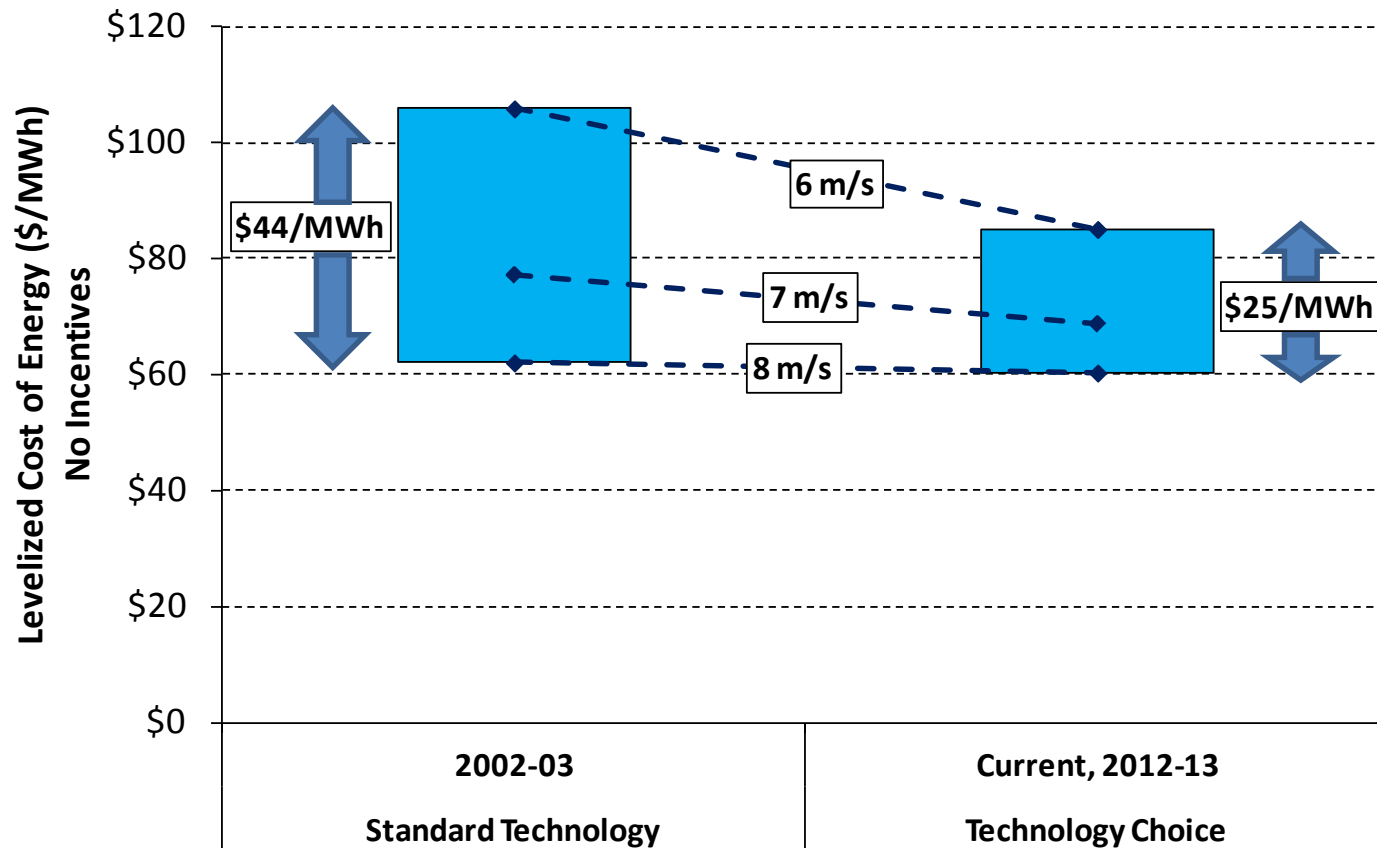
Lower Turbine Prices Since 2009 Along With Improved Wind Turbine Performance May Yield a Return to Historically Low LCOE Levels in 2012–2013



Source: Lantz et al. 2012

- Estimated wind plant LCOE based on observed market variation in capital investment and modeled wind plant performance
- Incentives or policies that reduce price of wind energy in wholesale power markets (e.g., production tax credit) excluded.

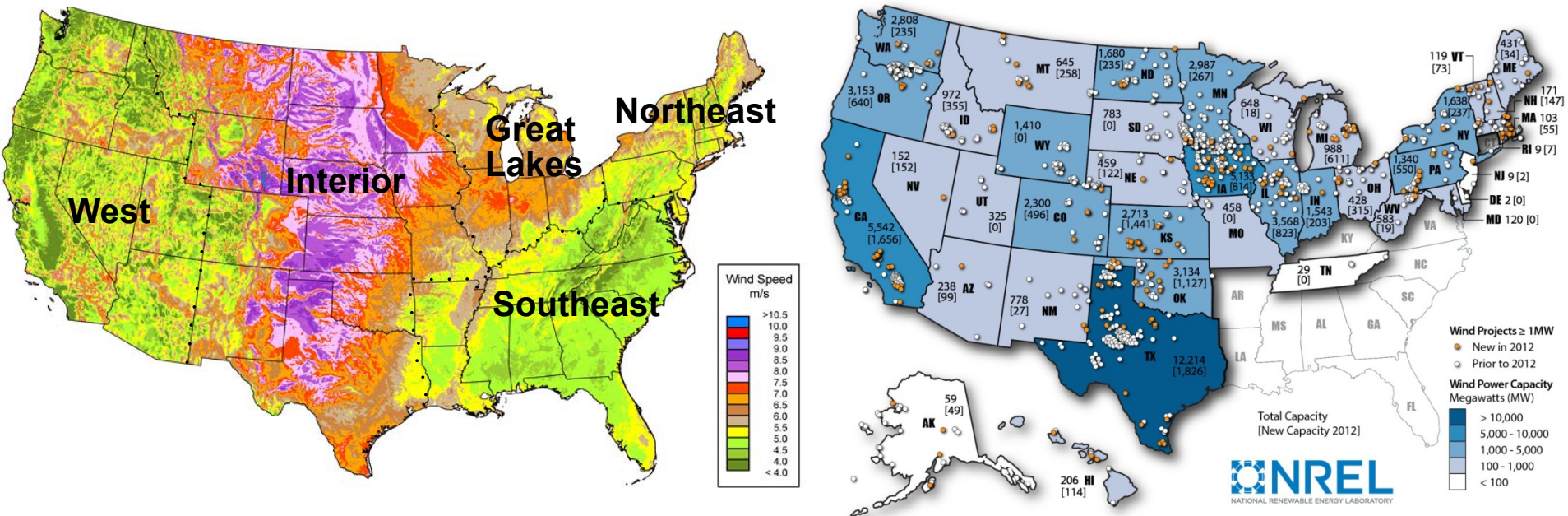
New Technology Options Reduce Variability in LCOE Across a Range of Wind Resource Sites



Source: Lantz et al. 2012

- Low wind speed technology with larger rotor and taller tower size options provides Technology Choice in 2012–2013 for annual-average sea level equivalent wind speeds at 50 meters.

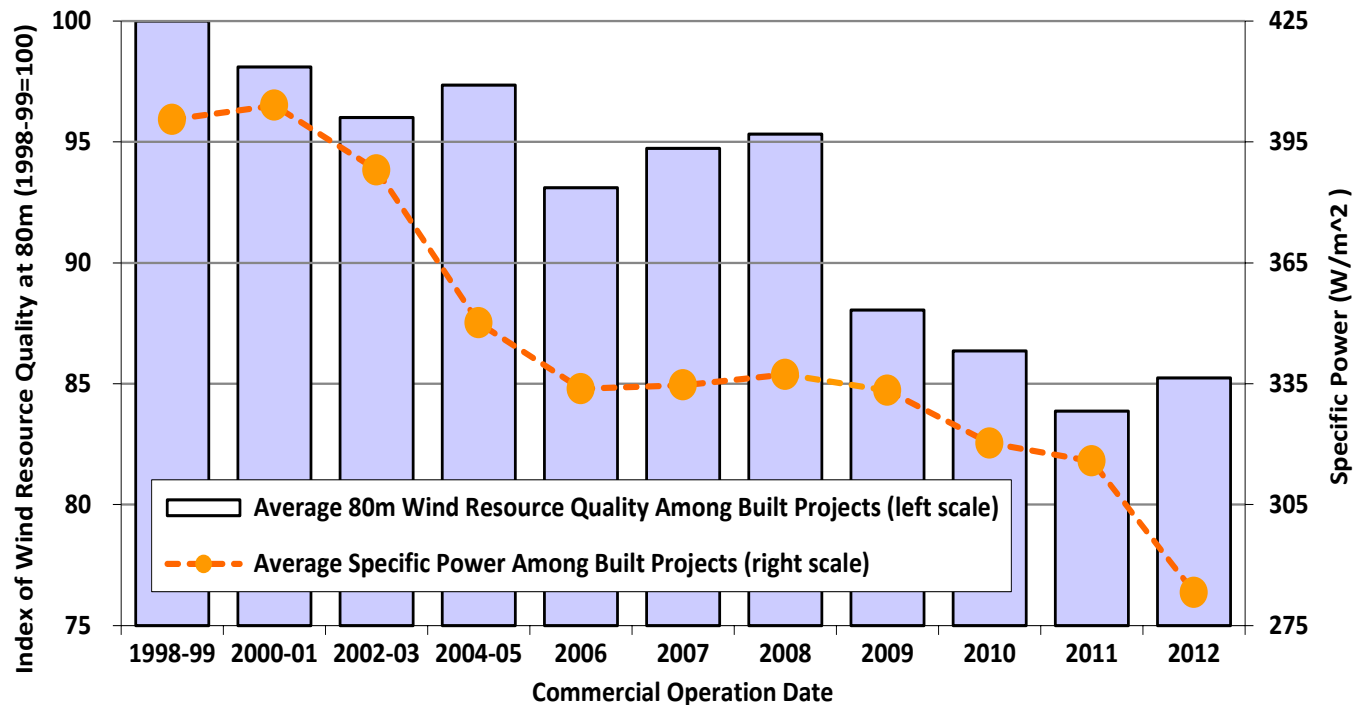
Geographic Spread of Wind Power Projects in the United States Spans a Range of Wind Resources



Source: Wiser and Bolinger, 2013

Note: Numbers within states represent cumulative installed wind capacity and, in brackets, annual additions in 2012.

Recent Wind Projects Utilize Low Wind Speed Technology in Lower Wind Resource Quality Locations than Were Used a Decade Ago

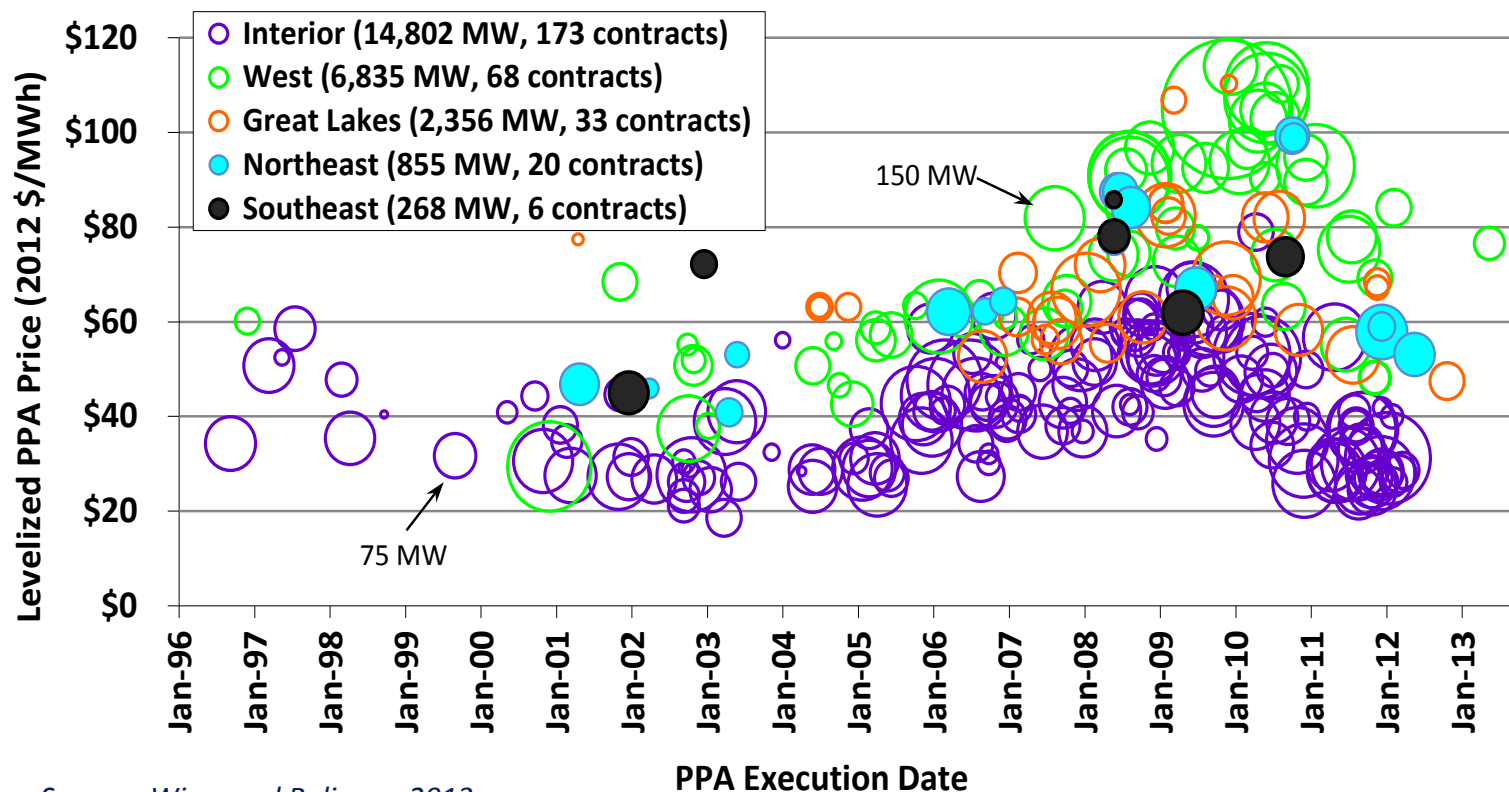


Source: *Wiser and Bolinger, 2013*

- Specific power is a ratio of generator rating to rotor swept area

Wind PPA Prices Generally Have Been Falling Since 2009 and Now Rival Previous Lows Set a Decade Ago

(this despite the trend to lower-quality wind resource sites)

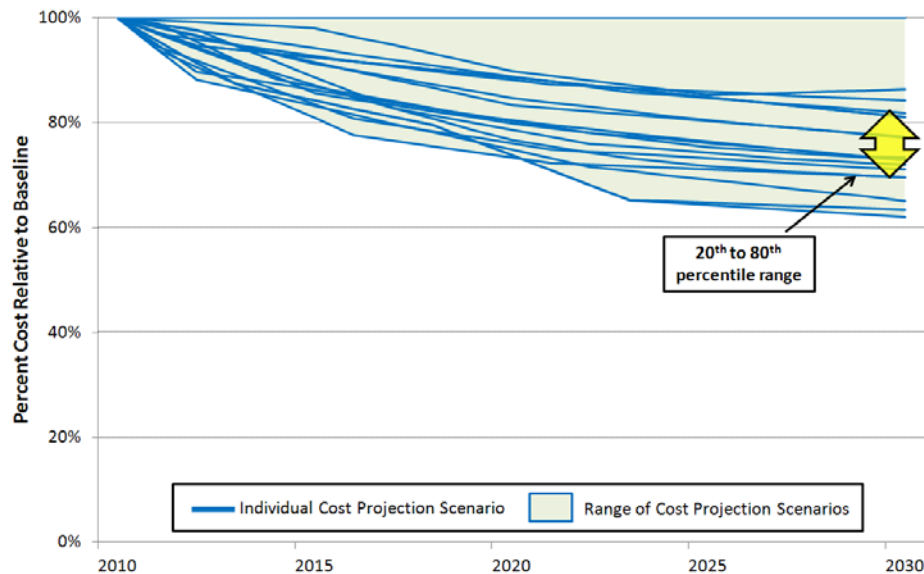


Source: *Wiser and Bolinger, 2013*

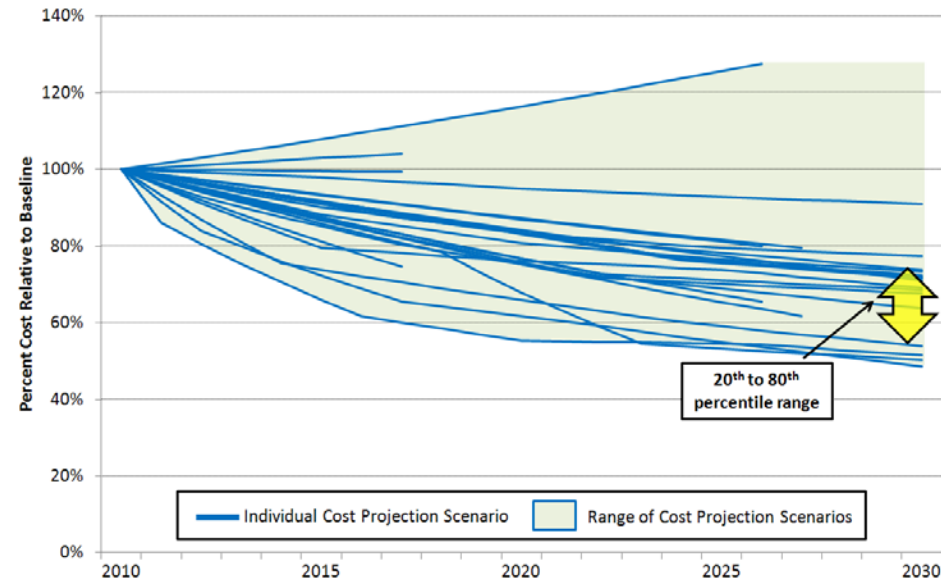
- PPA prices include incentives or policies that reduce price of wind energy in wholesale power markets (e.g., production tax credit).

Most Projections for Wind Plant LCOE Anticipate Future Reductions With Opportunities for Greater Reductions in Offshore Wind Plant LCOE

Land-Based Wind LCOE



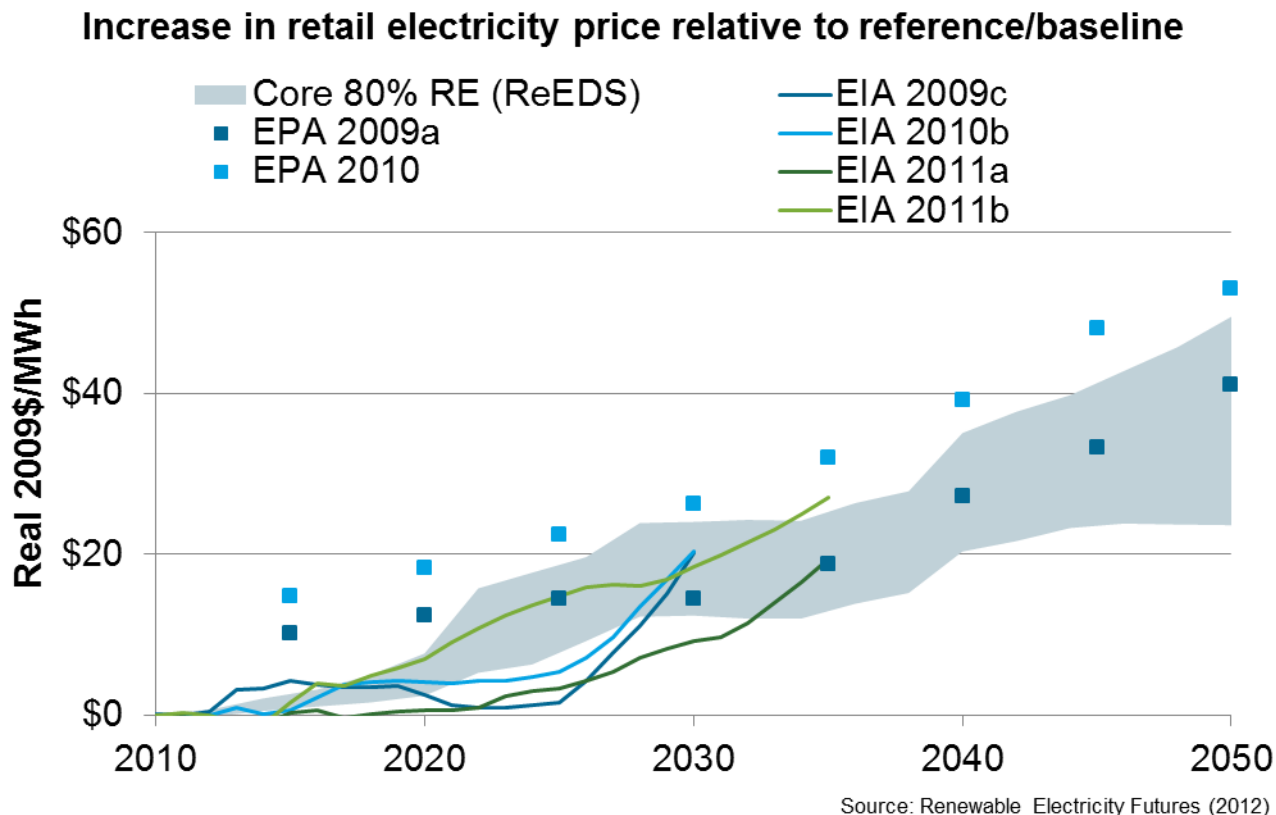
Offshore Wind LCOE



Source: Tegen et al. 2012

- Projections included here were published and derived from a variety of methods including learning curves, expert elicitation, and engineering-based models.

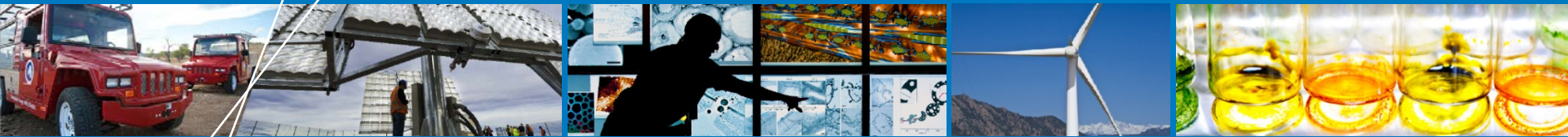
Demonstrating Future Cost Reduction of Wind Energy is Important for Understanding Future Electric Sector Evolution



- Renewable Electricity (RE) Futures showed that the incremental cost of high RE scenarios is comparable to published cost estimates of other clean energy scenarios
- Improvement in the cost and performance of renewable technologies is the most impactful lever for reducing this incremental cost.

Conclusions

- **The offshore wind industry is expanding into deeper waters farther from shore contributing to a wide range of the cost of energy**
- **U.S. land-based wind plant cost of energy may be returning to a historical low as a result, in part, of new wind turbine options**
- **Projections for future wind plant cost of energy anticipate reductions for both land-based and offshore wind plants**



Thank you. For more information...

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