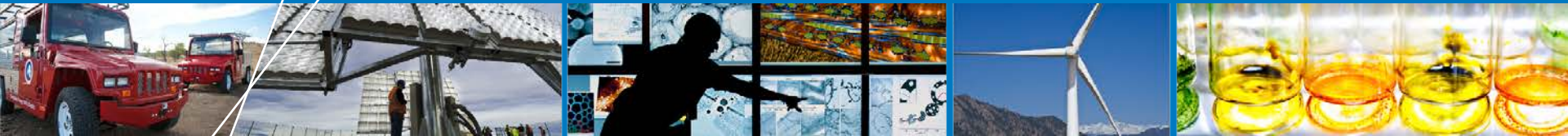


# Tracking the Cost of Wind Energy



**M. Maureen Hand, Ph.D.**

**North American Wind Energy Academy 2013  
Symposium**

**Boulder, CO**

**August 6, 2013**

**NREL/PR-6A20-60237**

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This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-08-GO28308 with the National Renewable Energy Laboratory.

# 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:

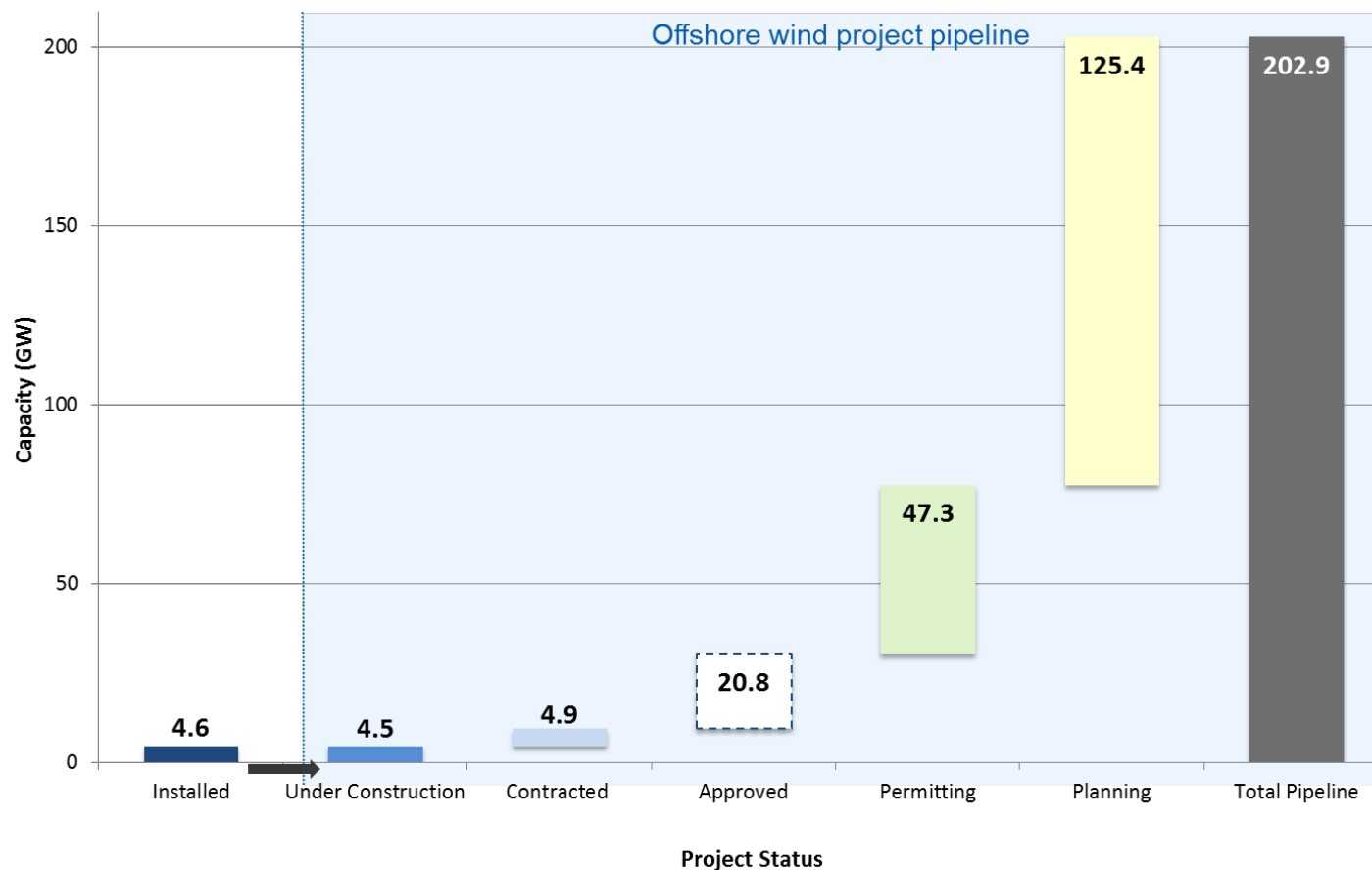
- Capital Investment** points to  $ICC$  in the numerator of the first term.
- Financing** points to  $FCR$  in the numerator of the first term.
- Operating Expense** points to  $AOE$  in the numerator of the second term.
- Annual Energy Production** points to  $AEP_{net}$  in the denominator of both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

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

Source: Short et al. 1995

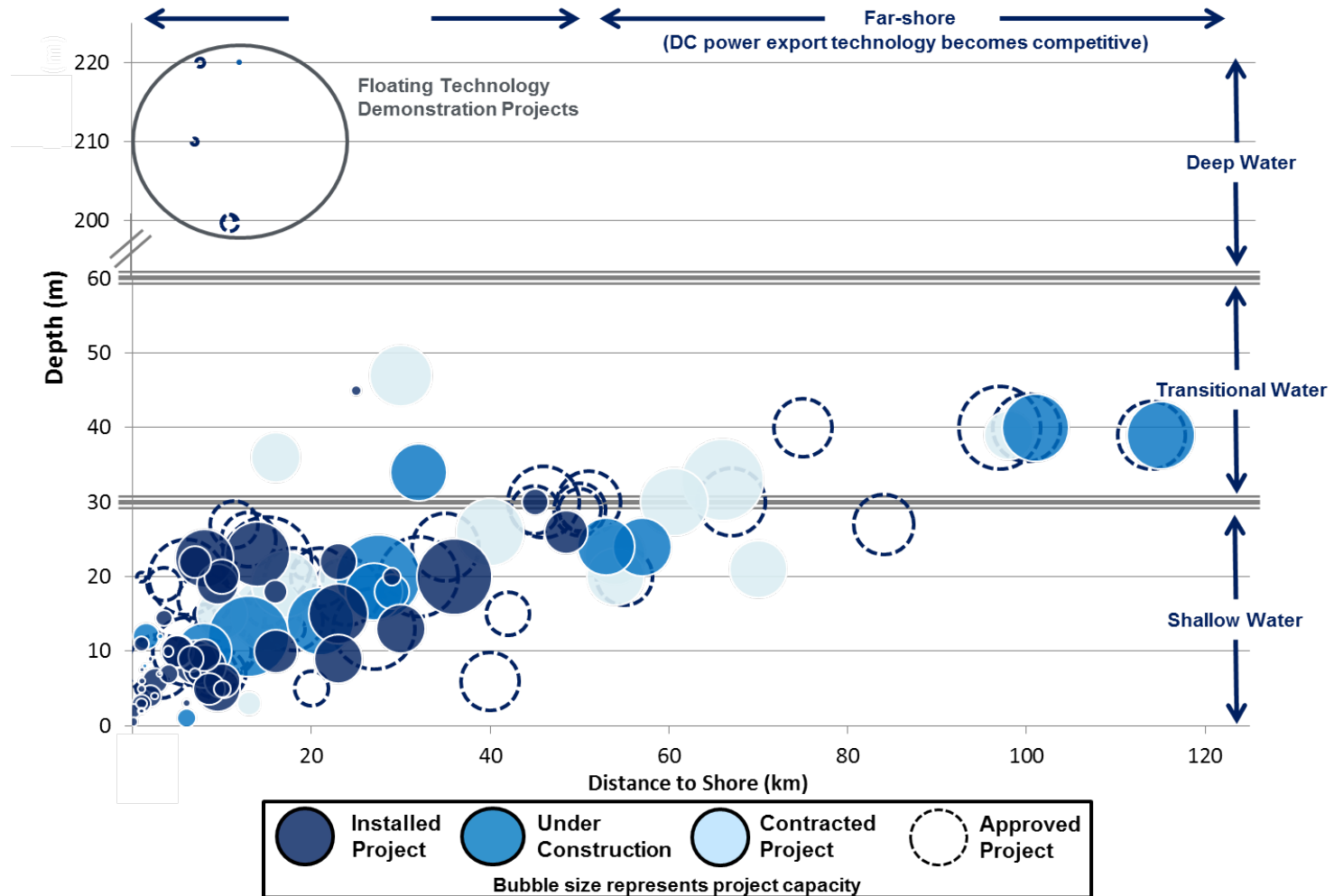
- **Four basic parameters**
  - Initial Capital Cost (ICC), Annual Operating Expenses (AOE), finance parameters (Fixed Charge Rate (FCR)), and net Annual Energy Production (AEP)
- **Metric is useful to explore**
  - Long-term trends or projections
  - Relative differences in resource quality, geographic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



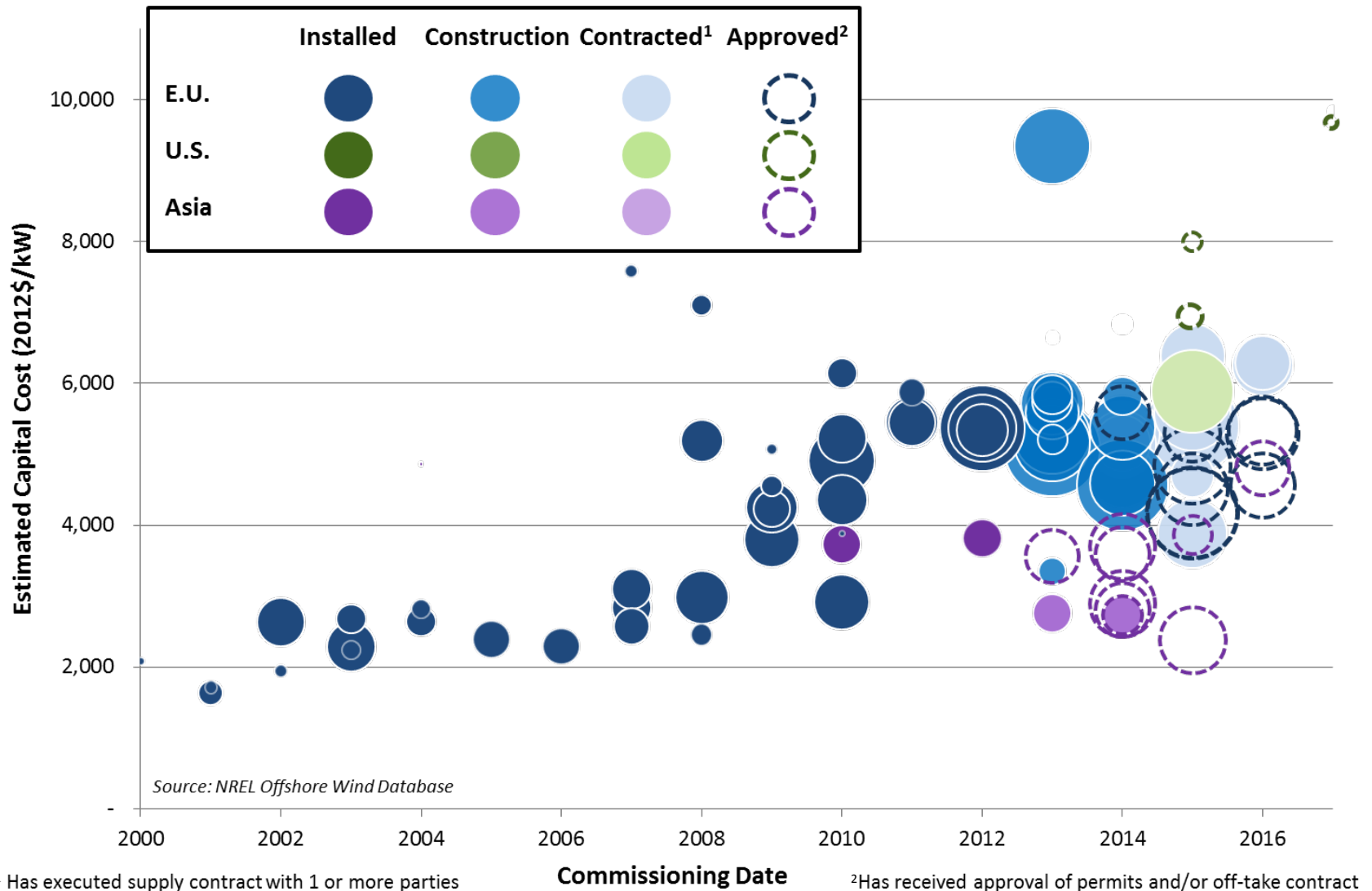
Source: NREL Offshore Wind Database

# 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

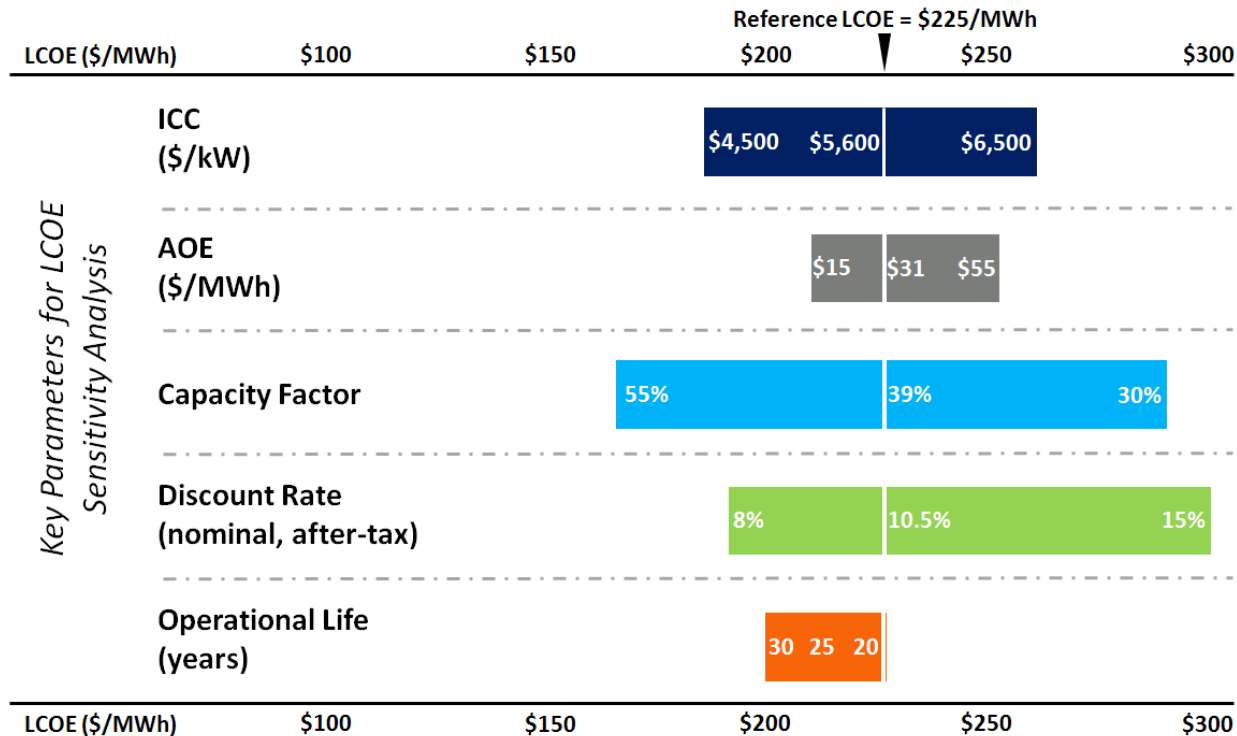


Source: NREL Offshore Wind Database

# 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

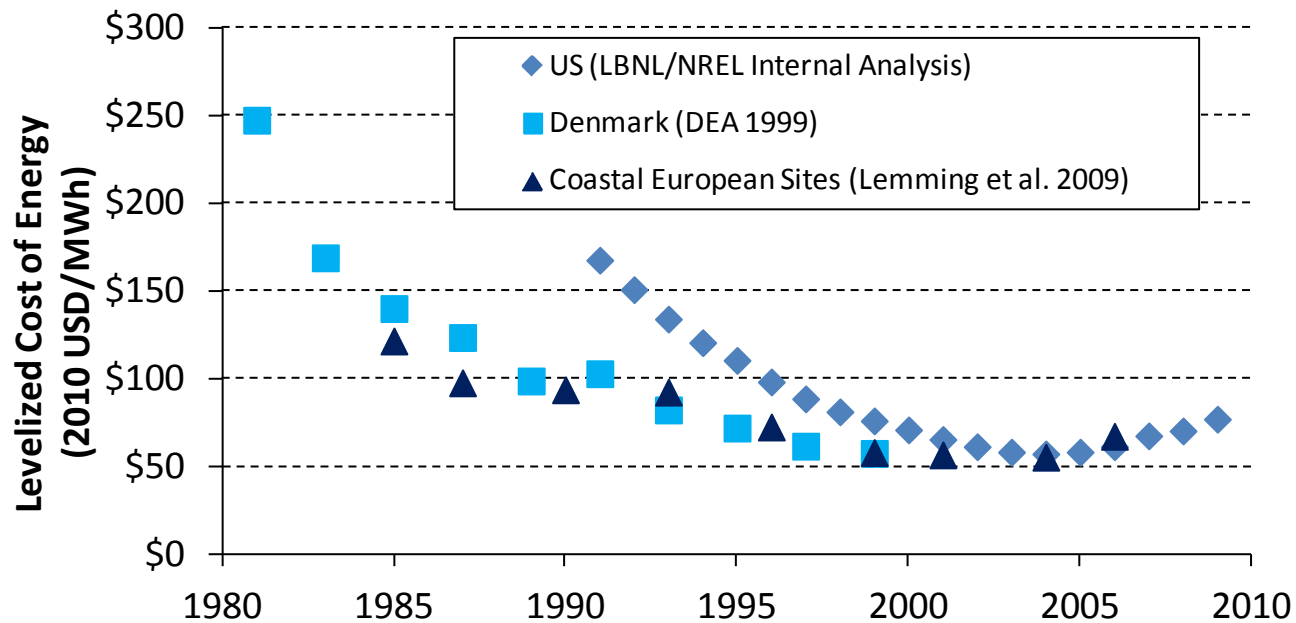


Source: Tegen et al. 2013

- 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

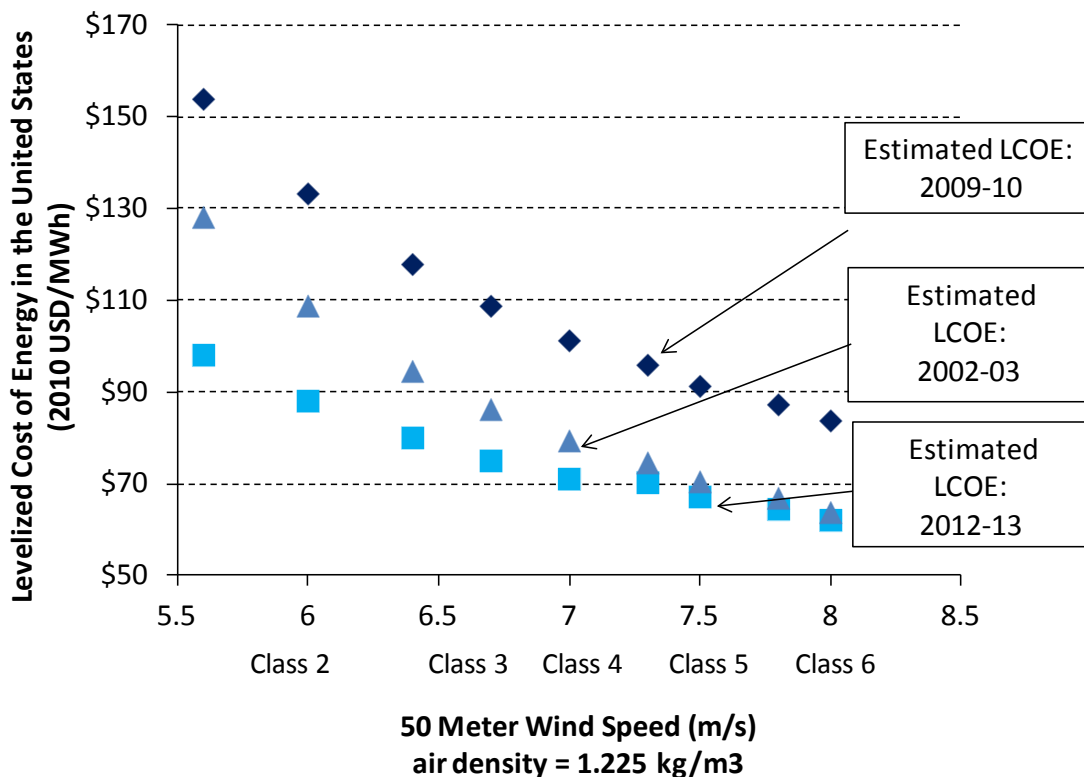


Source: Lantz et al. 2012

Escalation in wind power capital costs since 2003 resulted from:

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

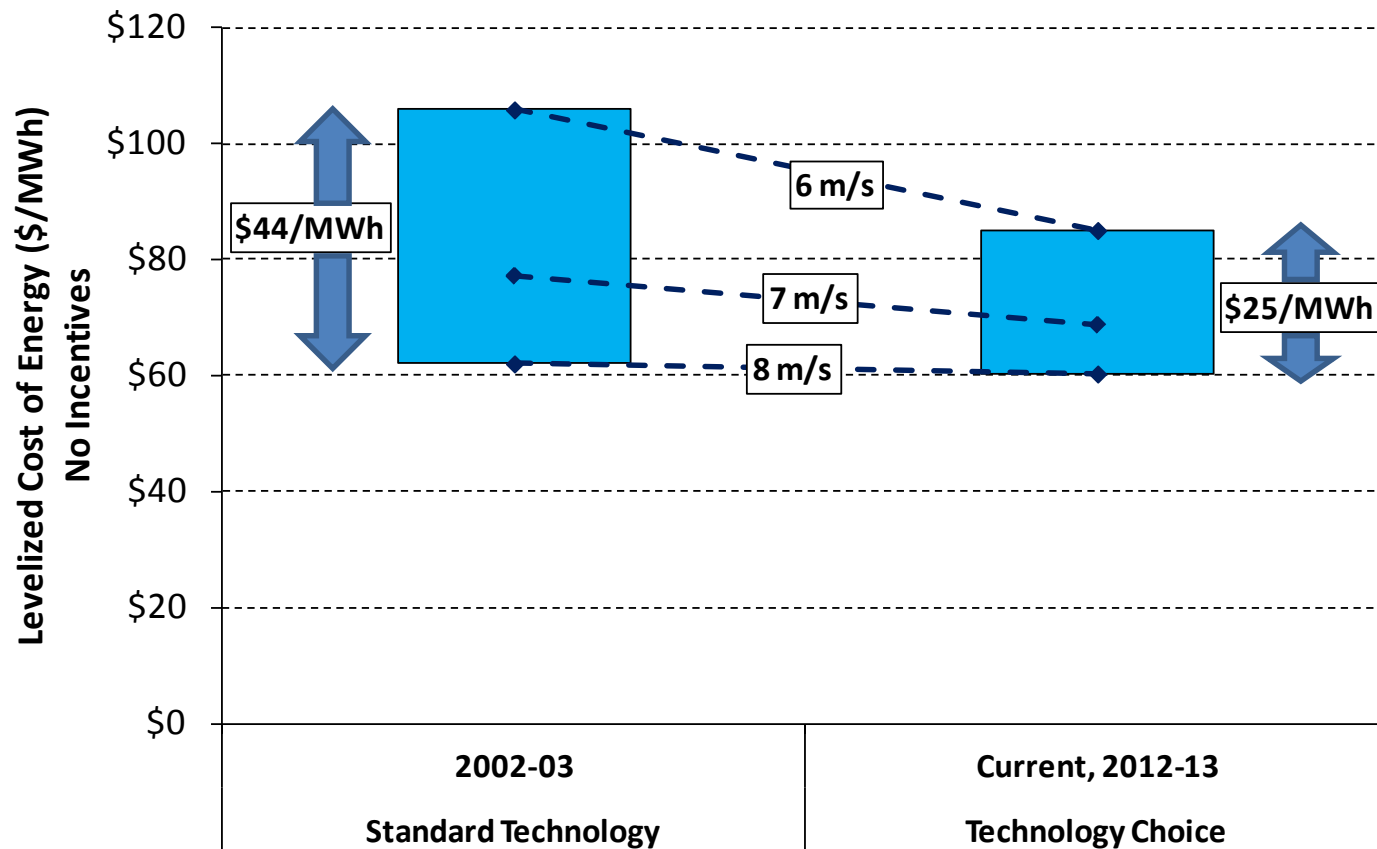
# Lower Turbine Prices Since 2009 Along With Improved Wind Turbine Performance May Yield a Return to Historically Low LCOE Levels in 2012–2013



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.

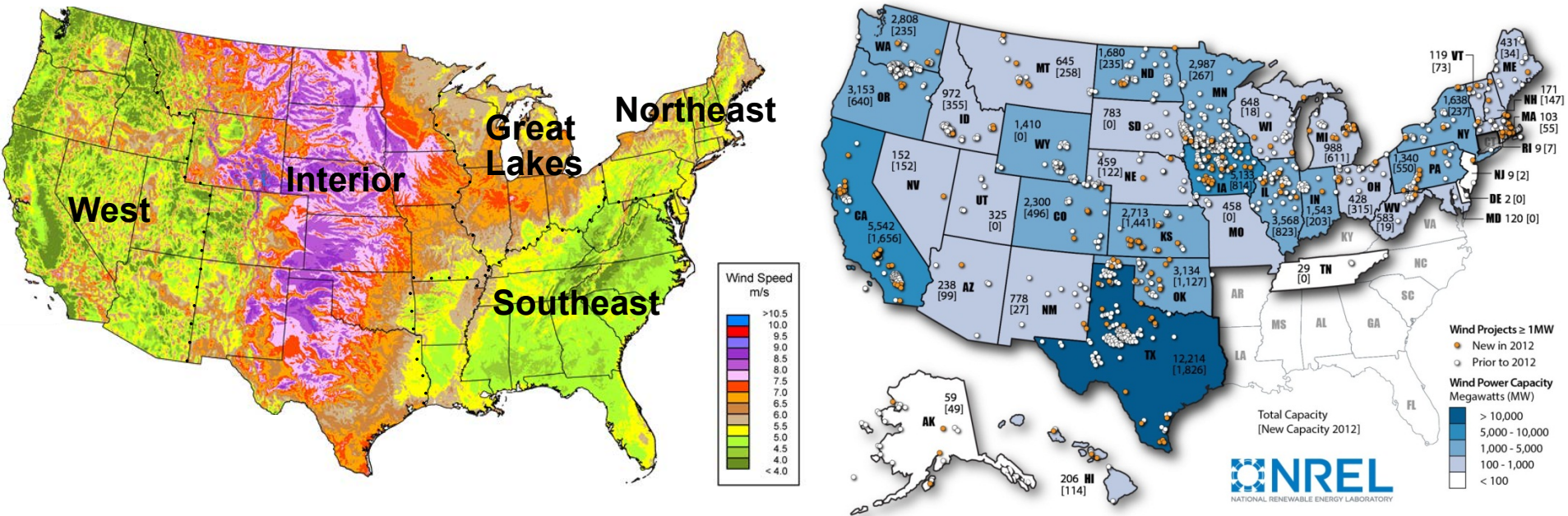
# New Technology Options Reduce Variability in LCOE Across a Range of Wind Resource Sites



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.

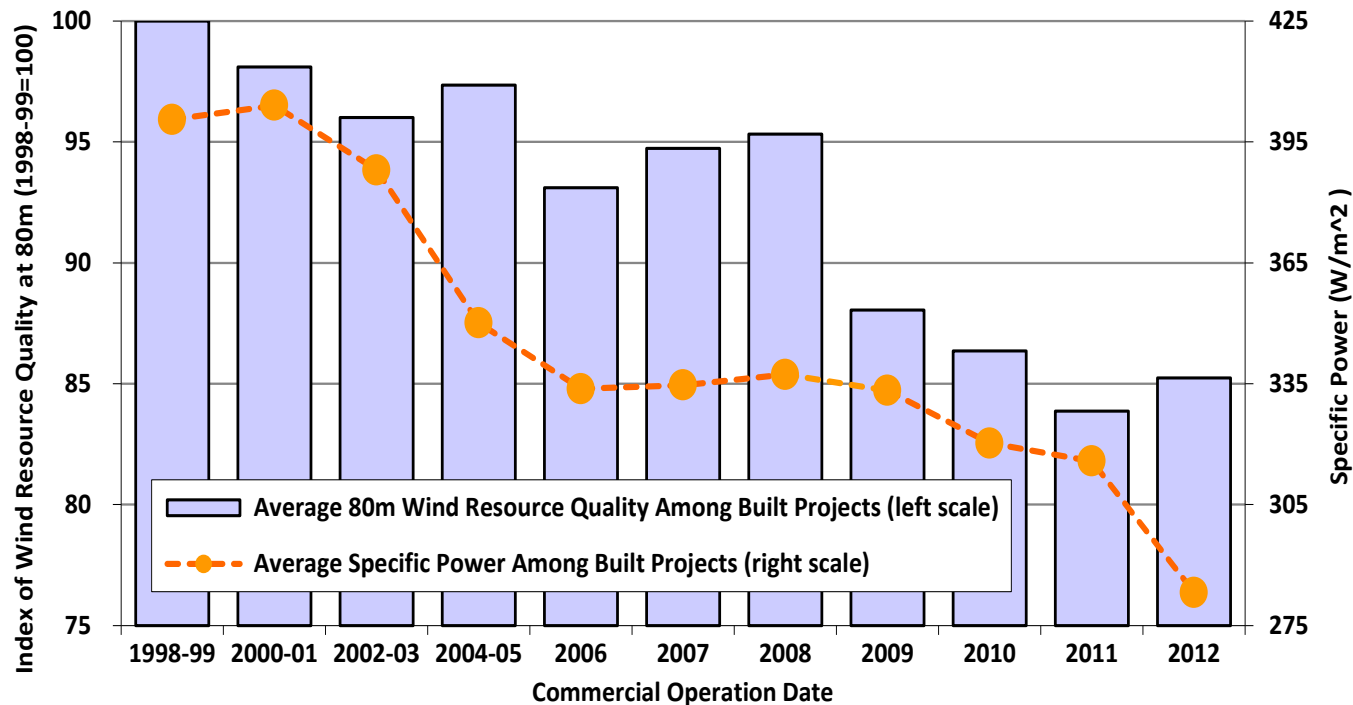
# Geographic Spread of Wind Power Projects in the United States Spans a Range of Wind Resources



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

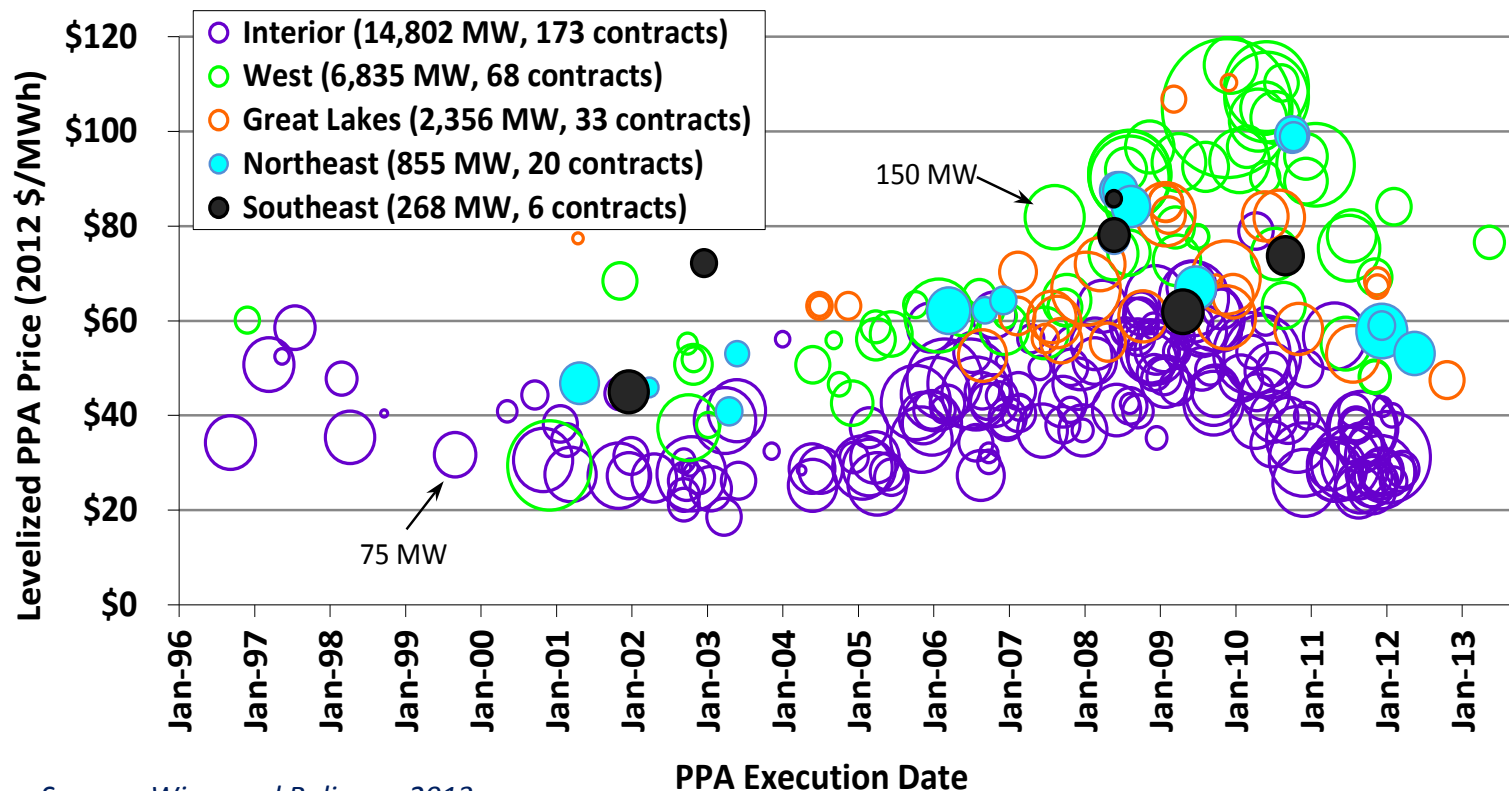


Source: *Wiser and Bolinger, 2013*

- 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)

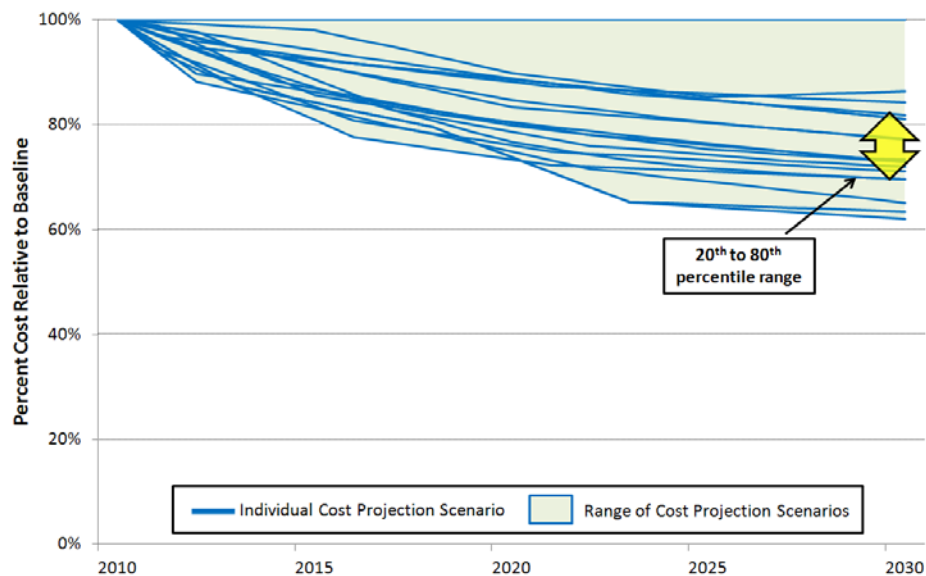


Source: *Wiser and Bolinger, 2013*

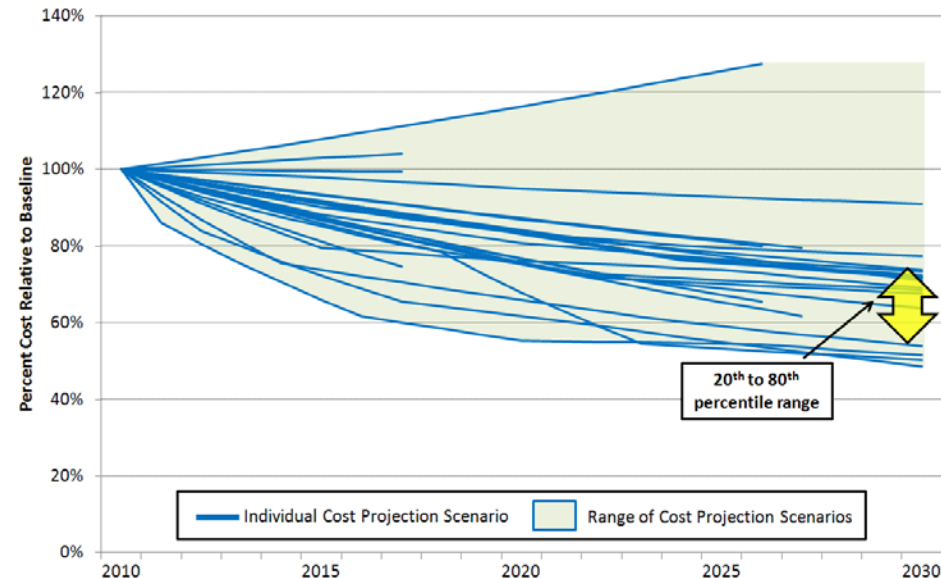
- PPA prices include incentives or policies that reduce price of wind energy in wholesale power markets (e.g., production tax credit).

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

## Land-Based Wind LCOE



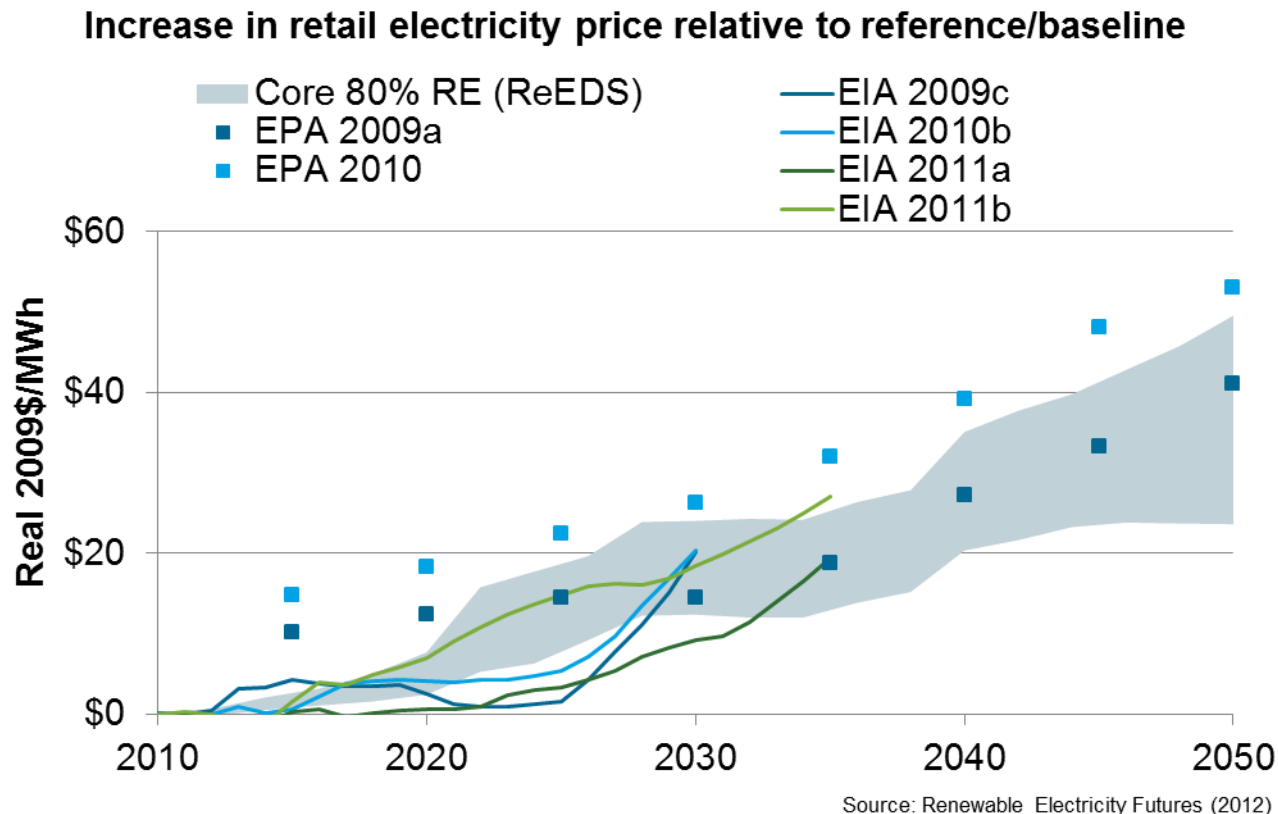
## Offshore Wind LCOE



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

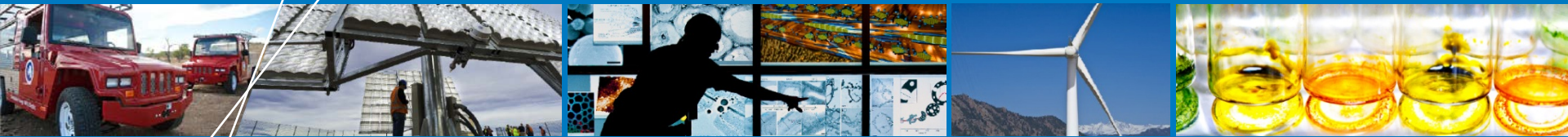


- Renewable Electricity (RE) Futures showed that the incremental cost of high RE scenarios is comparable to published cost estimates of other clean energy scenarios
- Improvement in the cost and performance of renewable technologies is the most impactful lever for reducing this incremental cost.



# 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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