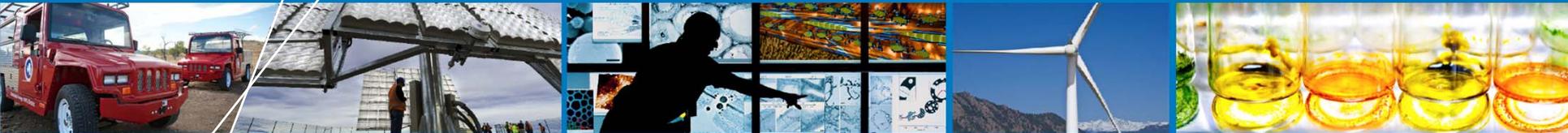


# Wind Plant Cost of Energy: Past and Future



**Maureen Hand, Ph.D.**

**2<sup>nd</sup> NREL Wind Energy System Engineering Workshop**

**Broomfield, CO**

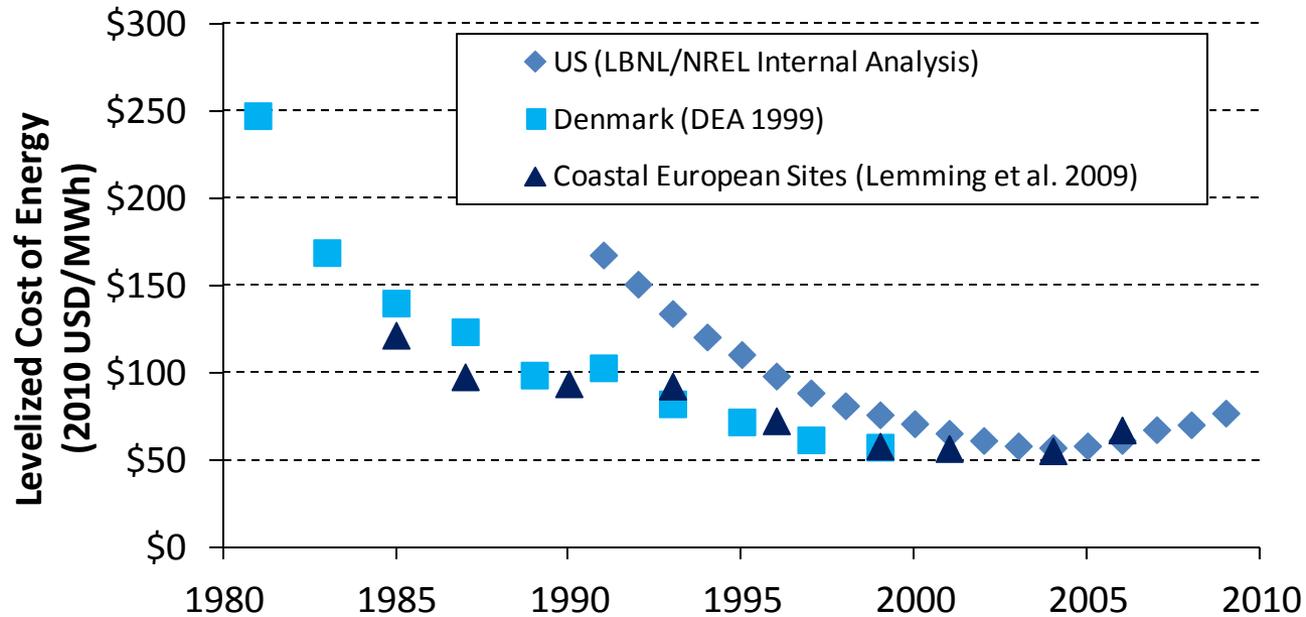
**January 29–30, 2013**

**NREL/PR-6A20-57841**

# Overview

- **Historical trend for wind plant levelized cost of energy (LCOE) including influence of turbine pricing fluctuation and introduction of low wind speed turbine technology**
- **Projections for future wind plant LCOE based on learning curve, expert elicitation, and engineering-based modeling.**

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

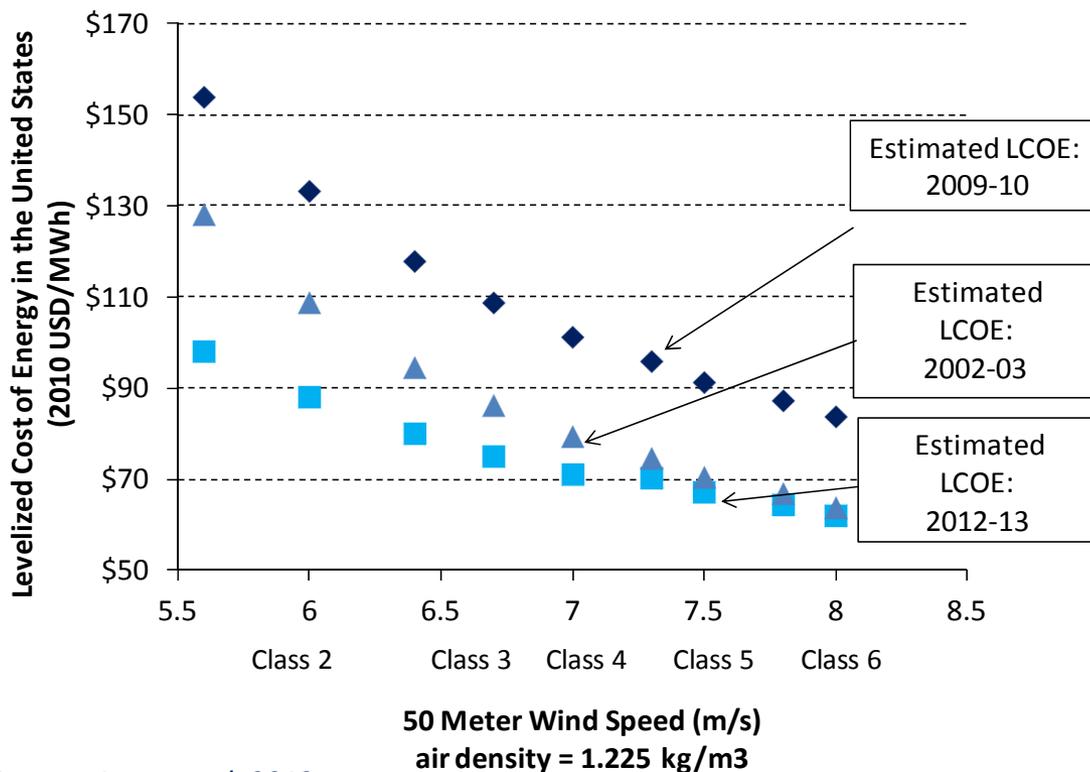


Source: Lantz et al. 2012

Escalation in wind power capital costs since 2003 resulted from:

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

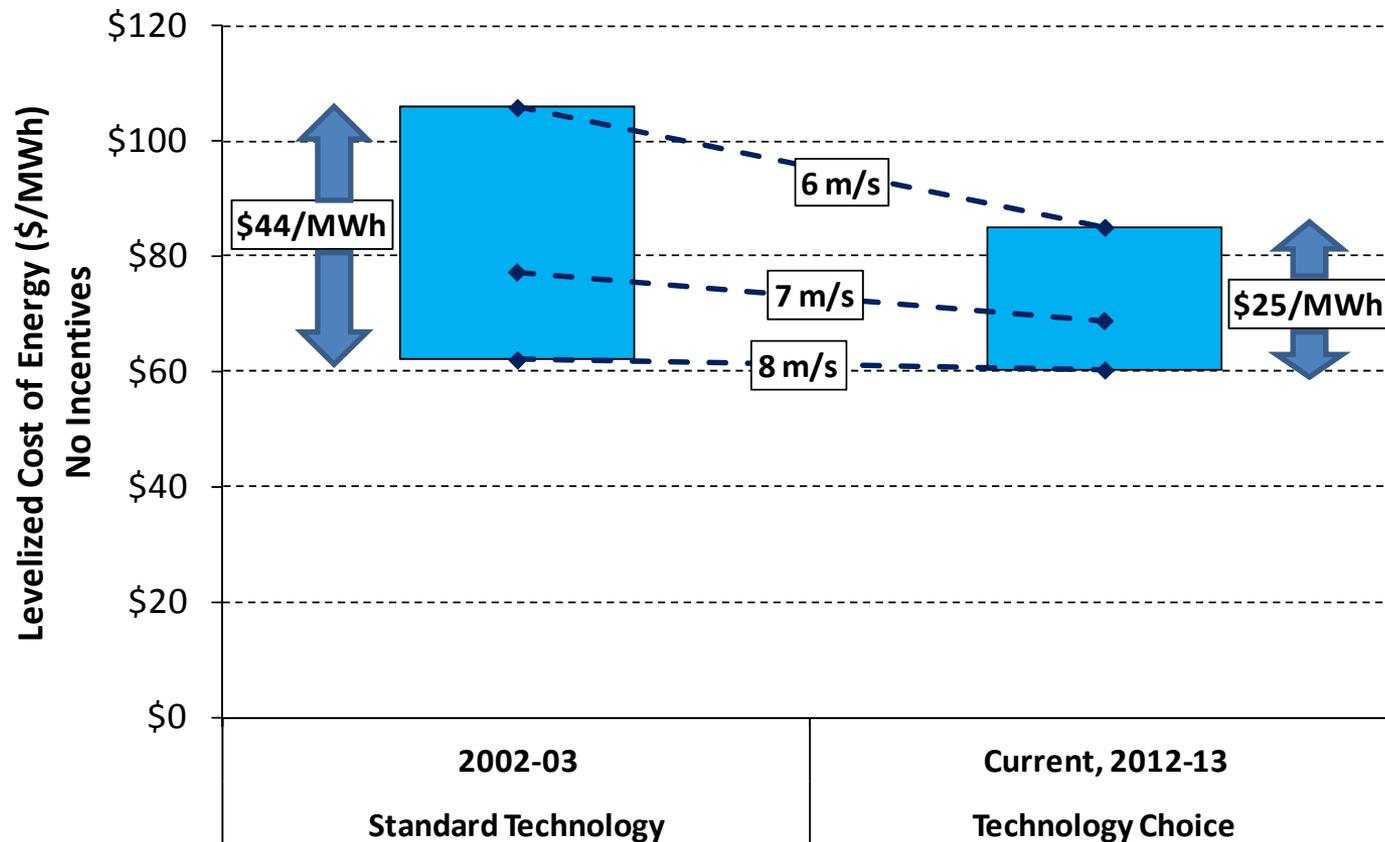
# Lower Turbine Prices Since 2009 Along With Improved Wind Turbine Performance May Yield a Return to Historically Low LCOE Levels in 2012–2013



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

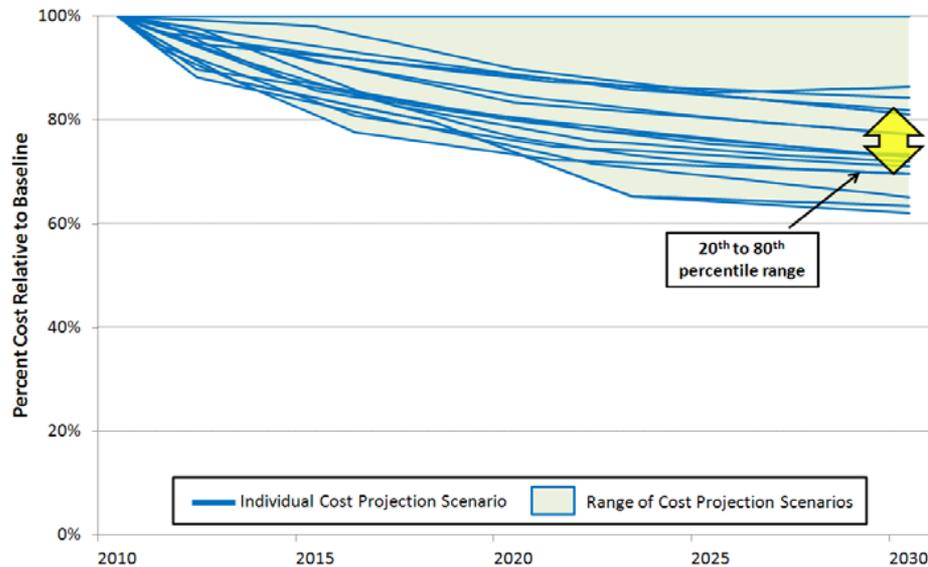


Source: Lantz et al. 2012

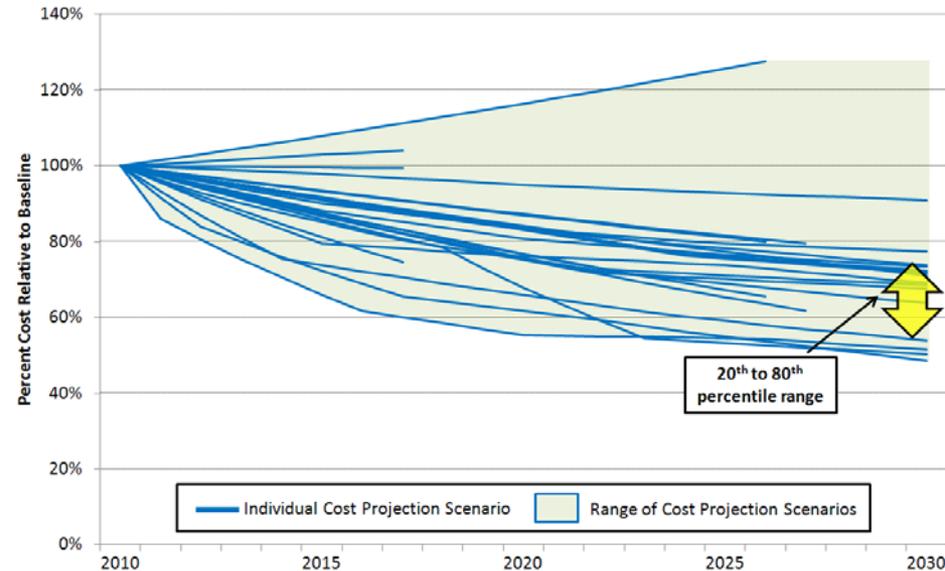
- Low wind speed technology designed for International Electrotechnical Commission Class III sites provides Technology Choice in 2012–2013 for annual average sea level equivalent wind speeds at 50 meters.

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

## Land-Based Wind LCOE



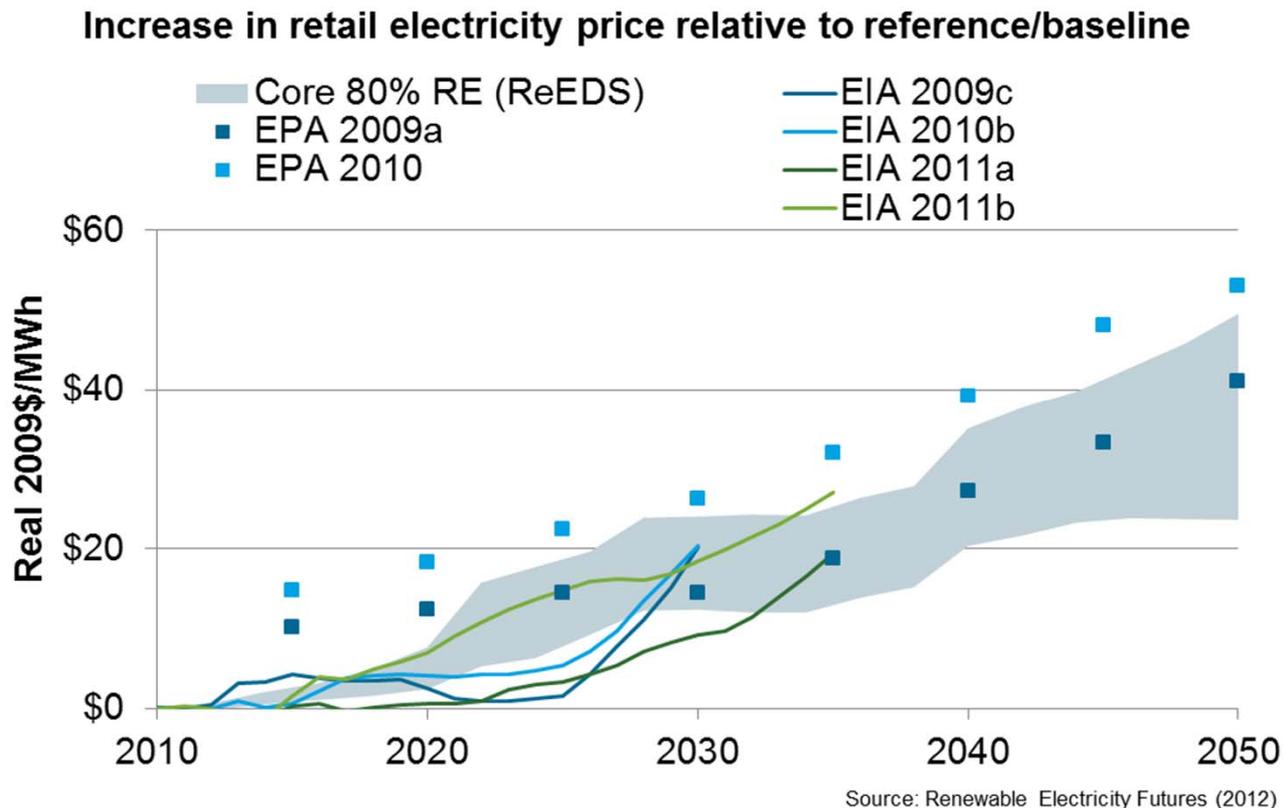
## Offshore Wind LCOE



Source: Tegen et al. 2012

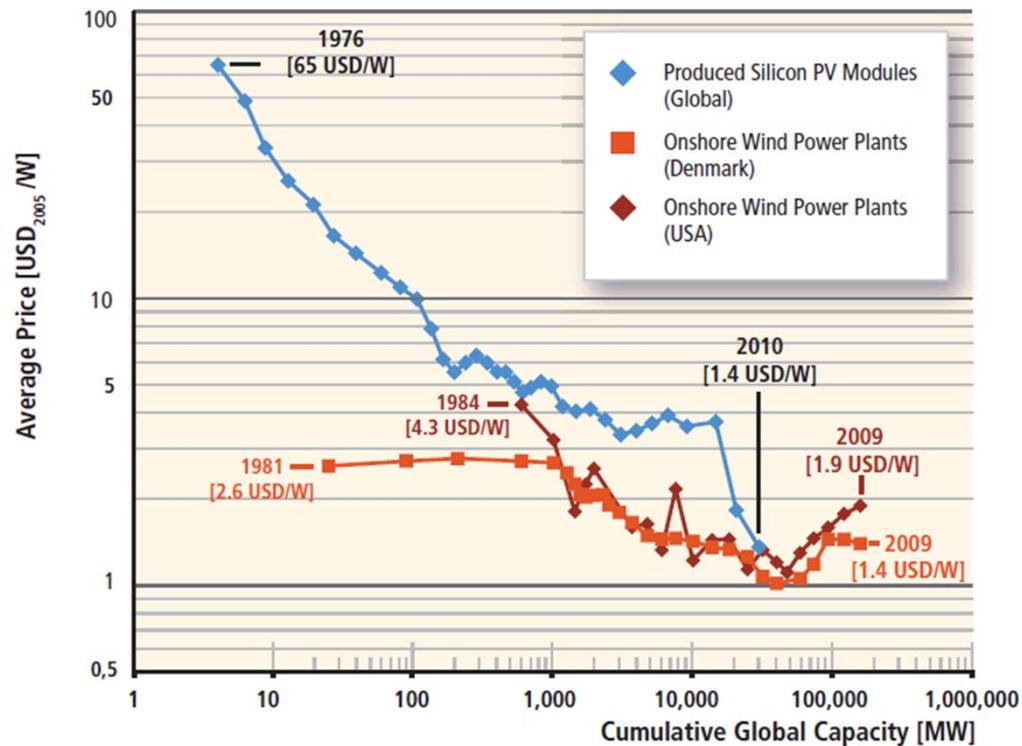
- Projections included here were published and derived from a variety of methods including learning curves, expert elicitation, and engineering-based models.

# 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.

# Learning Curves Capture Industry-Level Advances but Do Not Provide Insight Into the Role of Technology Research and Development Specifically

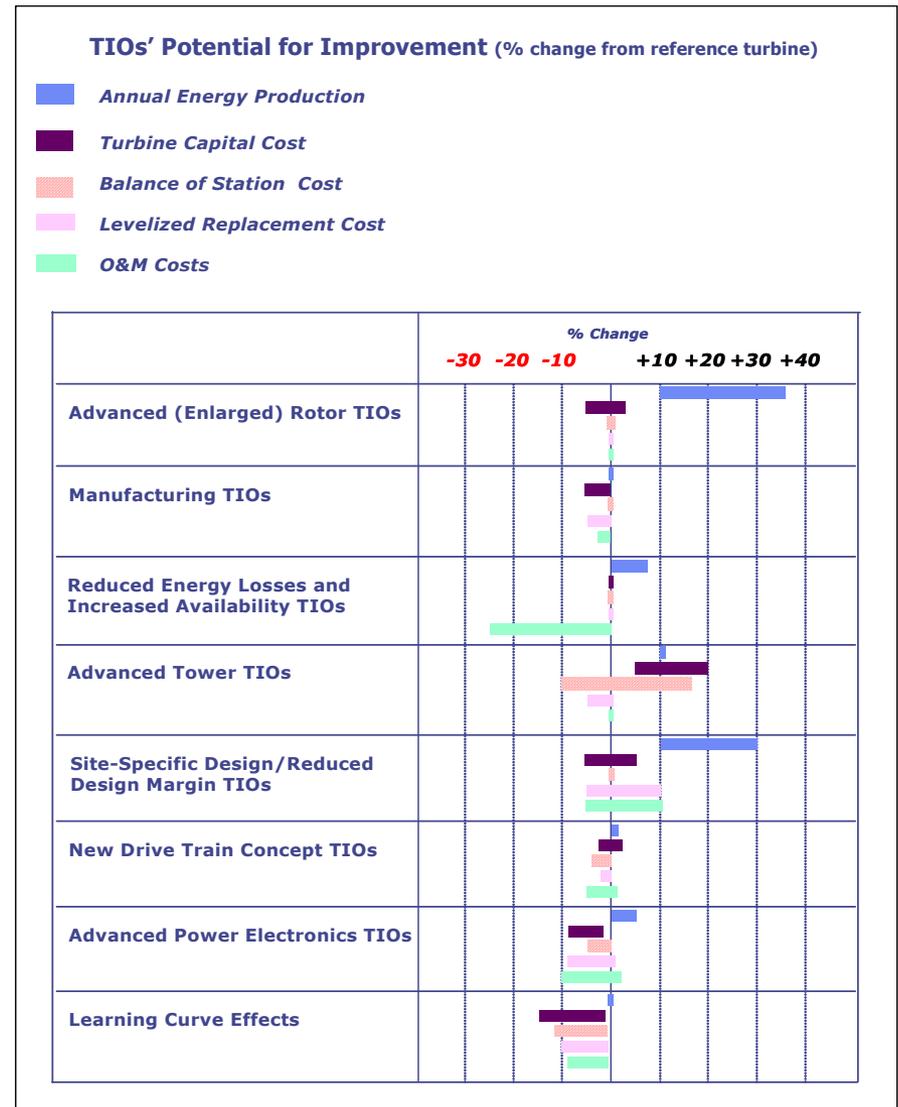


Source: IPCC 2011

- Describe cost reduction potential as a function of cumulative experience related to cumulative installed capacity
- Do not attempt to identify specific factors that yield cost reductions
- Represent learning by research and development (R&D), learning by experience, learning by deployment, learning by doing, and so on.

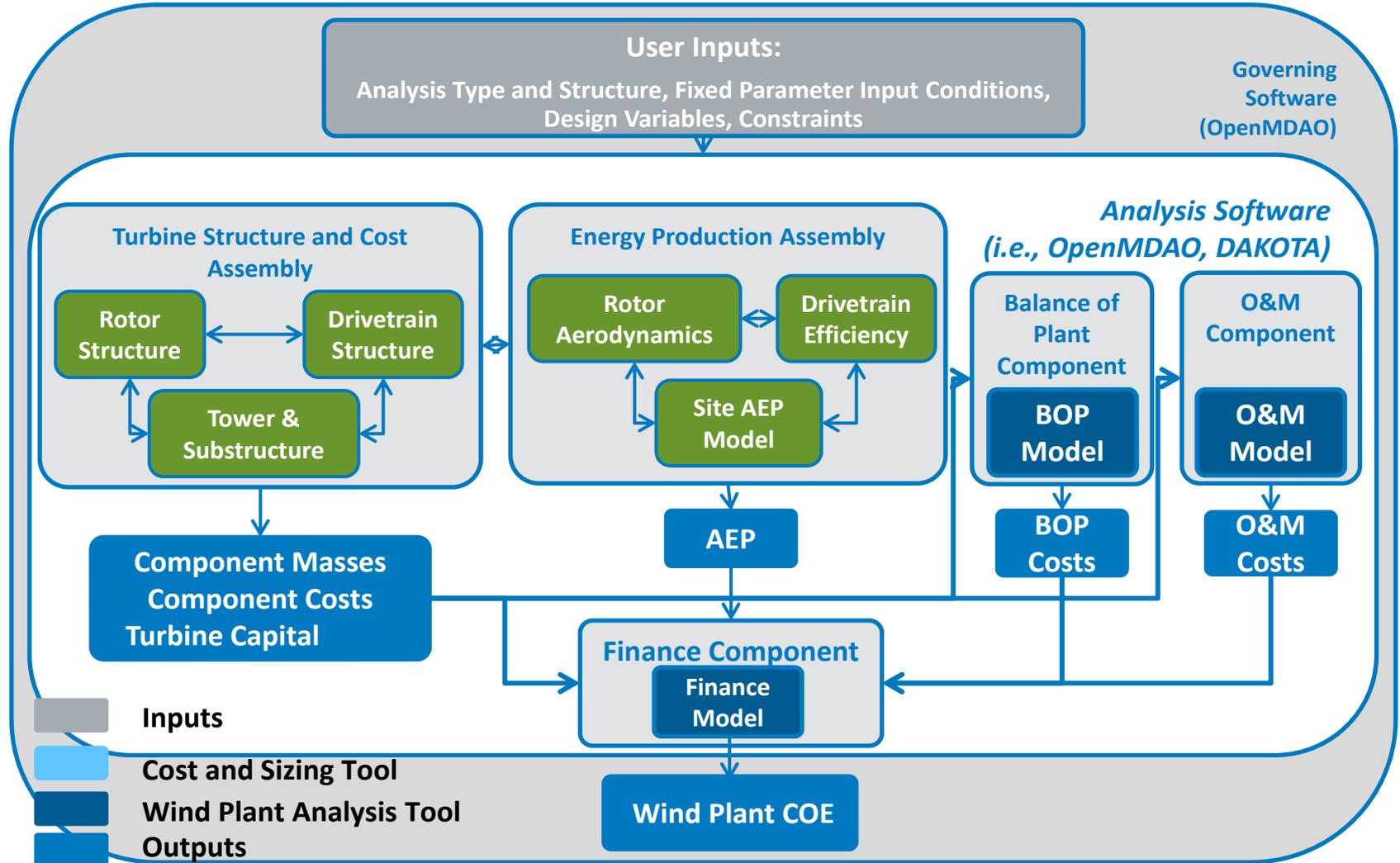
# Expert Elicitation Can Represent Deep Knowledge and Experience but Is Difficult to Translate Into LCOE

- Survey industry experts for a range of possible technology outcomes to achieve future cost reductions
- Develop probability distributions associated with various technical outcomes to represent the likelihood of successful innovations
- Difficult to capture interactions between component innovations that impact system LCOE.



Source: Cohen et al. 2008

# Engineering-Based Modeling and Analysis Can Capture Interactions Between Components to Quantify the Impact of Specific Technology Innovations on LCOE at the System Level



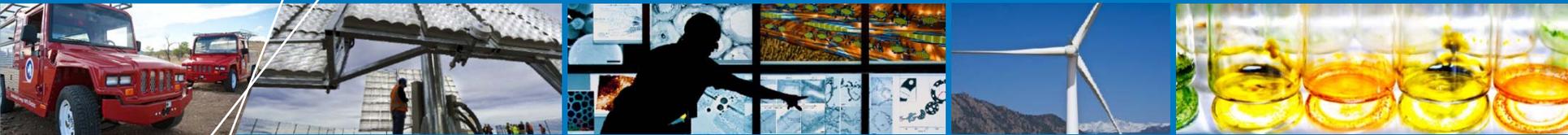
Source: NREL

# Conclusions

- **Wind energy LCOE has decreased since the 1980s and is likely to continue this downward trend**
- **Projections for future cost of wind energy with greater precision in magnitude and likelihood will influence electric-sector evolution scenarios**
- **Engineering-based models provide the opportunity to quantify the impact of innovative concepts on wind plant system LCOE.**

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Thank you. For more information...

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