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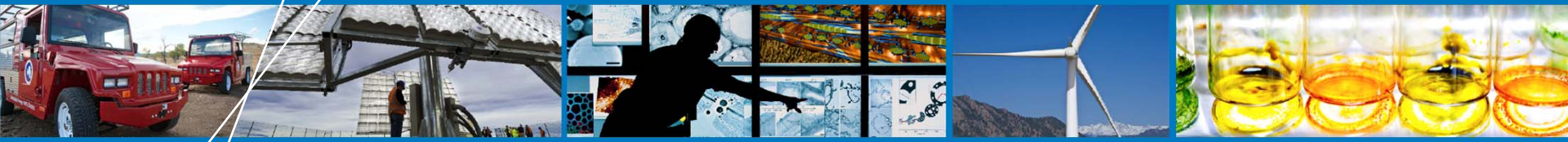
Understanding Wind Power Costs: The Value of a Comprehensive Approach



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Eric Lantz

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Presentation Overview

- Background
- Historical data and limitations
- The value of levelized cost of energy and how it is calculated
- Conclusions

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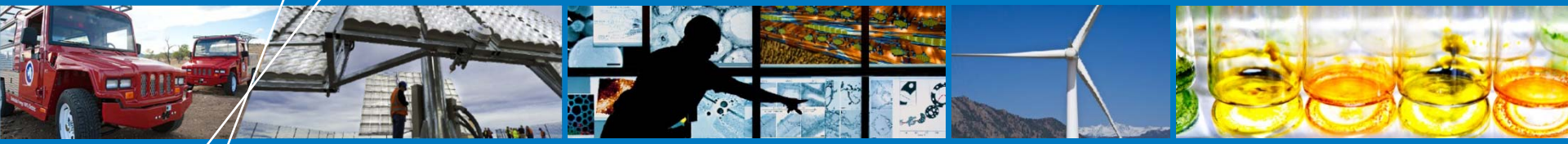

Background

For Much of the History of the Wind Industry, All Measures of Progress Pointed in the Same Direction

- Less-than-perfect industry metrics came to be used inside and outside of the industry
- But, with more emphasis on optimization and incremental advancement today, prior indicators may fail to tell the full story
- Levelized cost of energy (LCOE) offers a means to capture the array of critical variables in a transparent and consistent way that provides greater industry insights

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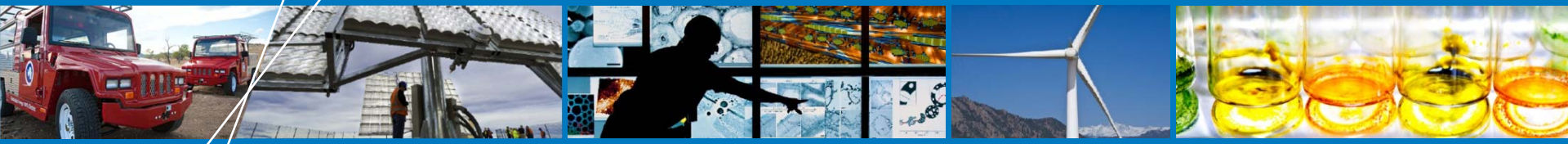
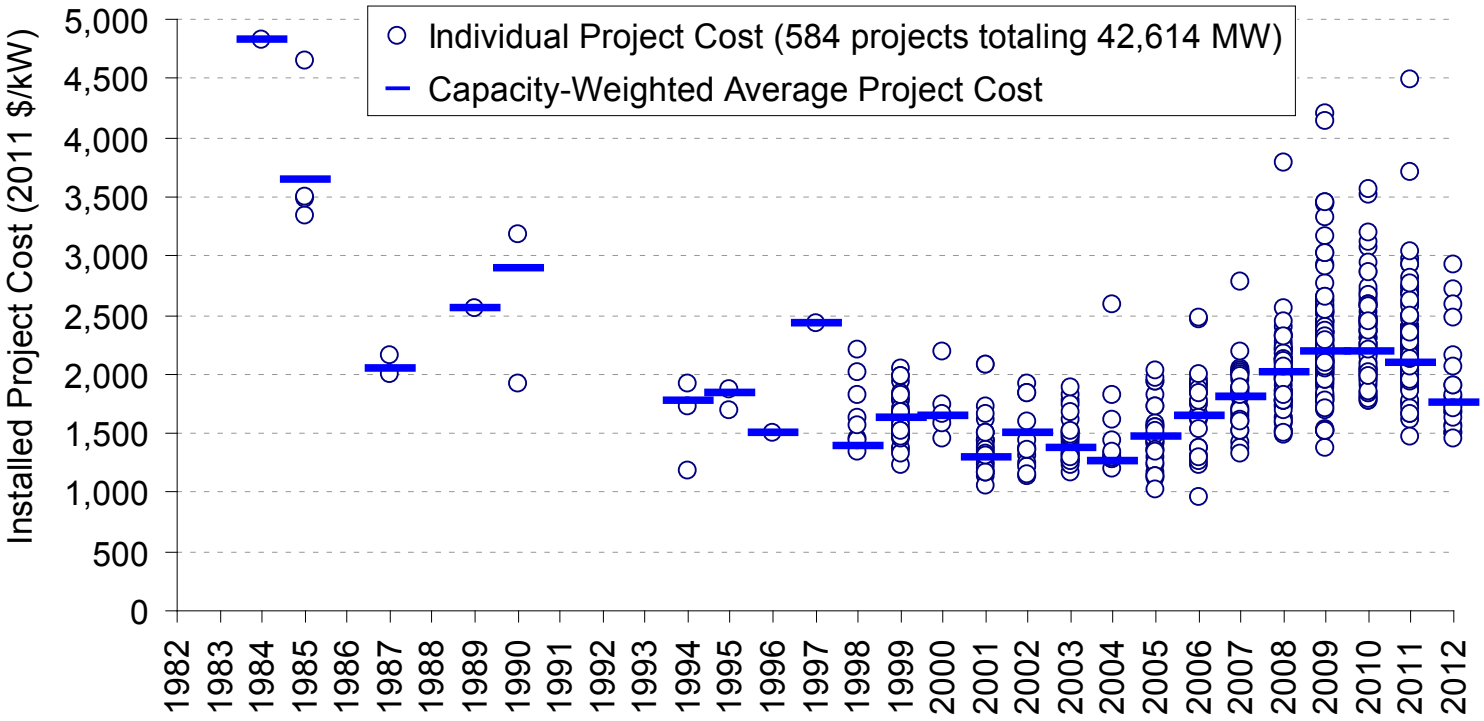


Historical Data and Limitations

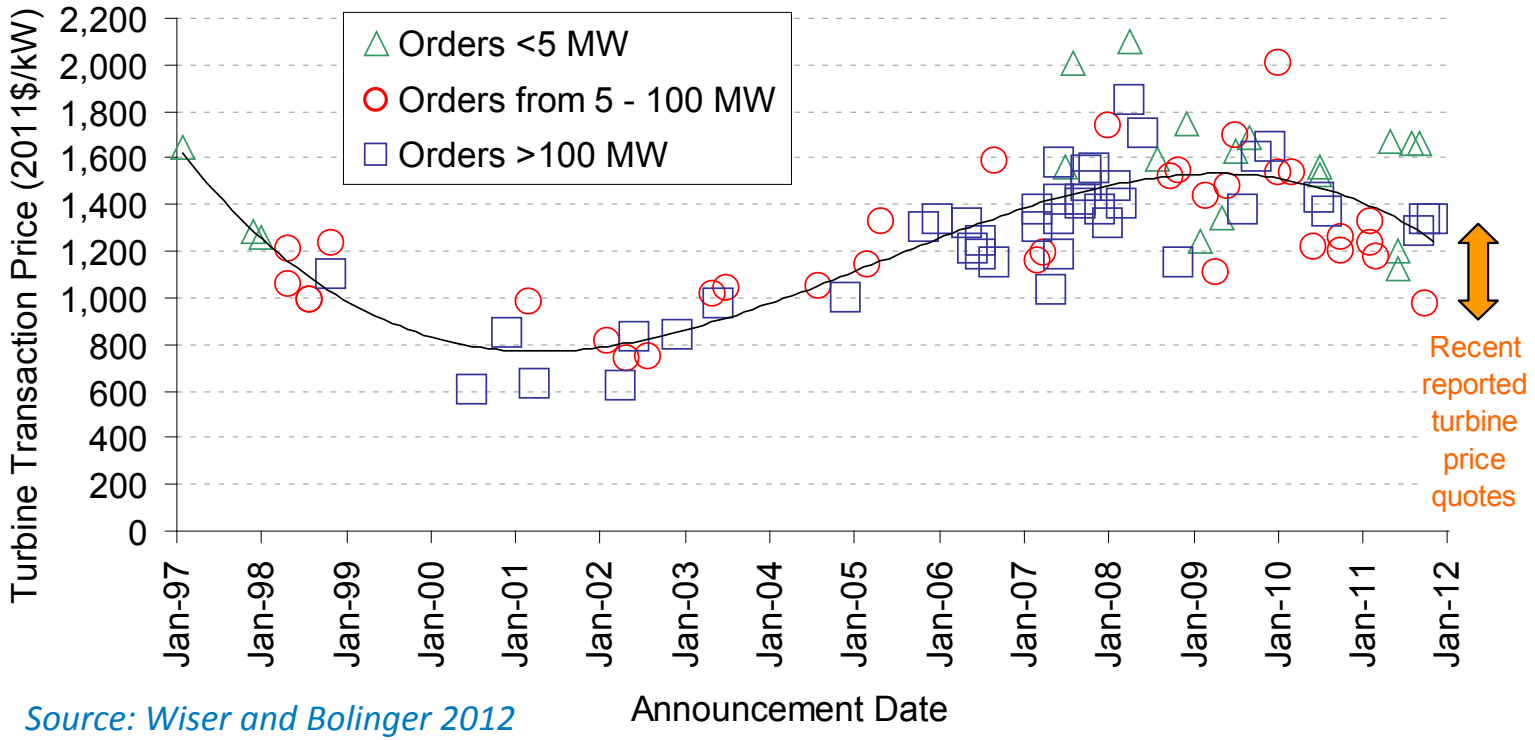
Capital Cost is a Very Common Metric for Characterizing Industry Progress



Source: Wiser and Bolinger 2012

- These data are relatively accessible and clearly illustrate trends in hardware and installation costs
- Throughout the 1980s and 1990s, capital cost declined substantially
- Over the last 5-7 years, the story has become more complex—input prices increased and, at the same time, technology underwent a shift to greater productivity resulting from larger rotors and taller towers

Along With Capital Cost Data, Turbine Price Data Can Be an Indicator of Installation Costs

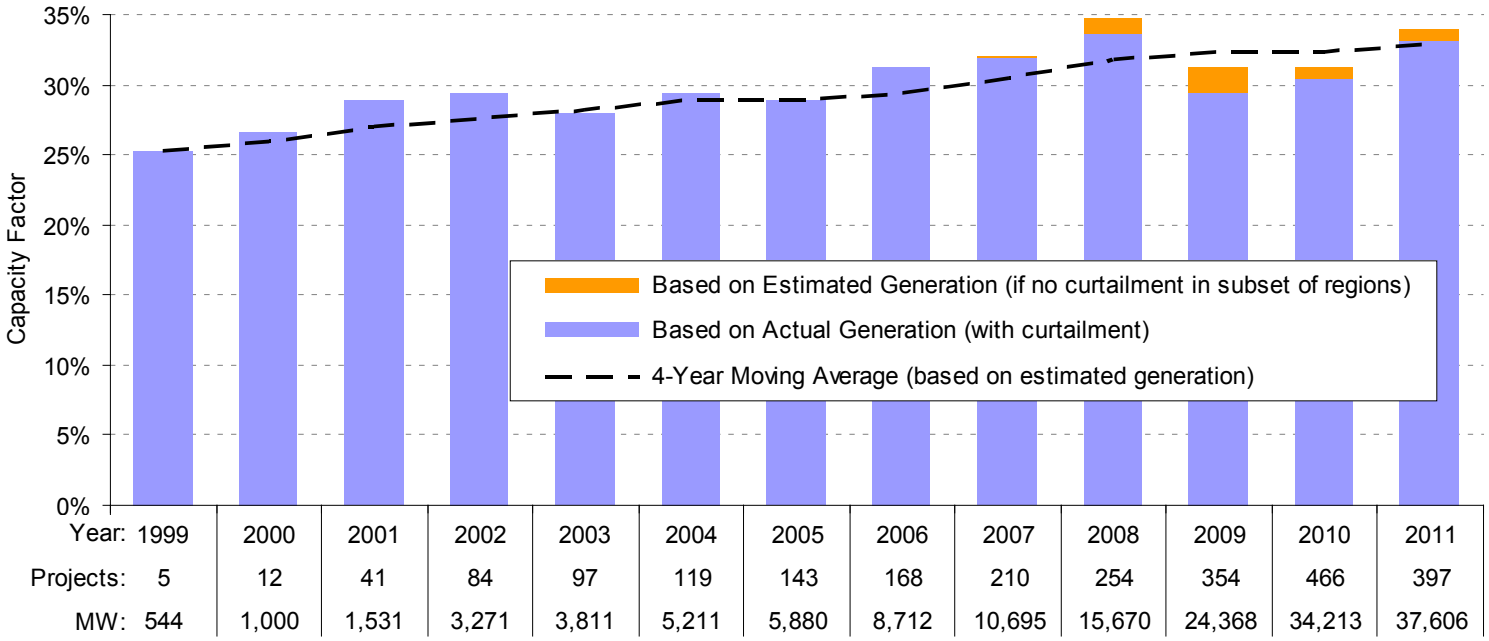


Source: Wiser and Bolinger 2012

- Turbine price data offer a real-time perspective on hardware costs, which are typically 65% to 75% of installed costs
- However, the lag time between execution of turbine supply agreements and a project's commercial operation date complicates one's ability to reliably use turbine pricing as an indicator of project costs
- Turbine price data may not fully reflect technological innovations that allow for increased productivity at a given turbine price

In Some Instances, Analysts Will Use Capacity Factors to Supplement Capital Cost or Turbine Price Data

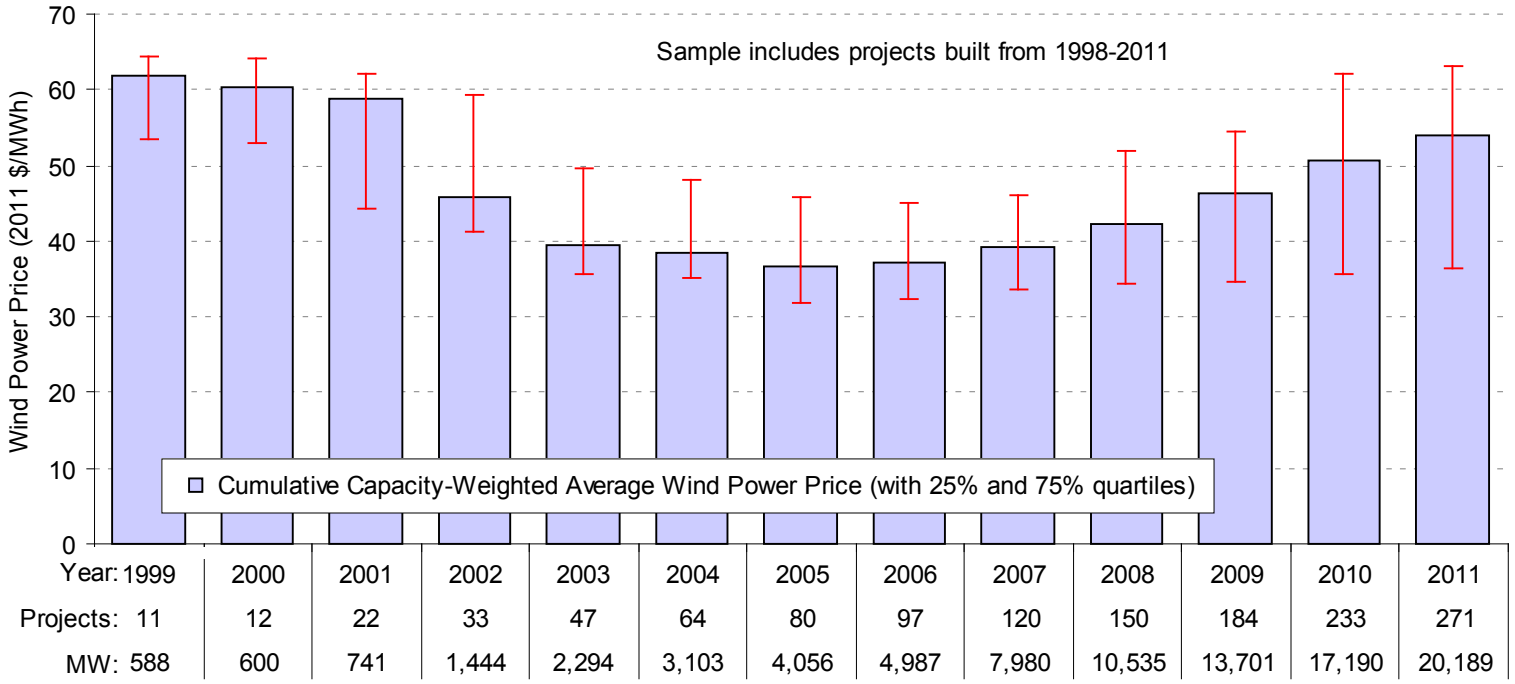
- These data are also relatively accessible and give a sense of industry performance trends
- U.S. fleet-wide data suggest that improvements on the order of 20% to 40% (e.g., 25% NCF to 35% NCF) have occurred since the early 2000s
- At the same time, the data appear contradictory. For example:
  - In Spain, capacity factors have been declining since 2000
  - U.S. gains appear most dramatic from 1999 to 2002, with only marginal periodic gains occurring since the mid-2000s



Source: Wiser and Bolinger 2012

Analysis of Power Market Transactions Provides an Additional Layer of Insights

- Actual market-based payments for wind-generated electricity can sometimes be a good proxy for wind power costs
- Such data may not reflect all revenue streams (e.g., the production tax credit and state tax incentives) and shed little insight on what factors determine market prices (e.g., wind resource, capital costs, turbine performance, and financing parameters) or if payments even result in profitability



Source: Wiser and Bolinger 2012

No Single Metric Tells the Complete Story

- **Capital cost (and turbine price) data fail to explain exogenous industry cost drivers (input prices or exchange rates) as well as improvements in performance**

- **Capacity factor data are subject to year-on-year wind resource variability and don't show megawatt-hours (MWh) per dollar invested or potential changes in the quality of the wind resource where a project is located**
  - Capacity factor is also limited, at least in part, by the possibility of energy losses at the top end of the power curve that result from lower cut-out speeds

- **Market transaction data do not necessarily reflect a full accounting of industry costs and say very little about cost drivers, including the wind regimes where projects are sited**

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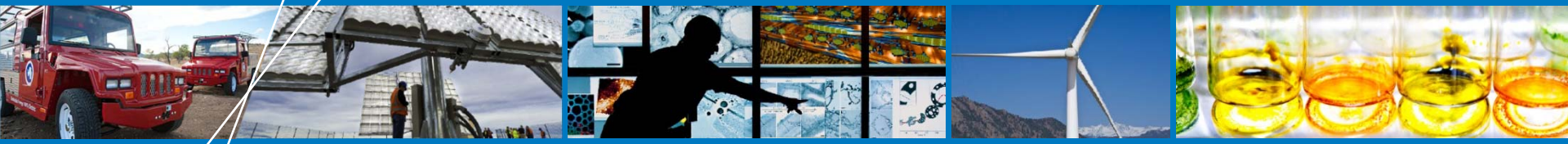


The LCOE Solution

LCOE Applies a Relatively Comprehensive Approach to Resolve Most of These Issues

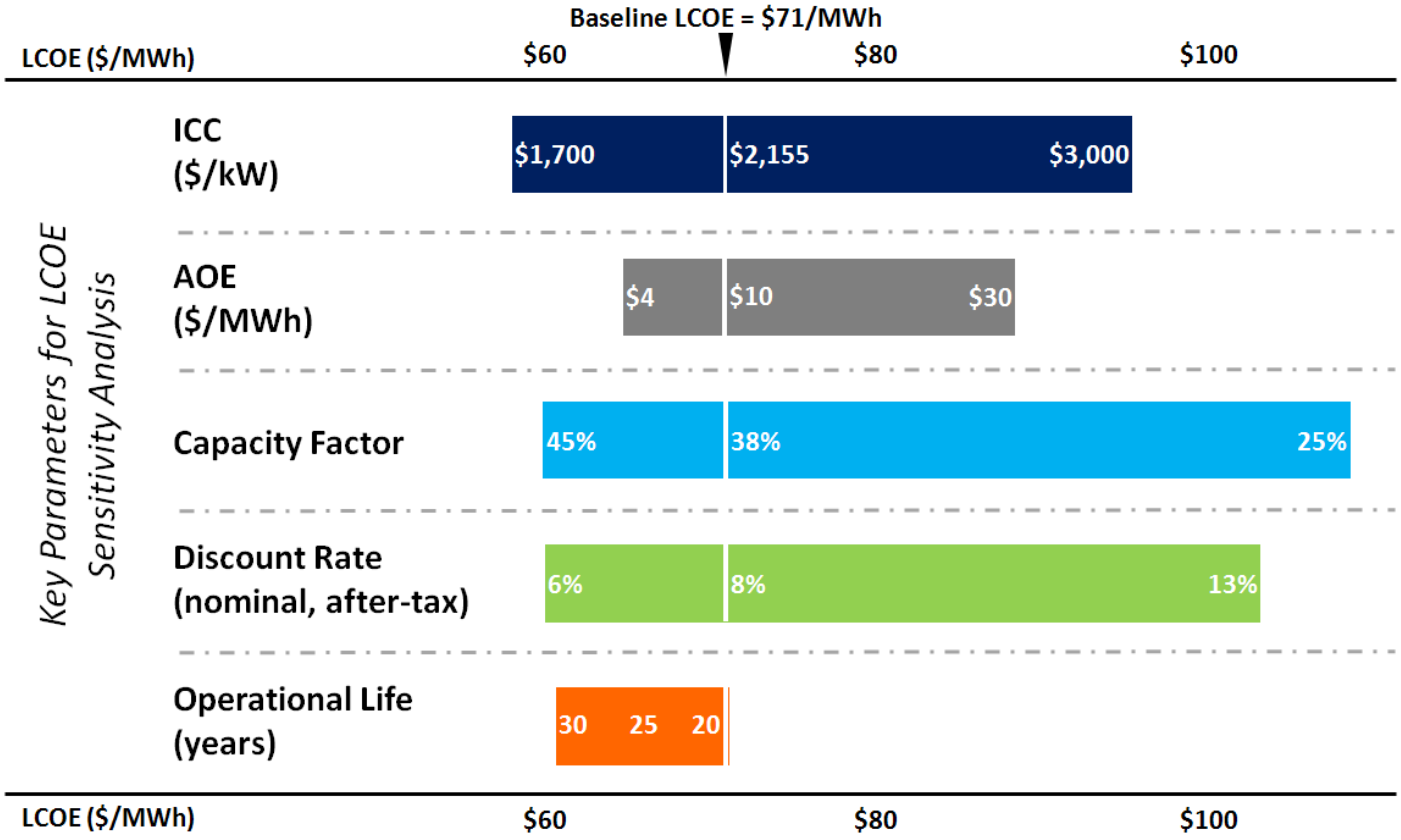
- **At its most basic level:** $$\text{LCOE} = \frac{\text{PV Lifetime costs}}{\text{Lifetime Energy Production}}$$
- **At a slightly more detailed level, LCOE is comprised of four key elements:**
  - Installed Capital Cost (ICC)
  - Net Annual Energy Production (AEP_{net})
  - Annual Operations Expenses (AOE)
    - Operation and maintenance + insurance, land lease payments, other costs
  - Fixed Charge Rate
    - Cost of financing
    - Assumed plant life
- **The relationship among these variables is summarized as:**

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

LCOE helps provide a greater understanding of the impact of changes in a given variable and is a better reflection of changes in wind power costs than any other independent metric

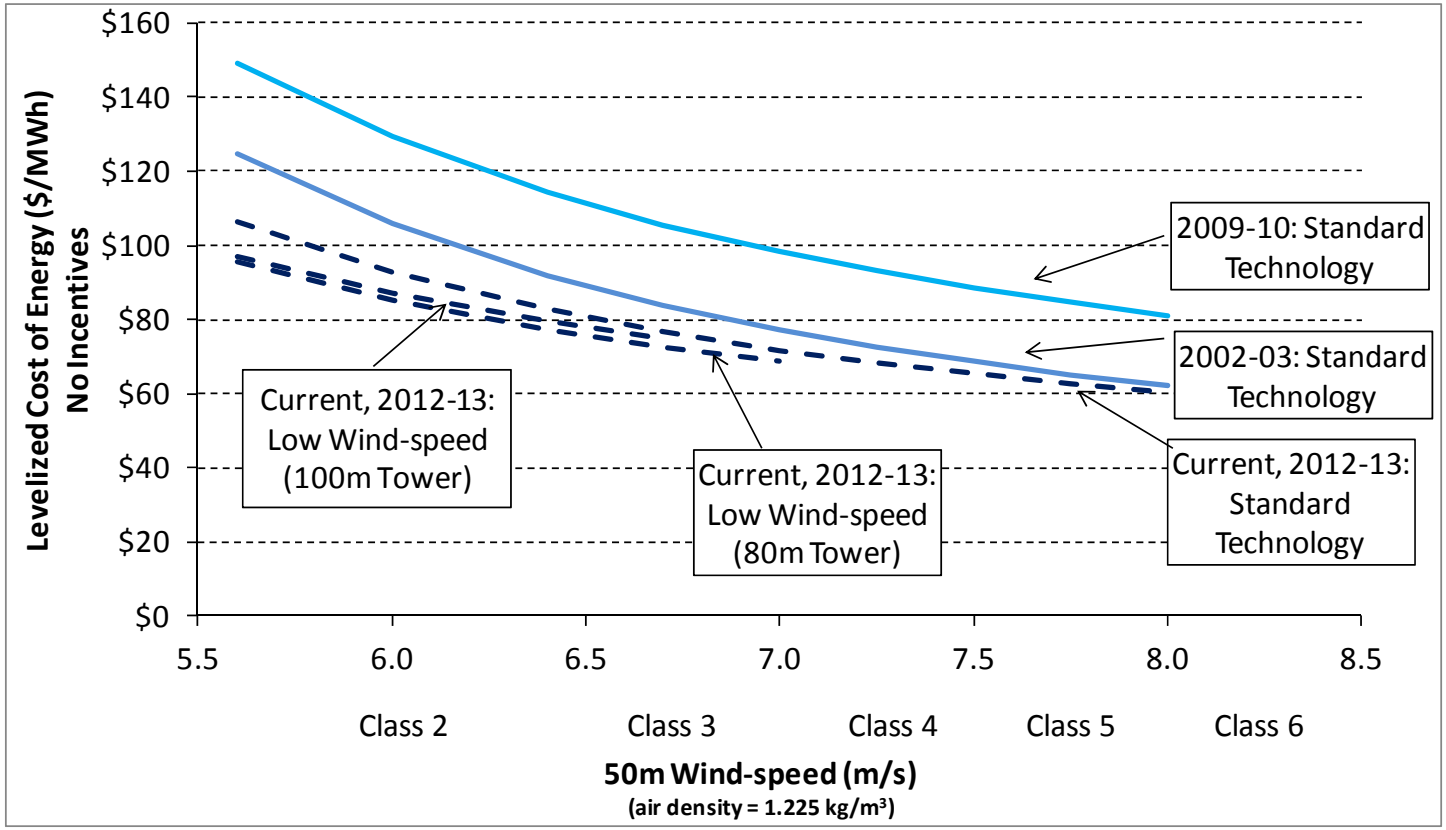
The LCOE Approach Also Offers Insights into the Sensitivity of Costs to Changes in Project Parameters

Capital cost and capacity factor are two of the most critical drivers, but others are also important



Source: Tegen et al. 2012

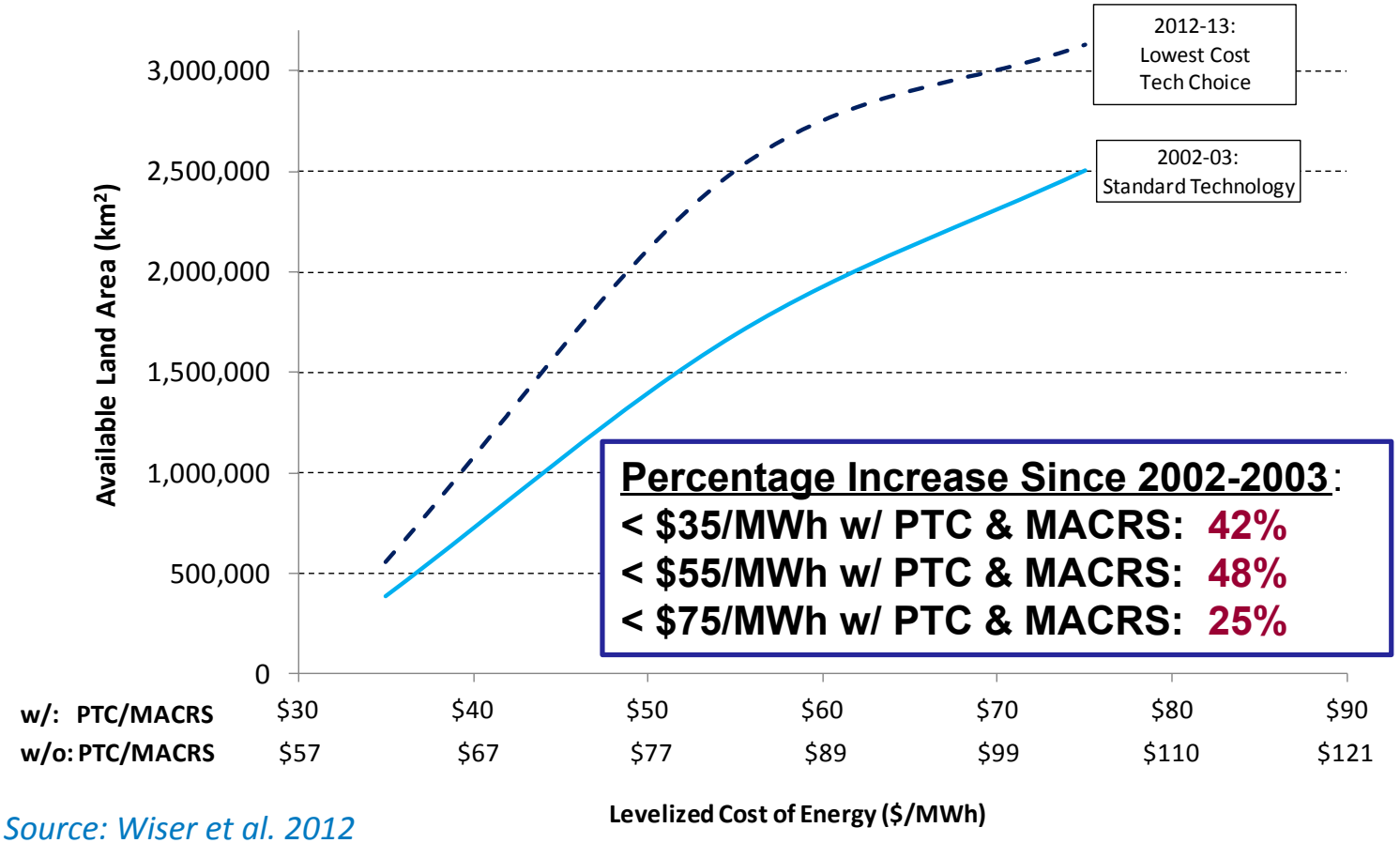
LCOE Offers an Enhanced Ability to Analyze Real-World Tradeoffs



Source: Wiser et al. 2012

Recent technological innovations demonstrate that higher capital costs may be merited at lower wind speed sites when the performance gains achieved by using a larger rotor or taller tower offset the incremental cost resulting from increased material use and more difficult logistics

Linking LCOE to Representative Technology and Wind Resource Data Allows for Further Industry Insights



Source: Wiser et al. 2012

The more nuanced perspective offered by detailed LCOE analysis provides the ability to apply specific technology cost and performance data to understand how new regional markets might be opened by technological advancements

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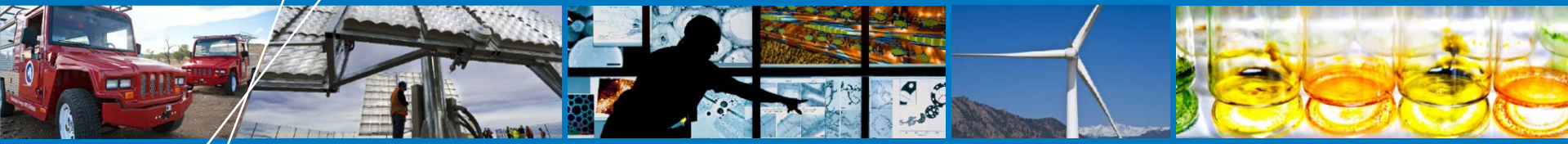

Conclusions

Conclusions

- **In an era that emphasizes turbine and plant optimization, industry metrics such as capital cost may be less indicative of future technological gains**

- **LCOE offers more nuanced market insights and increased transparency relative to any individual metric**
  - It also requires more data and a detailed understanding of industry trends

- **In the absence of a widespread shift to LCOE, it may be increasingly difficult to communicate the recent achievements of the industry as well as the future possibilities**

Thank You

Eric Lantz
Research Analyst
Strategic Energy Analysis Center
National Renewable Energy Laboratory
http://www.nrel.gov/analysis/
http://www.windpoweringamerica.gov/

Phone: (303) 384-7418
email: Eric.Lantz@nrel.gov

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