Is Class 2 the new Class 5?

Recent Evolution in Wind Power Technology and Implications for Community Wind

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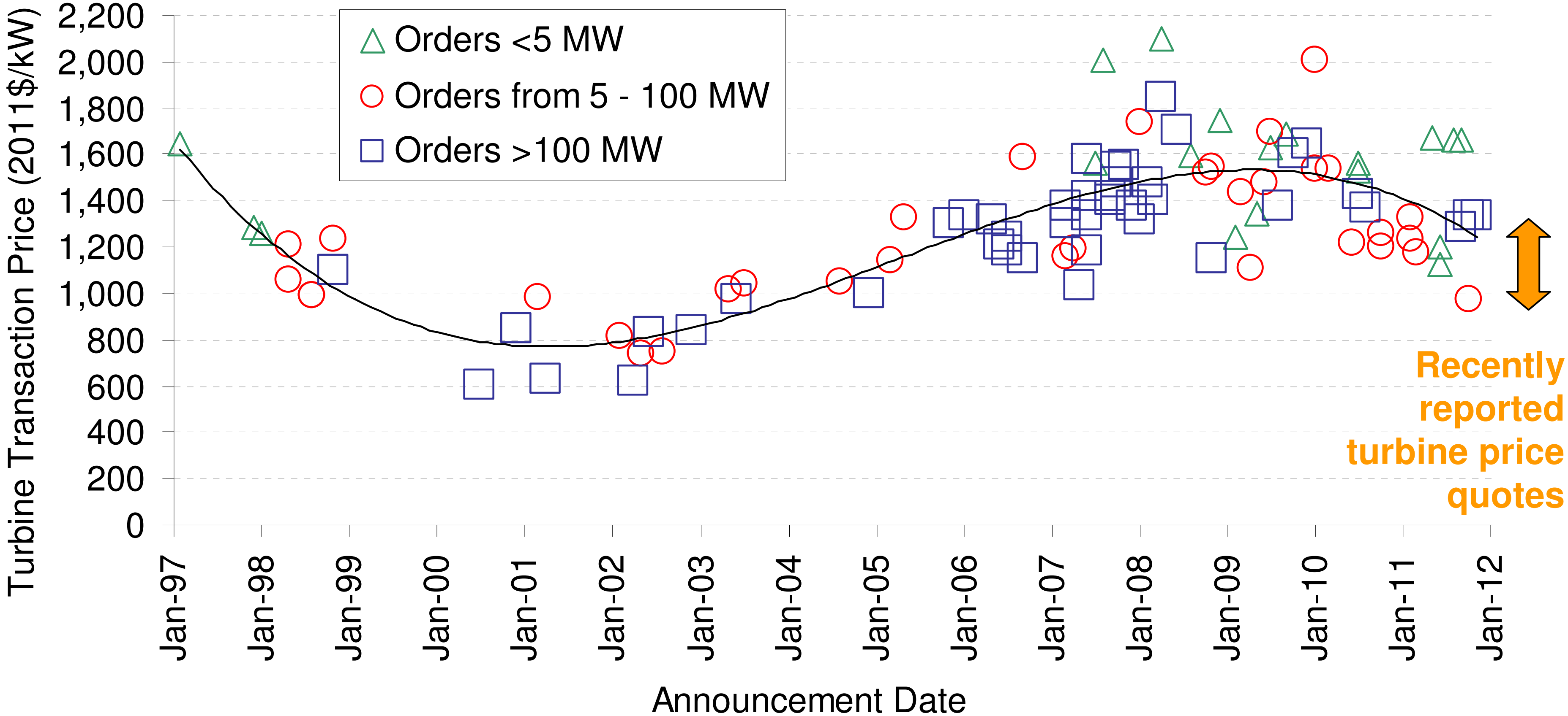
Presentation Overview

1) **Empirical Data (nationwide)**
   - Trends in turbine and project costs, turbine parameters, capacity factors, and power sales (PPA) prices

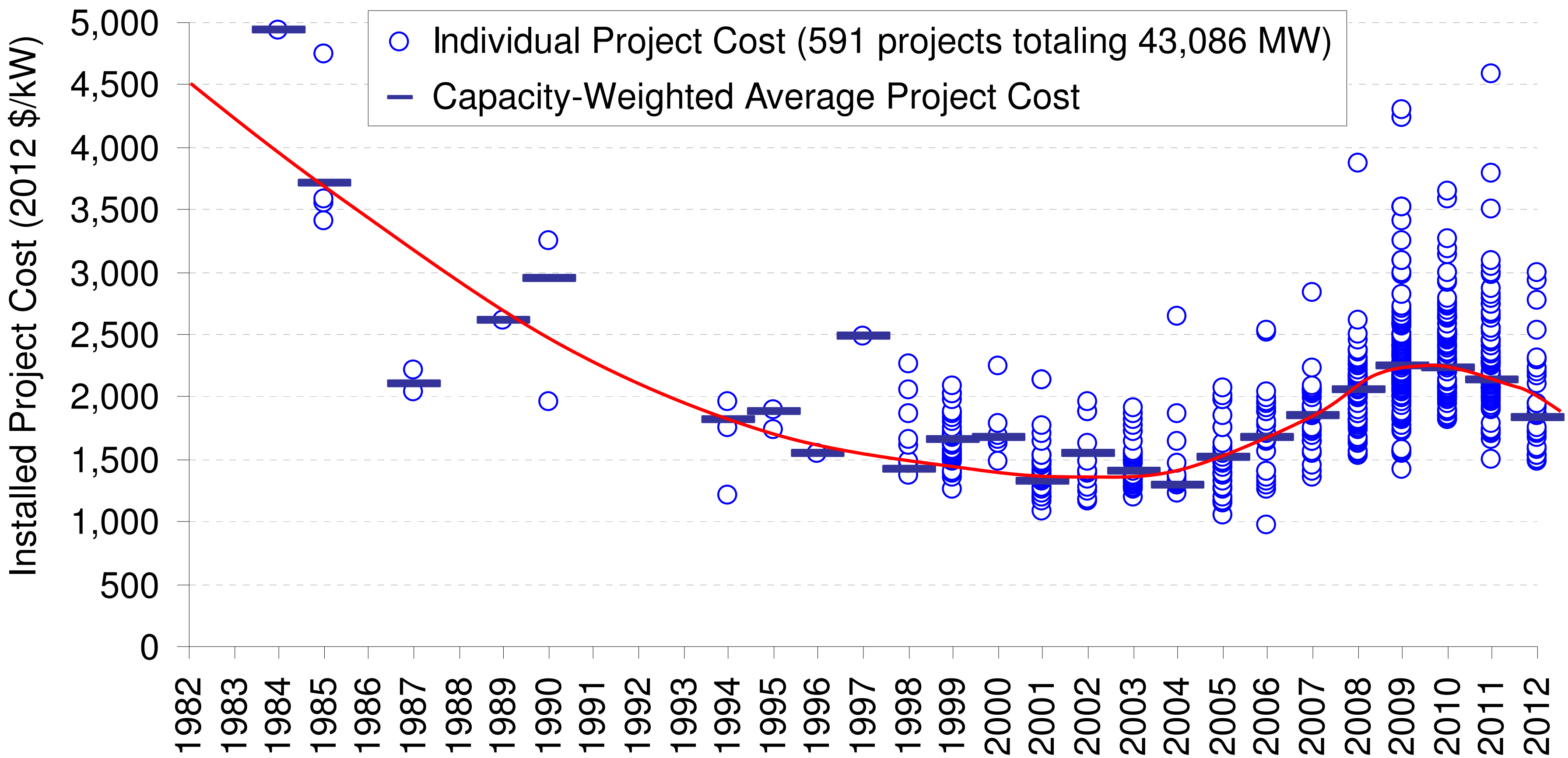
2) **LBNL/NREL Modeling Analysis (nationwide)**
   - Trends in capacity factor and levelized cost of energy (LCOE)

Wind Turbine Prices Have Softened Since the Highs of 2008



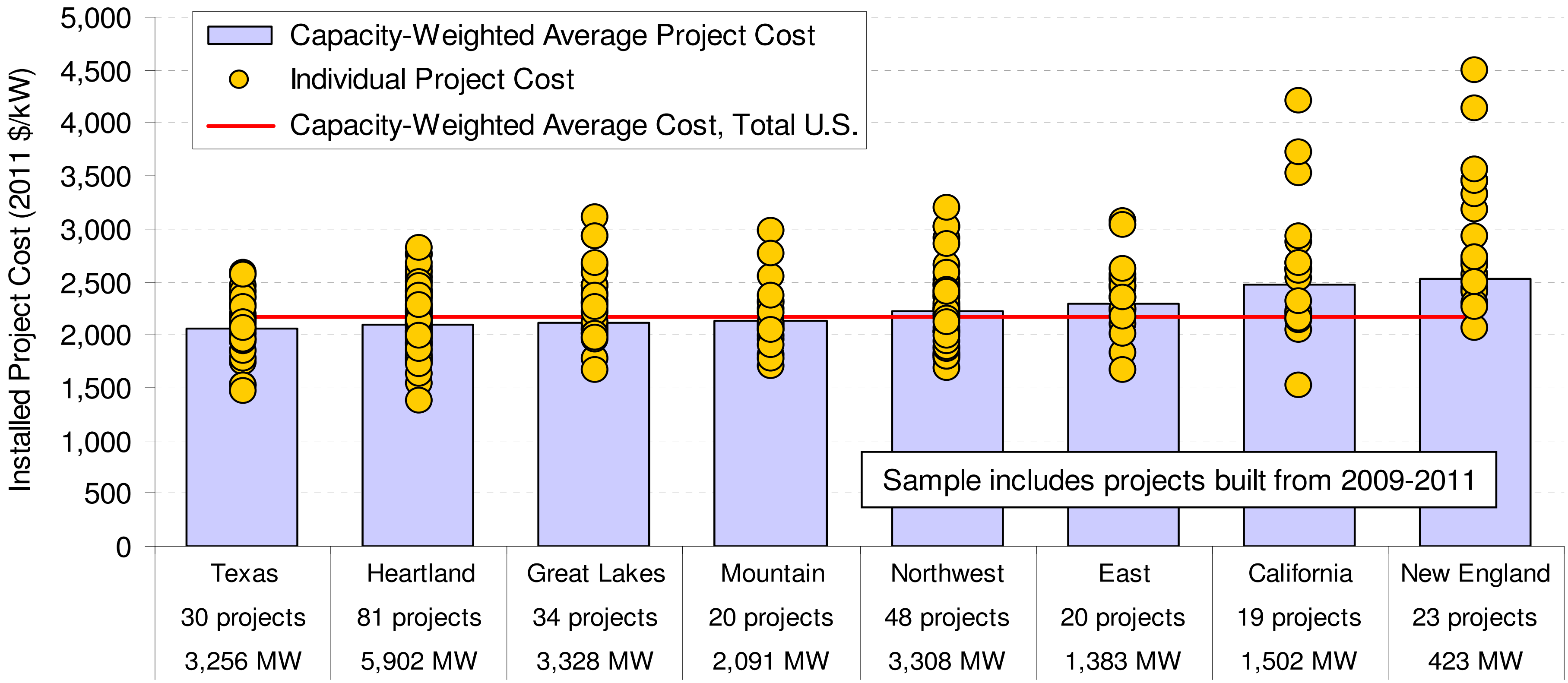
Recent visibility is low, due to dearth of orders for 2013 and beyond

Lower Turbine Pricing Finally Starting To Show Up In *Reported* Installed Project Costs



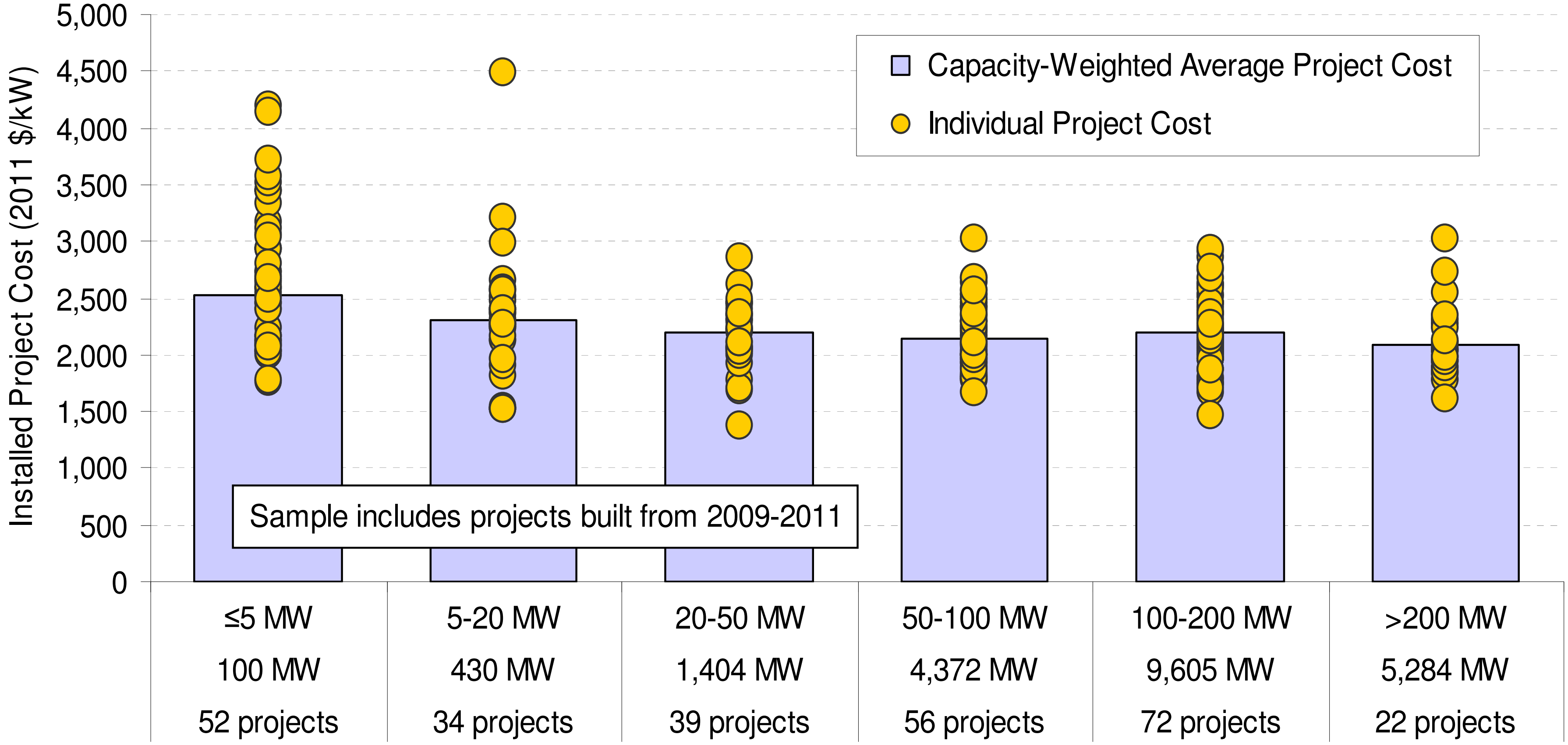
A preliminary sample of ~3 GW of 2012 projects shows estimated installed costs of around $1,830/kW on average

Costs Differ Regionally: Lowest in the Interior, Highest Along the Coasts

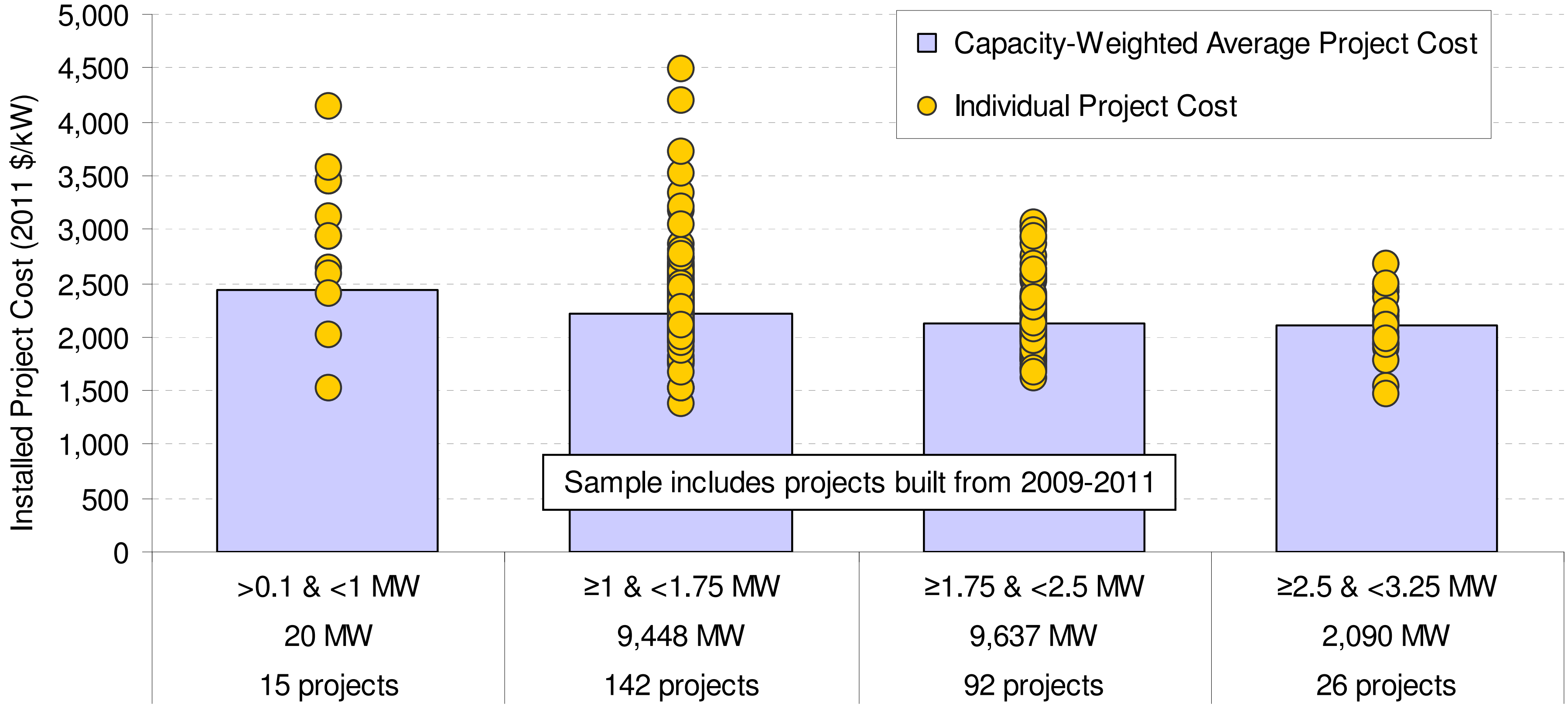


Different permitting/development costs may play a role at both ends of spectrum: it's easier to build in TX and the Heartland and more difficult in New England and CA

Economies of Scale Evident, At Least At Low End of Project Size Range

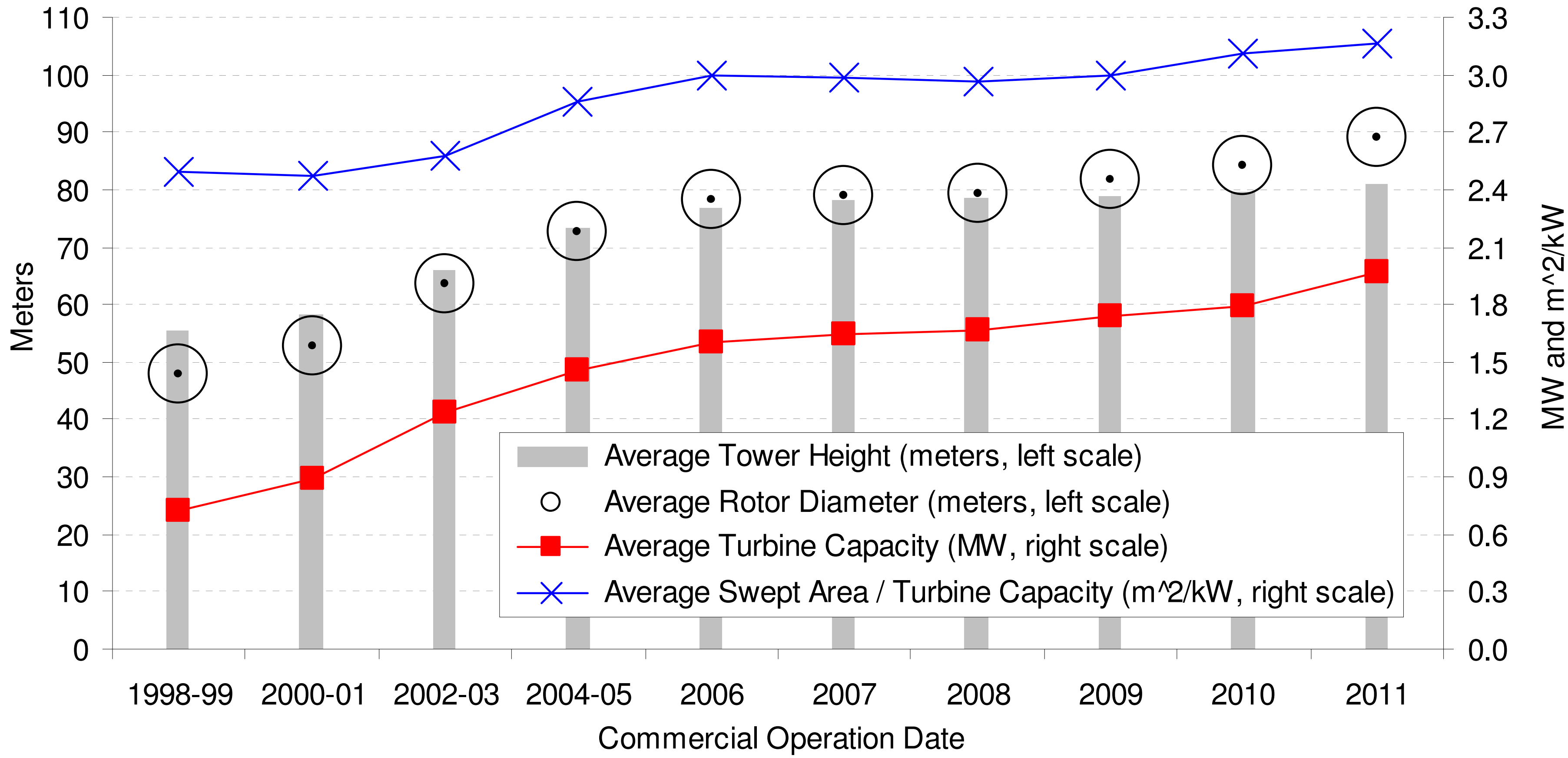


Economies of Scale Also Evident (Though Somewhat Less So) By Turbine Size



Theory: A project may be built less-expensively using fewer larger turbines instead of a larger number of smaller turbines

Physical Characteristics of U.S. Turbine Fleet: Significant Turbine Scaling Over Time



- Two periods of rapid scaling: 1998-2006 and 2010-present
- 2007-2009 mostly stagnant, as OEM's focused on meeting demand
- Rotors have grown faster than both towers and turbine capacity

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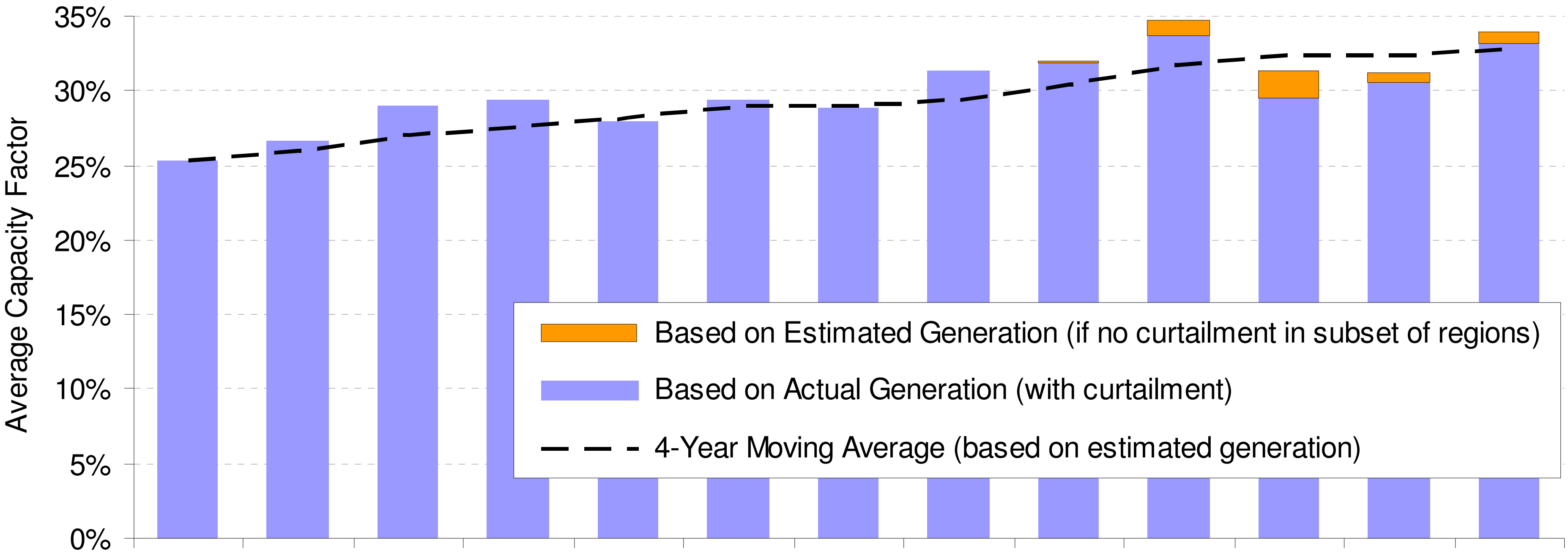
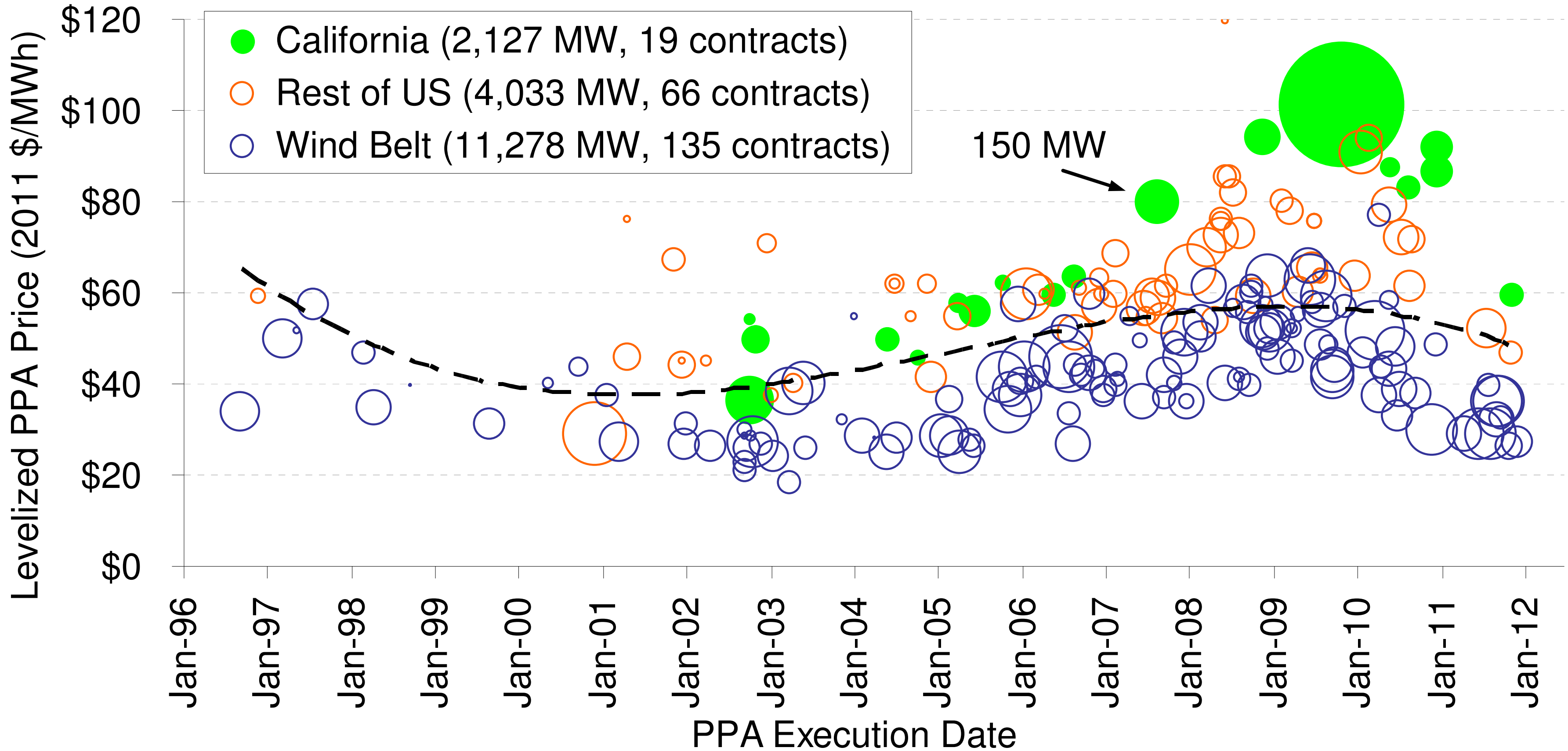
Fleet-Wide Average Capacity Factors Have (Generally) Increased Over Time



Year:	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Projects:	5	12	40	83	96	118	142	167	209	253	353	465	397
MW:	544	1,000	1,519	3,259	3,800	5,200	5,868	8,700	10,684	15,658	24,356	34,201	37,606

Capacity factor increase is less than what might be expected based on turbine scaling and other design improvements

Lower Costs and Better Capacity Factors Enable More Aggressive PPA Pricing



The “Wind Belt” includes 13 interior U.S. states with excellent wind resources (NM, CO, WY, MT, ND, SD, NE, KS, OK, TX, MO, IA, MN), and is a crude attempt to control for average wind speed (to better isolate the time trend)

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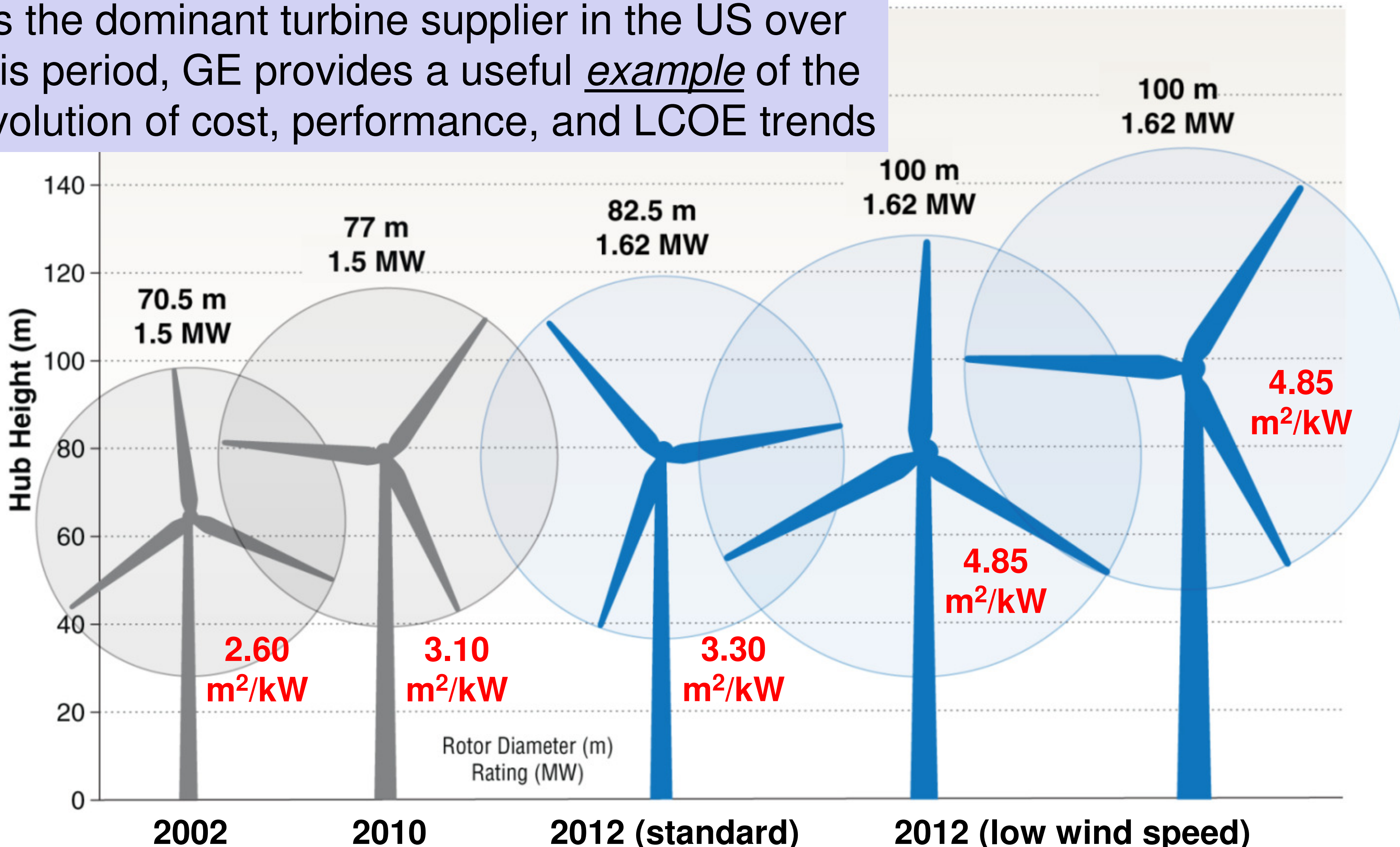
Modeling Approach: Focus On the Evolution of GE's 1.5 MW Platform

As the dominant turbine supplier in the US over this period, GE provides a useful *example* of the evolution of cost, performance, and LCOE trends



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Summary of Input Assumptions

Only Turbine Parameters, Power Curves, and Installed Costs Change

Inputs	2002	2010	2012		
Technology type	Standard	Standard	Standard	Low Wind	Low Wind
Nameplate capacity	1.5 MW	1.5 MW	1.62 MW	1.62 MW	1.62 MW
Hub height (hh)	65 m	80 m	80 m	80 m	100 m
Rotor diameter (rd)	70.5 m	77 m	82.5 m	100 m	100 m
Installed capital cost	$1,300/kW	$2,150/kW	$1,600/kW	$1,850/kW	$2,025/kW
Operating costs	← $60/kW-yr →				
Losses (availability, array)	← 15% →				
Financing (nominal)	← 9% →				

- Dollar values are all real 2010$
- Financing cost / discount rate reported in nominal terms
- Air density = 1.225 kg/m^3 (sea level wind speed)
- Weibul K Factor = 2 in all scenarios
- 1/7th power law scaling to estimate hub height wind speed
- 20-year assumed project/economic life in all scenarios
- Aggregate income taxes assumed to equal 38.9%

Note: All assumptions are intended to represent "standard" project conditions, but obviously inputs can and do vary considerably from one project to the next.

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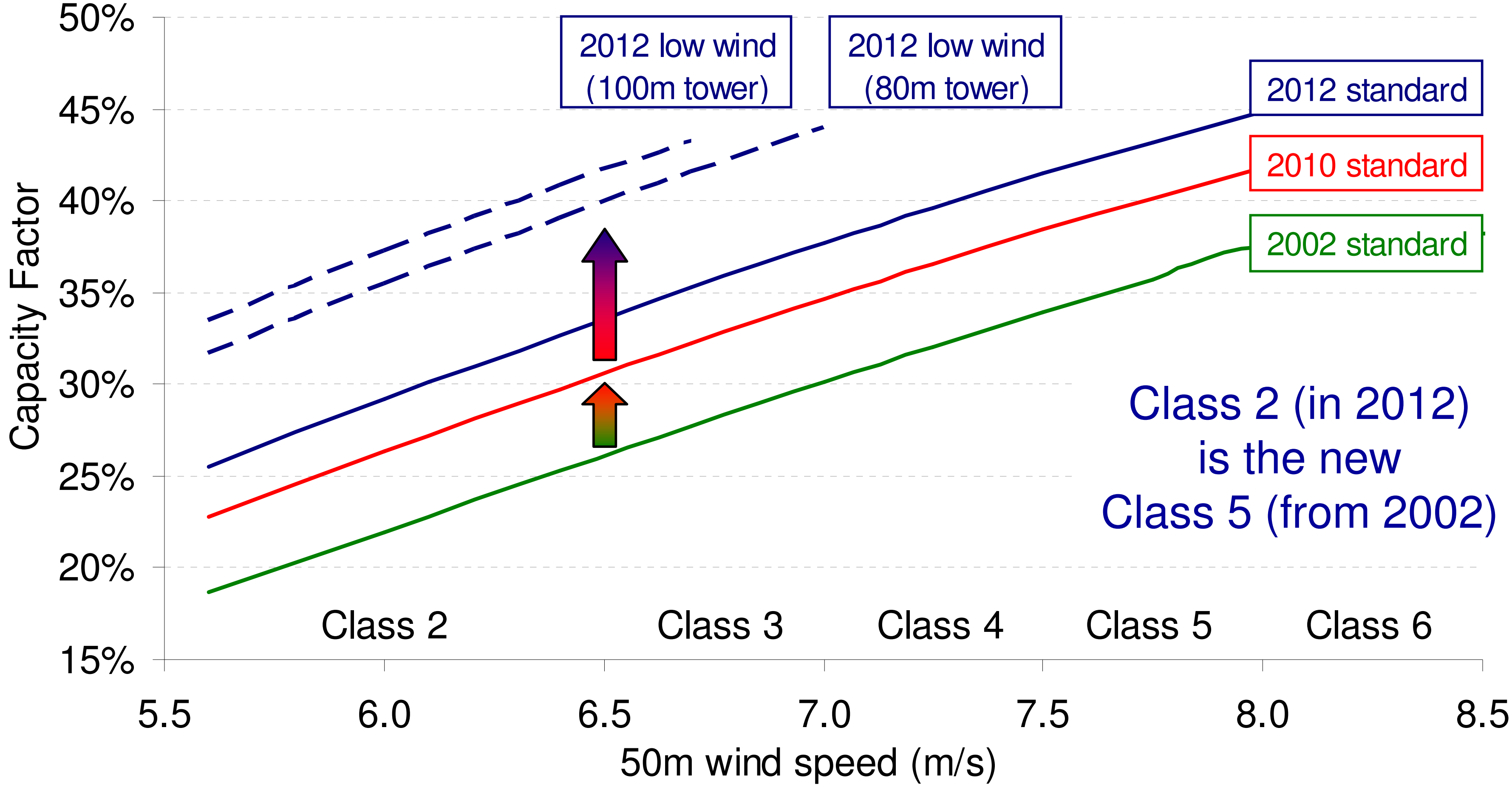
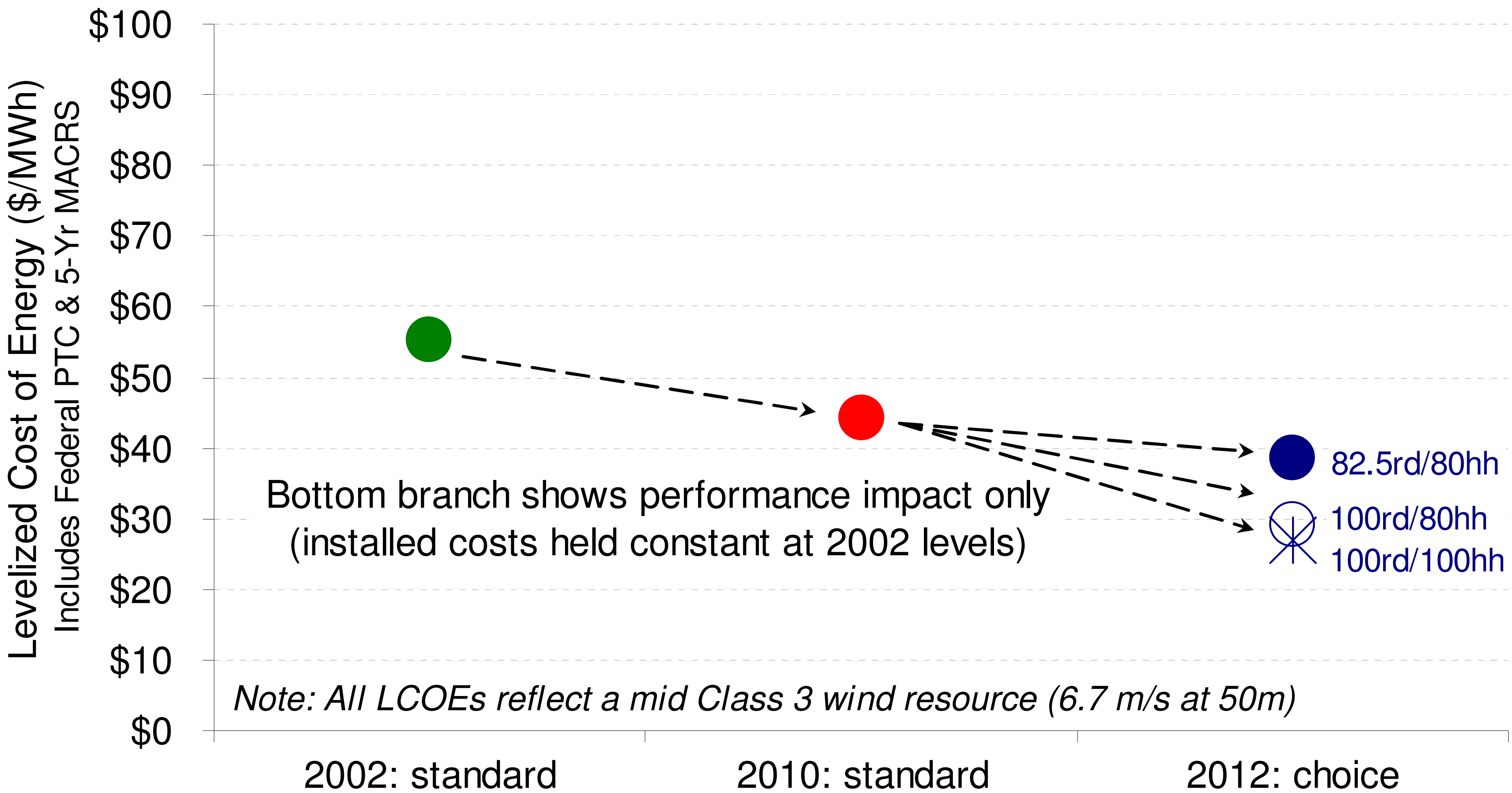
Turbine Design Improvements Lead To Significant Increase in Capacity Factors

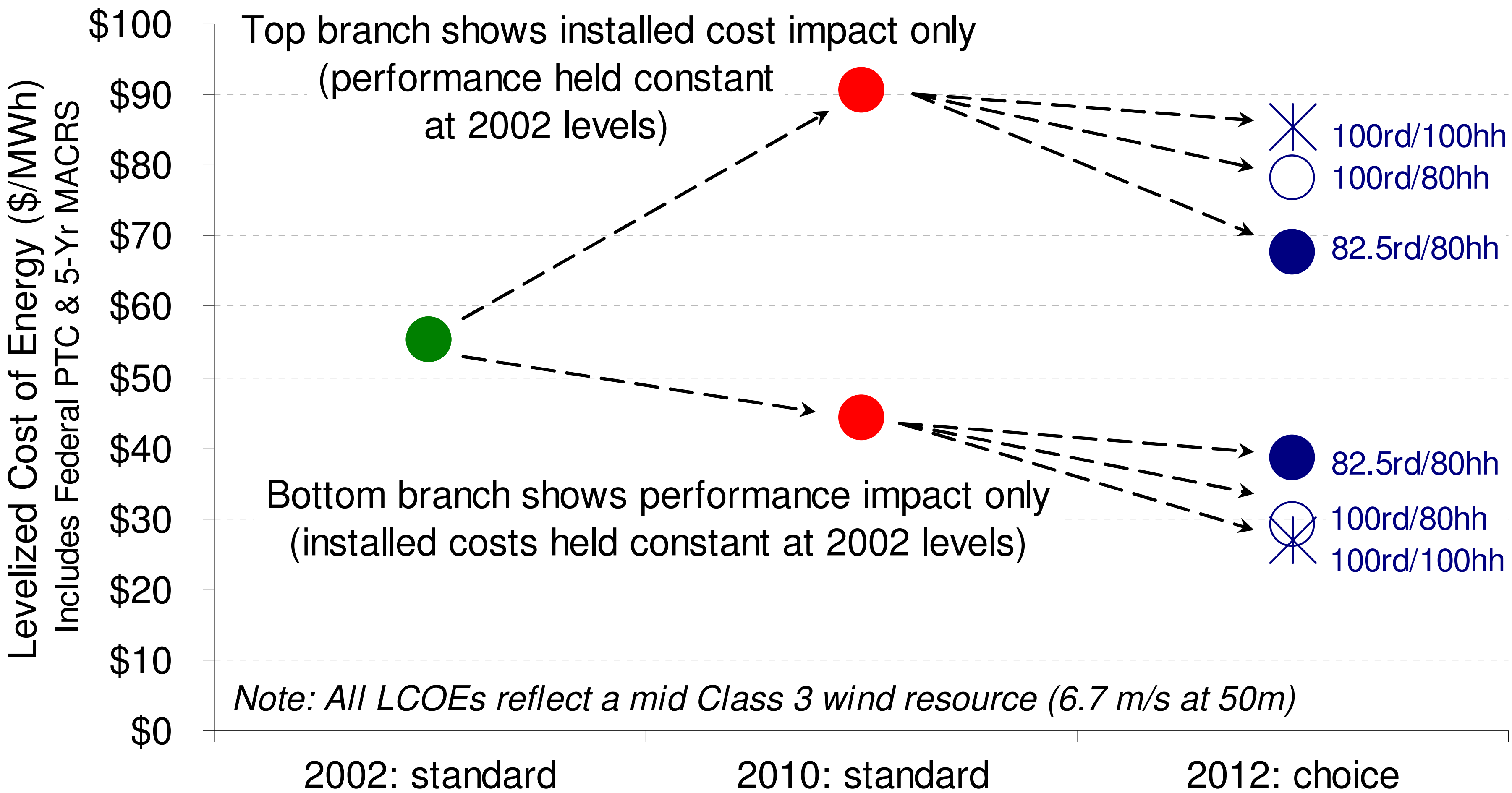


Modeled capacity factor improvement driven by larger rotor swept area in proportion to nameplate capacity, as well as higher hub heights; increase is especially apparent with newest batch of low-wind-speed turbines

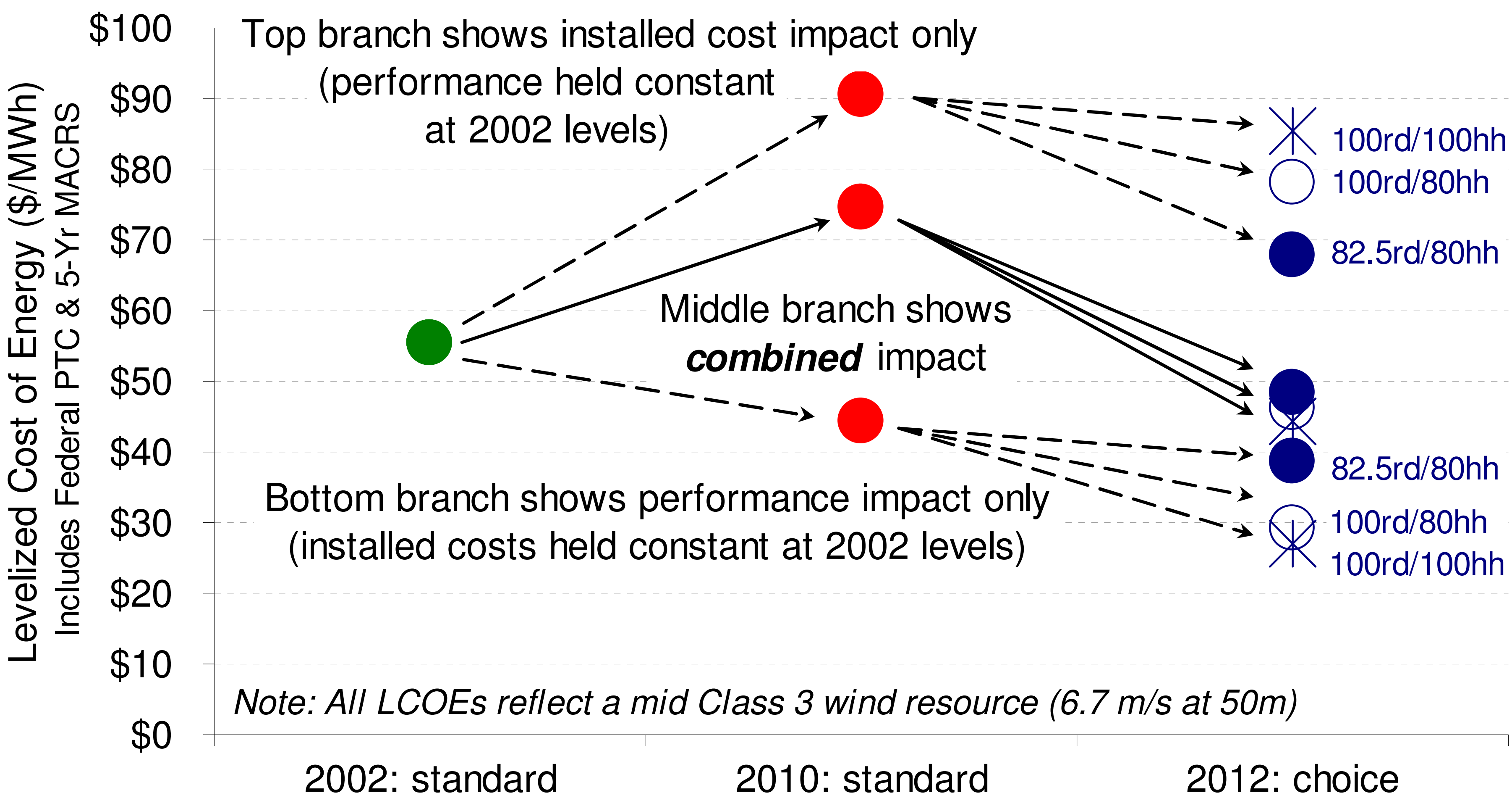
If Not For Higher Costs, Better Performance Would Have Continually Pushed LCOE Lower



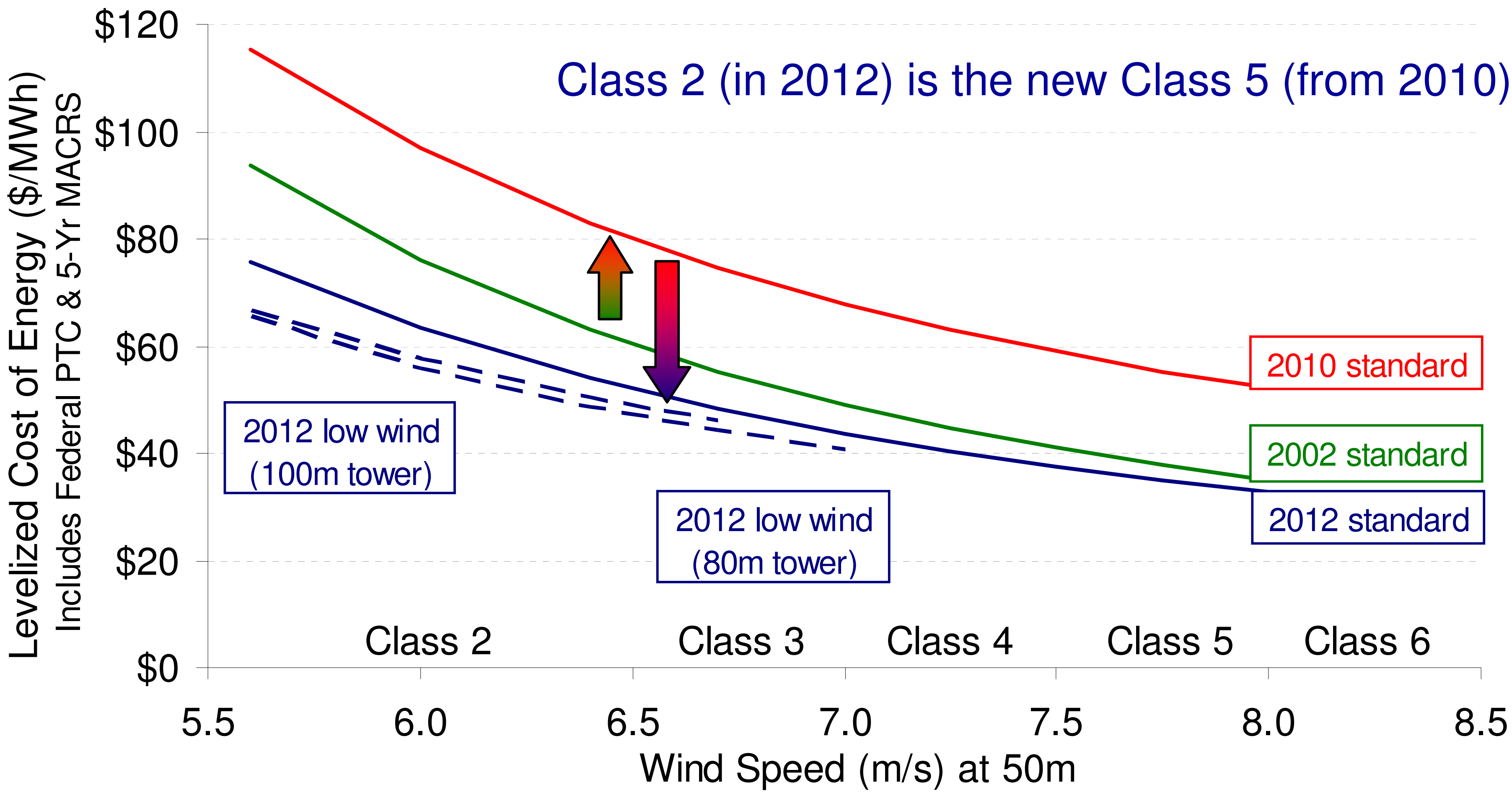
If Not For Better Performance, Higher Costs Would Mean Higher LCOEs Than In 2002



Accounting for Both Higher Costs *and* Better Performance, LCOE Is Now Less Than In 2002

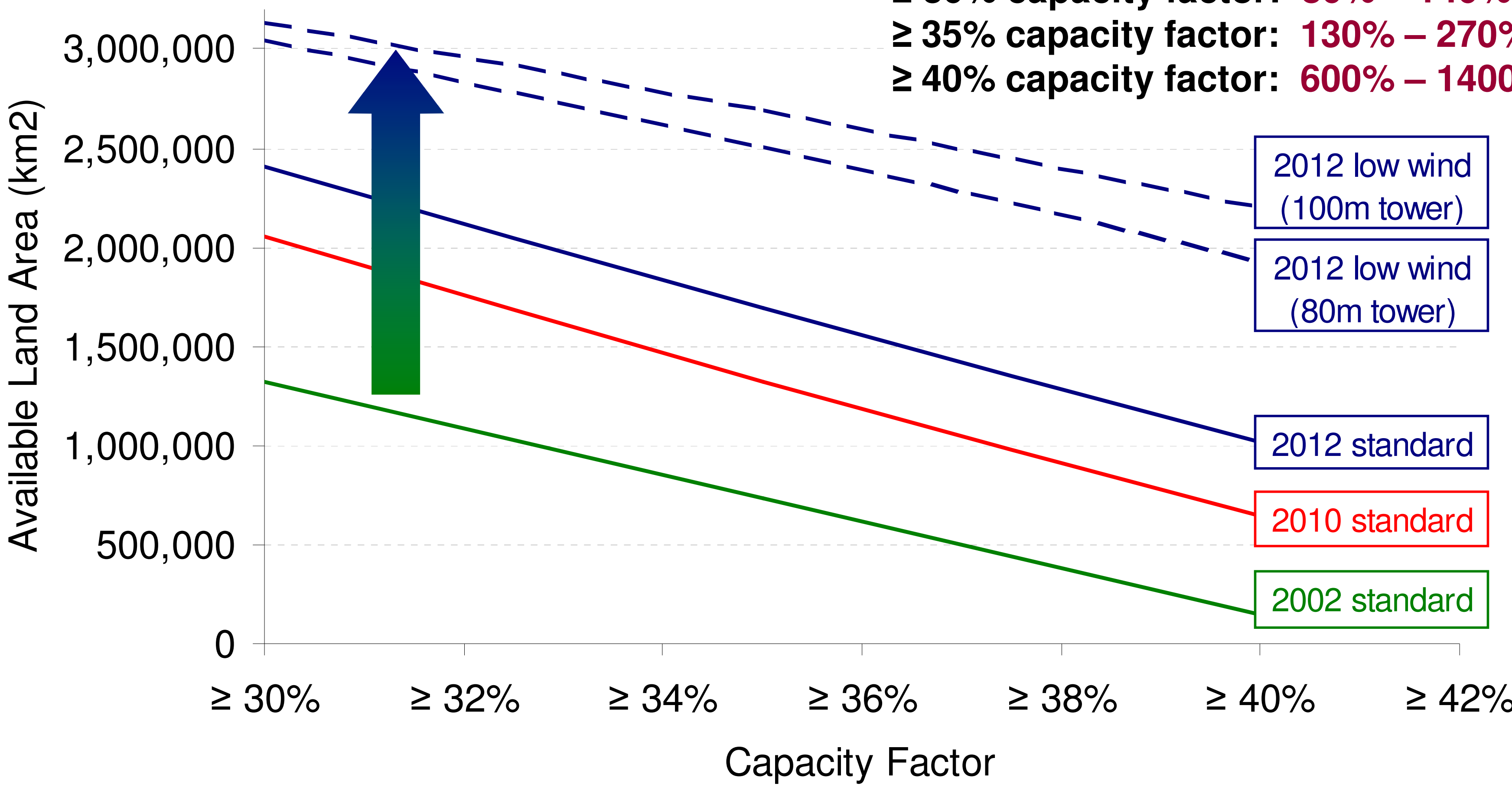


Drop in LCOE is Particularly Pronounced Among Lower Wind Speed Sites

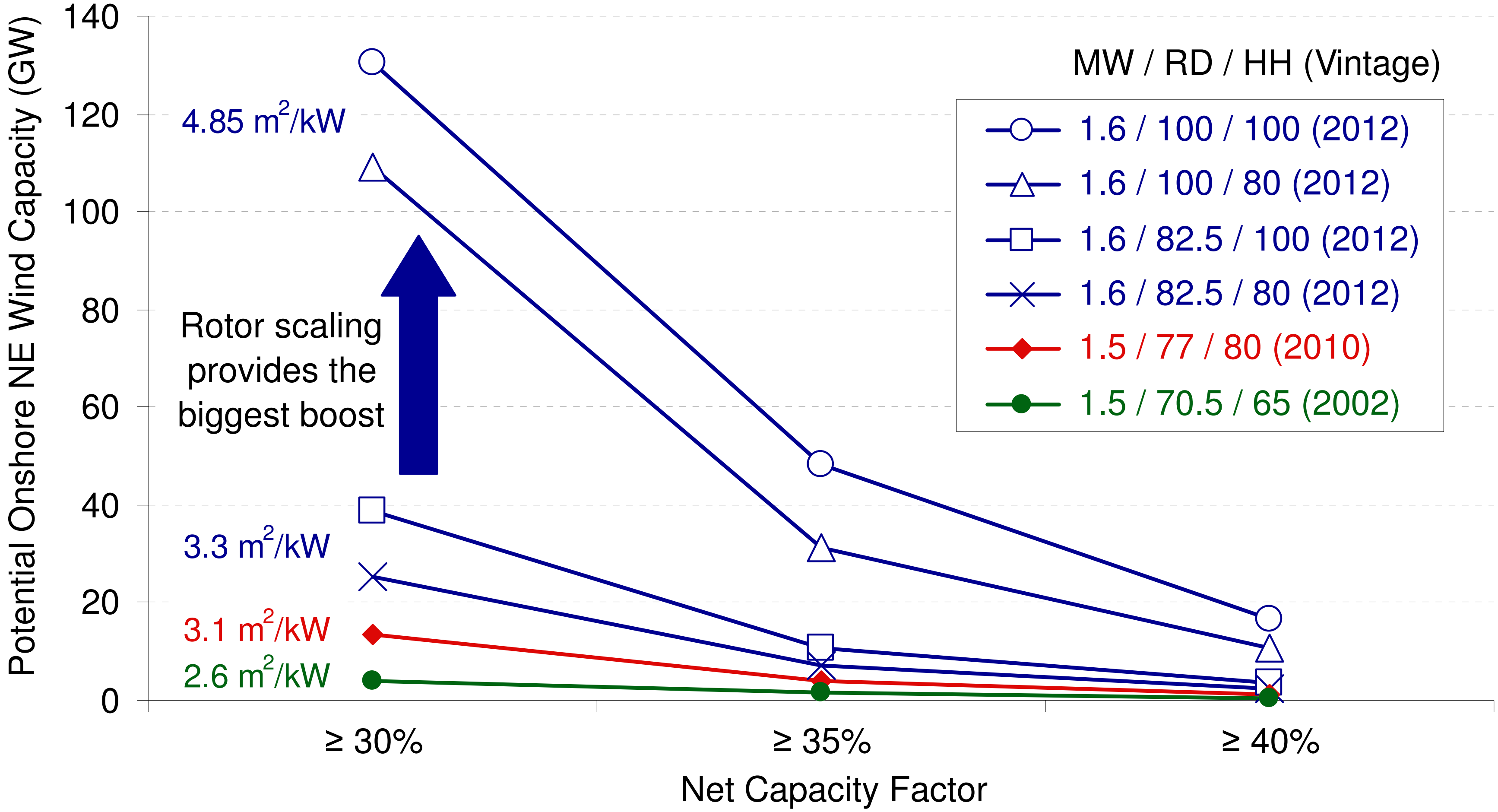


U.S. Land Area Exceeding Capacity Factor Thresholds Has Increased Dramatically

Percentage increase since 2002:
≥ 30% capacity factor: 80% – 140%
≥ 35% capacity factor: 130% – 270%
≥ 40% capacity factor: 600% – 1400%

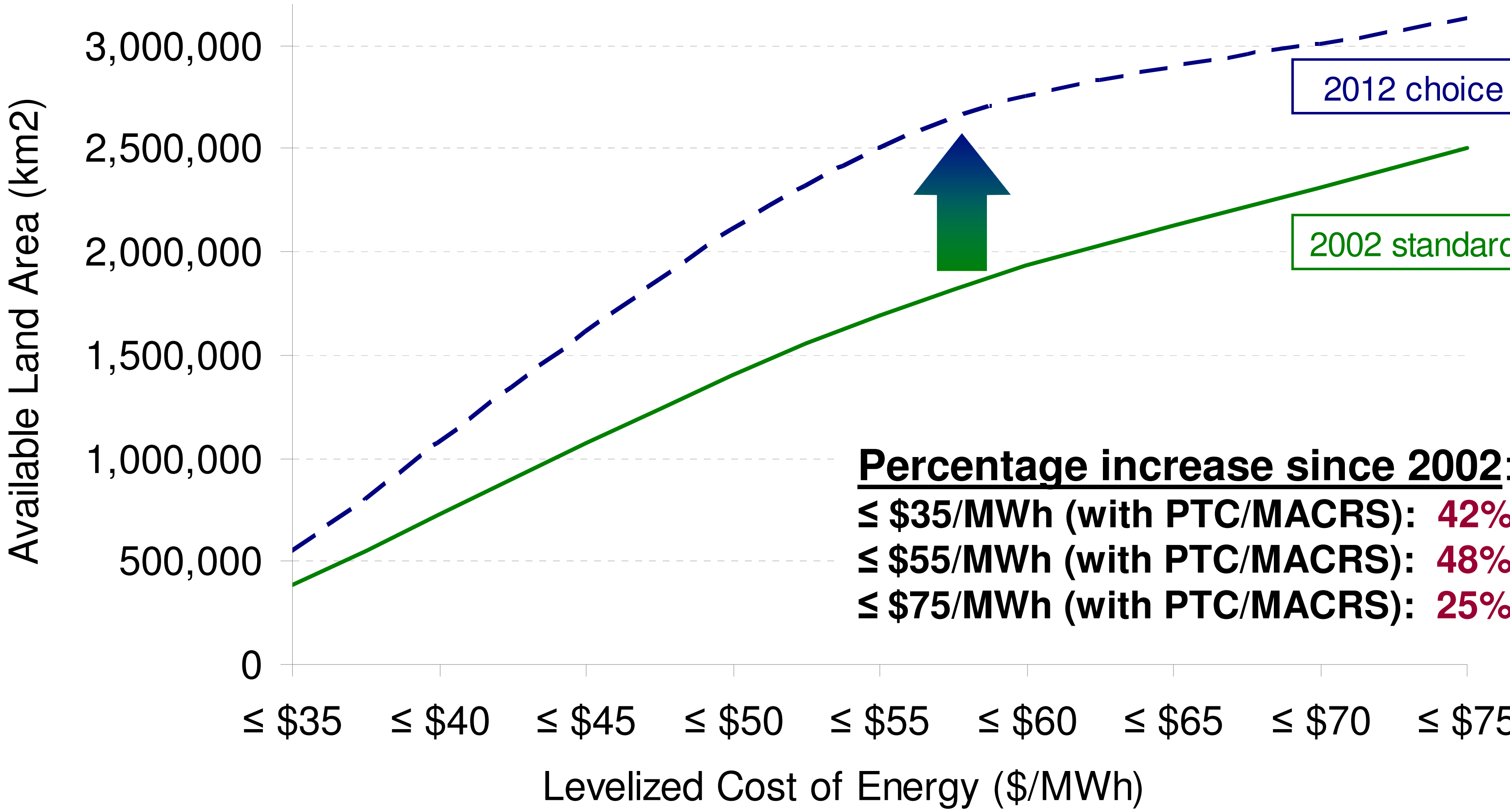


New England Example: Scaling Has Unlocked A Substantial Amount of Capacity Potential



- Rotor scaling (per kW) has a larger impact than tower scaling
- The largest potential capacity gains are at low wind speed sites (≥30% NCF)

U.S. Land Area Meeting LCOE Thresholds Has Also Increased Substantially



Note: Land area meeting LCOE thresholds has grown by less than land area meeting capacity factor thresholds because LCOE has been negatively impacted by higher installed costs

Implications for Community Wind

Clear Benefits:

- Community wind stands to benefit disproportionately from the increasing availability of low wind speed turbine designs, as previously marginal sites become viable with the new technology
- Discount on “old” standard technology, as market moves towards “new”

Potential Issues and (at least to me) Unknowns:

- Community wind projects are often sited in more-populated areas
  - Do more-populated areas tend to have lower height restrictions that could constrain the use of these taller turbines?
  - Turbine noise -- how do low wind speed turbines compare to standard technology?
- Greater technology risk from “unproven” (or at least newer) designs?
- Ready access to the largest cranes, which are needed to erect tall towers?