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Wind & Hydropower Technologies Program

# Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2006

**Ryan Wiser and Mark Bolinger**  
Lawrence Berkeley National Laboratory

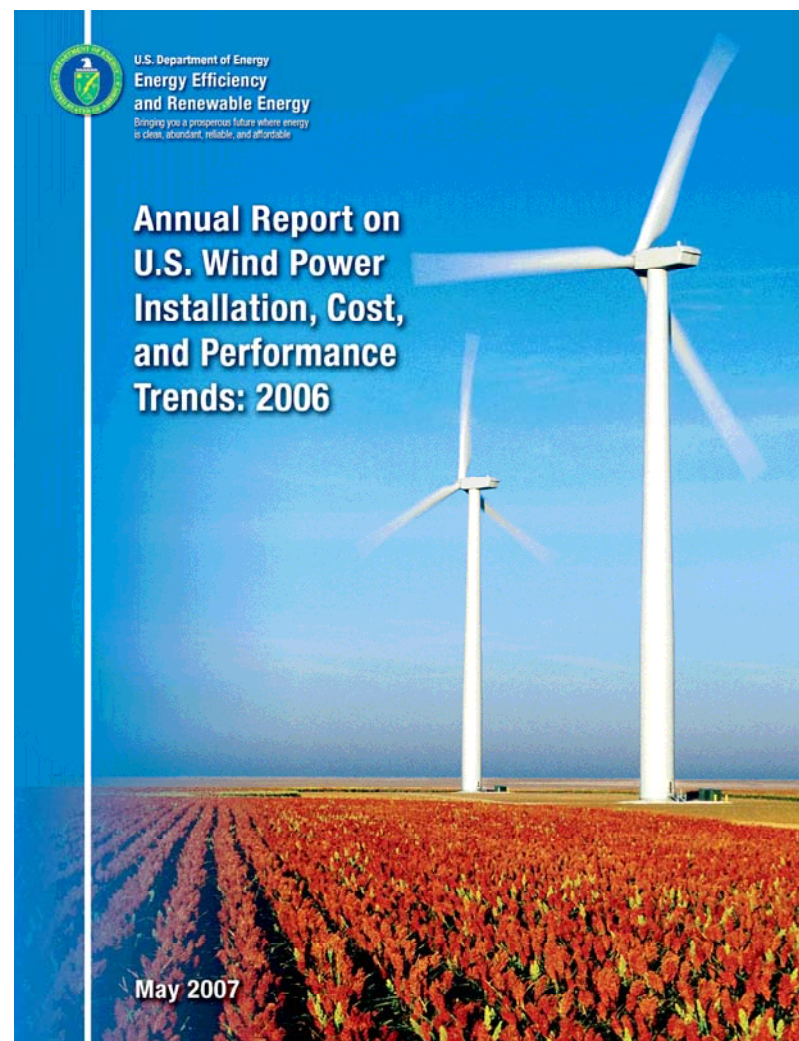
**- Report Summary -**

May 30, 2007



# Presentation Overview

- Introduction to *inaugural* DOE/LBNL/NREL U.S. wind market data report
- Wind installation trends
- Wind industry trends
- Evolution of wind pricing
- Installed wind project costs
- Wind turbine transaction prices
- Wind project performance
- O&M cost trends
- Integration/transmission/policy
- Coming up in 2007





# 2006 Annual Market Data Report: Inaugural Issue, First in Series

## Purpose, Scope, and Data:

- Offer an overview of trends in the U.S. wind power market, with a focus on 2006; scope includes wind turbines and projects over 50 kW in size
- Provide useful information on wind installations, industry developments, power sales prices, capital costs, performance, O&M costs, policy trends
- Data sources include AWEA/GEC, EIA, FERC, SEC, etc. (*see full report*)

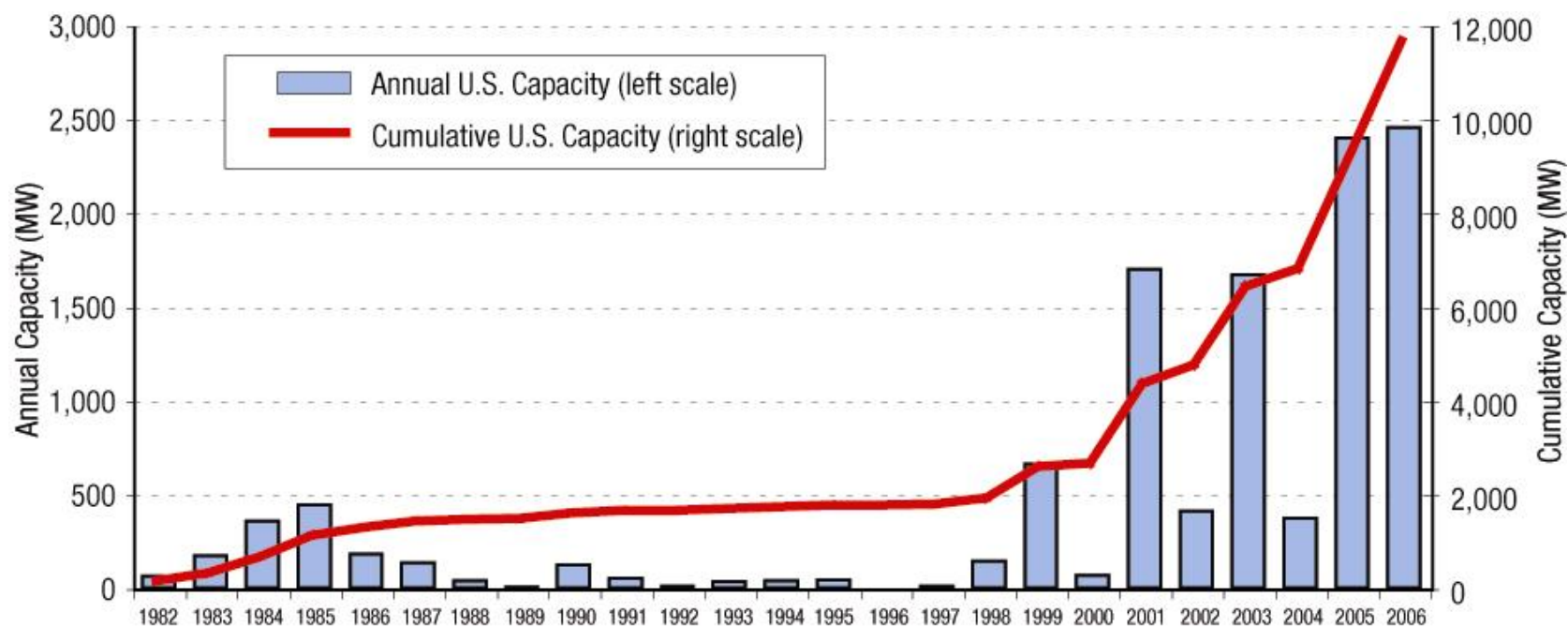
## Report Authors:

- Primary Authors: R. Wiser and M. Bolinger, Berkeley Lab
- Contributions from others at Berkeley Lab, AWEA, NREL, DOE, Black & Veatch, Exeter Associates

**Available at:** <http://www1.eere.energy.gov/windandhydro/>



# Cumulative U.S. Wind Power Capacity Up 27% in 2006



Source: AWEA/GEC database.

## Largest year on record for U.S. wind capacity additions, edging out 2005

- 2,454 MW of wind added
- Roughly \$3.7 billion in investment
- 19% of nameplate capacity added to grid in 2006 (second only to nat. gas) 4



# U.S. Leads World in Annual Wind Capacity Additions; Third in Cumulative Capacity

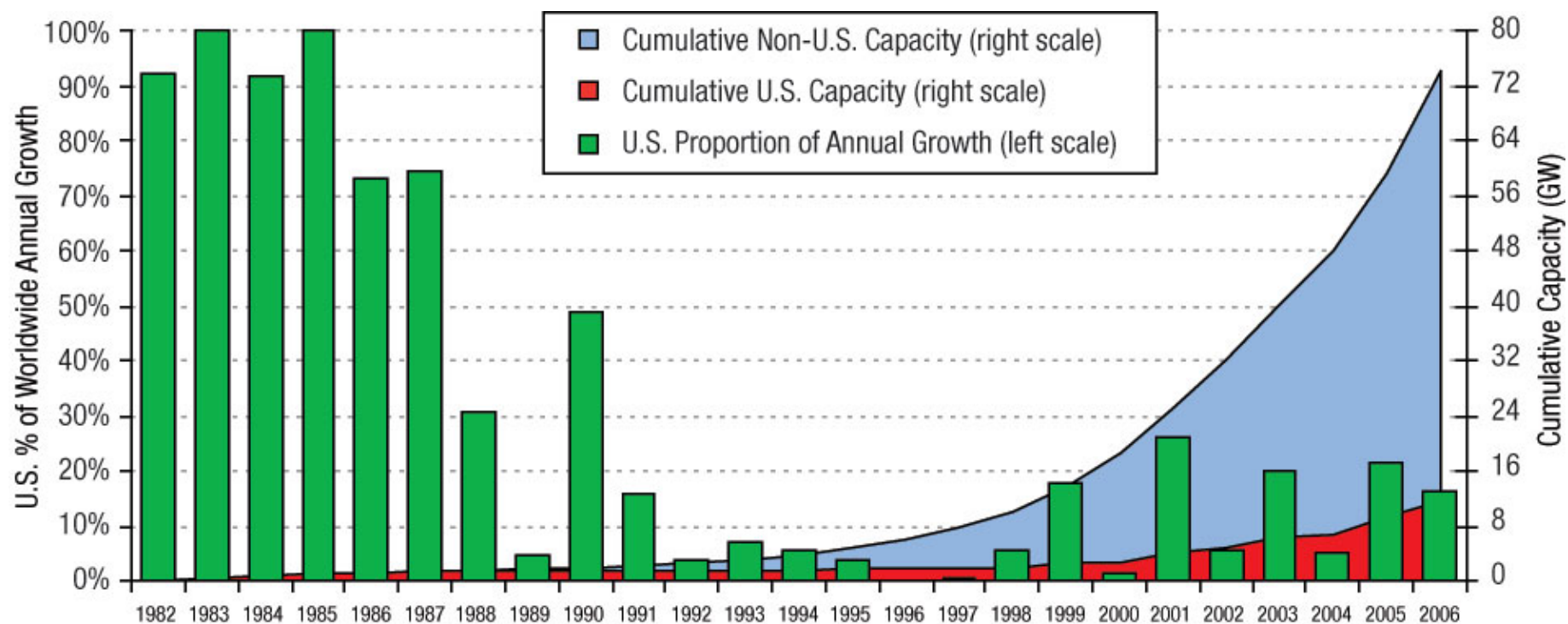
**Table 1. International Rankings of Wind Power Capacity**

Cumulative Capacity (end of 2006, MW)		Incremental Capacity (2006, MW)	
Germany	20,652	<b>US</b>	<b>2,454</b>
Spain	11,614	Germany	2,233
<b>US</b>	<b>11,575</b>	India	1,840
India	6,228	Spain	1,587
Denmark	3,101	China	1,334
China	2,588	France	810
Italy	2,118	Canada	776
UK	1,967	UK	631
Portugal	1,716	Portugal	629
France	1,585	Italy	417
Rest of Wold	11,102	Rest of World	2,305
<b>TOTAL</b>	<b>74,246</b>	<b>TOTAL</b>	<b>15,016</b>

Source: BTM, 2007; AWEA/GEC dataset for U.S. cumulative capacity.



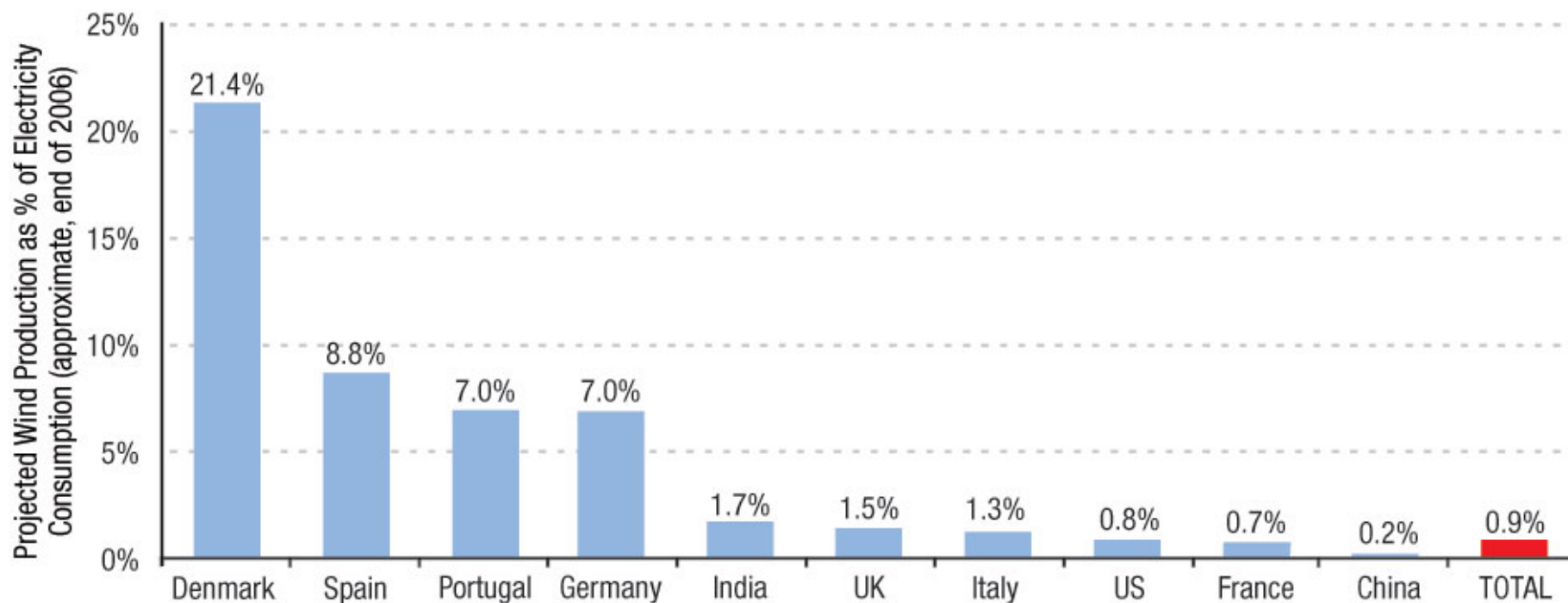
# U.S. Share of Worldwide Annual *and* Cumulative Wind Installations at 16%



Source: Earth Policy Institute; BTM Consult; AWEA/GEC dataset



# U.S Lagging Other Countries for Wind As a Percentage of Electricity Consumption



Source: Berkeley Lab estimates based on data from BTM and elsewhere.

Note: Figure only includes the 10 countries with the most cumulative installed wind capacity at the end of 2006



# Texas, Washington, and California Lead U.S. in Annual Capacity Additions

**Table 2. United States Wind Power Rankings: The Top 20 States**

Cumulative Capacity (end of 2006, MW)		Incremental Capacity (2006, MW)		Approximate Percentage of Retail Sales*	
Texas	2,739	Texas	774	New Mexico	7.3%
California	2,376	Washington	428	Iowa	6.0%
Iowa	931	California	212	North Dakota	5.1%
Minnesota	895	New York	185	Wyoming	5.1%
Washington	818	Minnesota	150	Minnesota	3.8%
Oklahoma	535	Oregon	101	Oklahoma	3.5%
New Mexico	496	Kansas	101	Montana	3.3%
Oregon	438	Iowa	99	Kansas	3.1%
New York	370	New Mexico	90	Oregon	2.4%
Kansas	364	North Dakota	80	Texas	2.3%
Colorado	291	Oklahoma	60	Washington	2.3%
Wyoming	288	Colorado	60	California	2.1%
Pennsylvania	179	Pennsylvania	50	Colorado	1.7%
North Dakota	178	Hawaii	41	South Dakota	1.5%
Montana	146	Montana	9	Nebraska	1.0%
Illinois	107	Maine	9	Hawaii	1.0%
Idaho	75	Massachusetts	2	Idaho	0.7%
Nebraska	73	New Hampshire	1	New York	0.6%
West Virginia	66	Rhode Island	0.7	West Virginia	0.6%
Wisconsin	53	Ohio	0.2	Pennsylvania	0.3%
Rest of U.S.	156	Rest of U.S.	0.3	Rest of U.S.	0.02%
<b>TOTAL</b>	<b>11,575</b>	<b>TOTAL</b>	<b>2,454</b>	<b>TOTAL</b>	<b>0.85%</b>

- 20 states had > 50 MW of wind capacity at the end of 2006
- Texas overtakes California in cumulative wind capacity in 2006
- But neither TX nor CA in top tier of states for wind as a % of retail sales

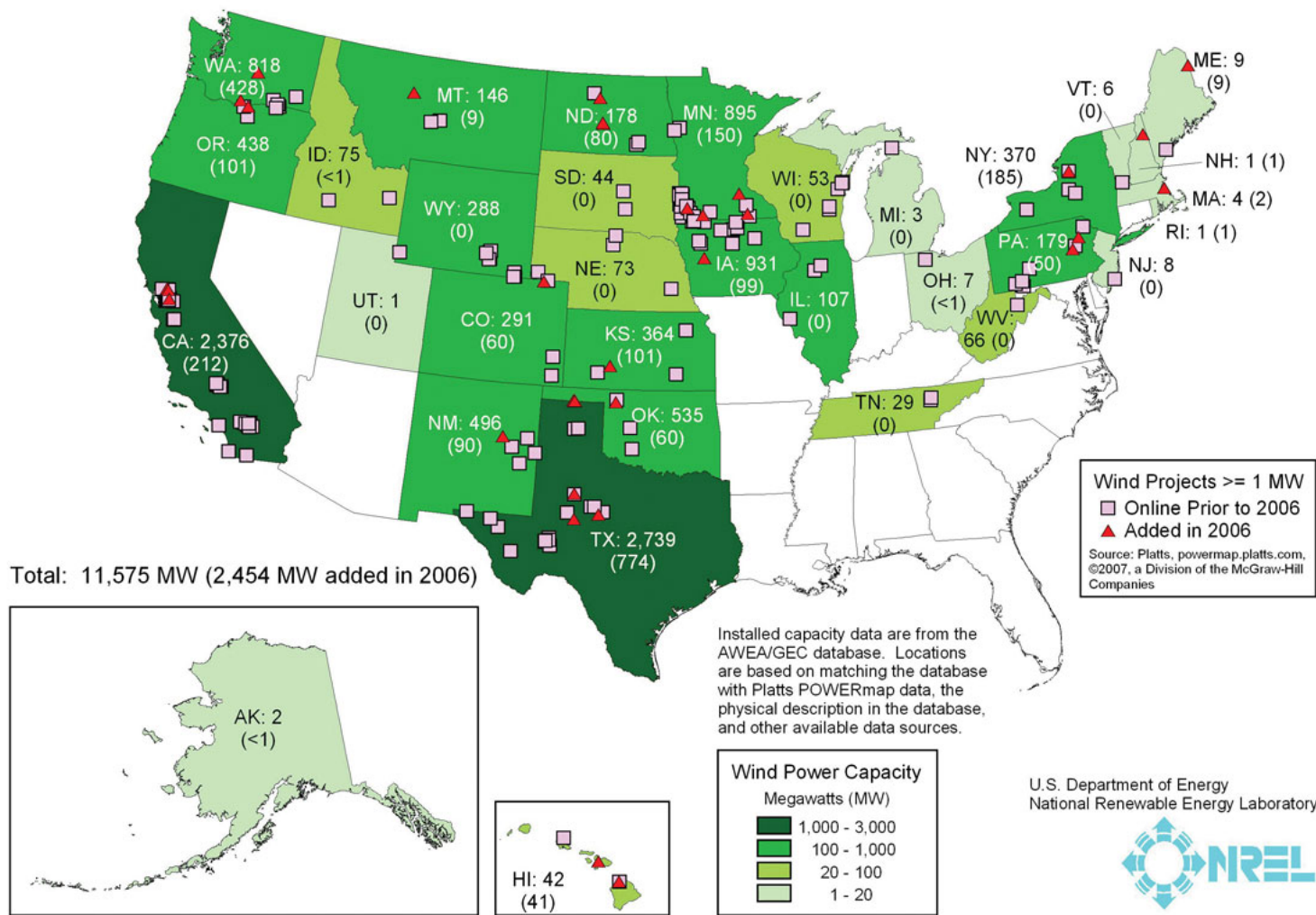
\*Assumes that wind installed in a state serves that state's electrical load; ignores transmission losses.

Source: AWEA/GEC database and Berkeley Lab estimates.





# Geographic Spread of Wind Projects in the United States is Reasonably Broad





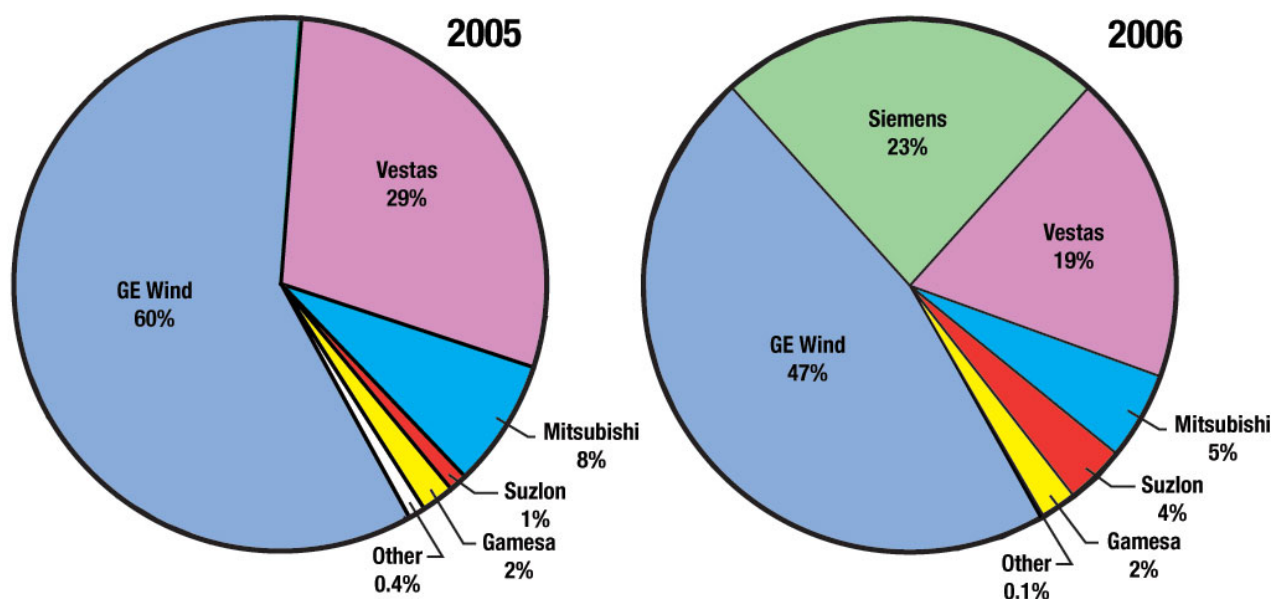
# Interest in Offshore Wind Continues in the U.S., but No Such Projects Are Yet Online

State	Proposed Offshore Wind Capacity
Massachusetts	735 MW
Texas	650 MW
Delaware	600 MW
New Jersey	300 MW
New York	160 MW
Georgia	10 MW
<b>TOTAL</b>	<b>2,455 MW</b>

- All wind projects installed in the U.S. to date are land-based
- Some interest exists in offshore wind in several parts of the U.S.
- Projects are in various stages of development



# GE Wind Is Dominant Turbine Manufacturer, with Siemens Gaining Market Share

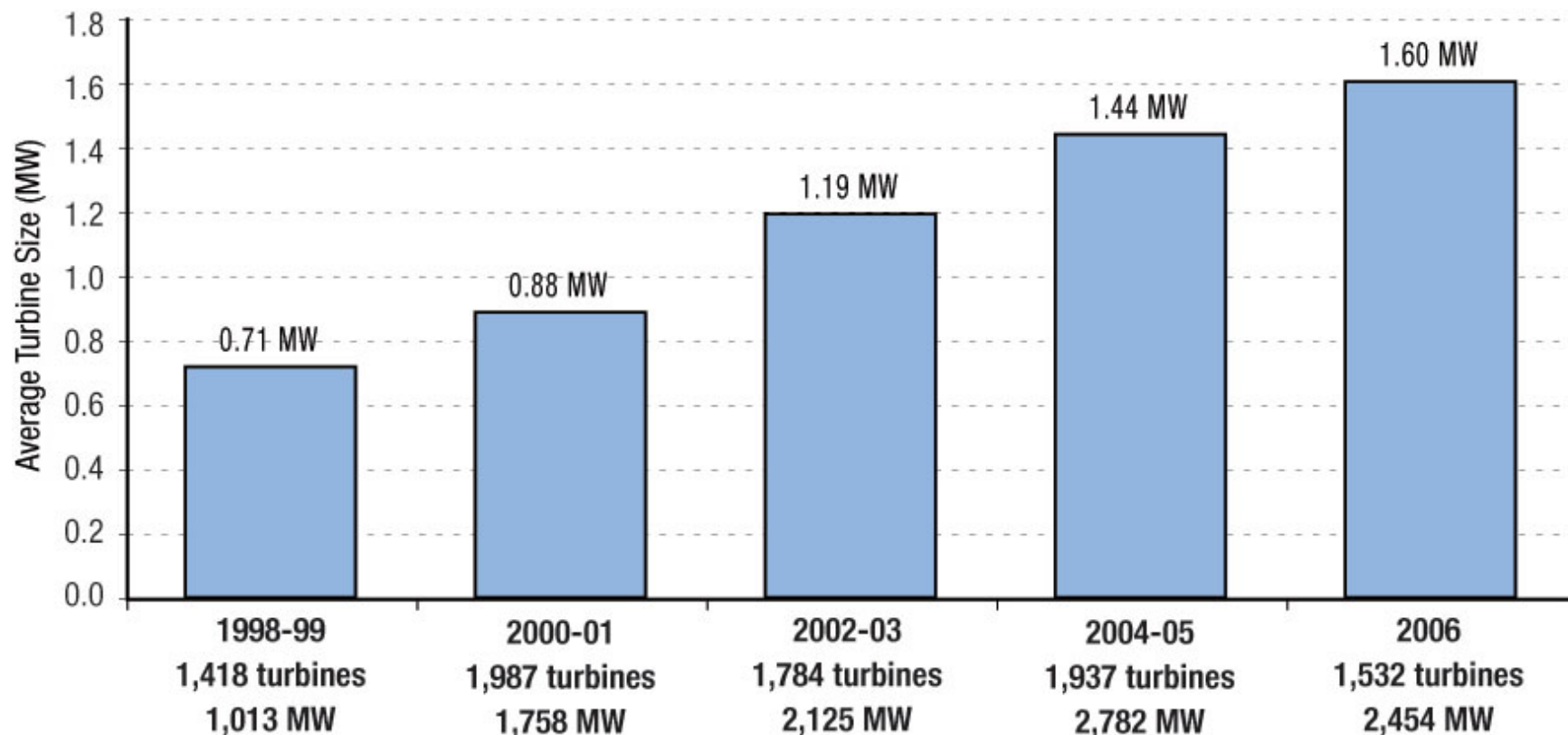


Source: AWEA/GEC wind project database.

- GE captured nearly half the market in 2006 with its 1.5 MW “workhorse,” but Siemens wins “rookie of the year”
- GE and Vestas lost market share from 2005 to 2006
- Domestic manufacturing of turbines and components remains limited, but localization of manufacturing in the U.S. is on the rise



# Average Turbine Size Continues to Increase



Source: AWEA/GEC project database.

17% of turbines installed in 2006 were greater than 2 MW, compared to just 0.1% from 2002 through 2005



# Wind Developer Consolidation Accelerates

- Mergers, acquisitions and investments continued strong trend that began in 2005
  - 2002-04: 4 deals = 4 GW of wind development pipeline
  - 2005: 9 deals = 12 GW
  - 2006: 13 deals = 35 GW
  - Trend continuing in 2007
- A number of large companies have entered wind development business in recent years

Table 4. Merger and Acquisition Activity among U.S. Wind Development Companies\*

Investor	Transaction Type	Developer	Announced
EDF (SIIF Energies)	Acquisition	enXco	May-02
Gamesa	Investment	Navitas	Oct-02
AES	Investment	US Wind Force	Sep-04
PPM Energy	Acquisition	Atlantic Renewable Energy Corp.	Dec-04
AES	Acquisition	SeaWest	Jan-05
Goldman Sachs	Acquisition	Zilkha (Horizon)	Mar-05
JP Morgan Partners	Investment	Noble Power	Mar-05
Arclight Capital	Investment	CPV Wind	Jul-05
Diamond Castle	Acquisition	Catamount	Oct-05
Pacific Hydro	Investment	Western Wind Energy	Oct-05
Greenlight	Acquisition	Coastal Wind Energy LLC	Nov-05
EIF U.S. Power Fund II	Investment	Tierra Energy, LLC	Dec-05
Airtricity	Acquisition	Renewable Generation Inc.	Dec-05
Babcock & Brown	Acquisition	G3 Energy LLC	Jan-06
Iberdrola	Acquisition	Community Energy Inc.	Apr-06
Shaw/Madison Dearborn	Investment	UPC Wind	May-06
NRG	Acquisition	Padoma	Jun-06
CPV Wind	Acquisition	Disgen	Jul-06
BP	Investment	Clipper	Jul-06
BP	Acquisition	Greenlight	Aug-06
Babcock & Brown	Acquisition	Superior	Aug-06
Enel	Investment	TradeWind	Sep-06
Iberdrola	Acquisition	Midwest Renewable Energy Corp.	Oct-06
Iberdrola	Acquisition	Gamesa's U.S. project pipeline	Oct-06
Iberdrola	Acquisition	PPM (Scottish Power)	Dec-06
BP	Acquisition	Orion Energy	Dec-06

\* Select list of announced transactions; excludes joint development activity.

Source: Berkeley Lab and Black & Veatch.

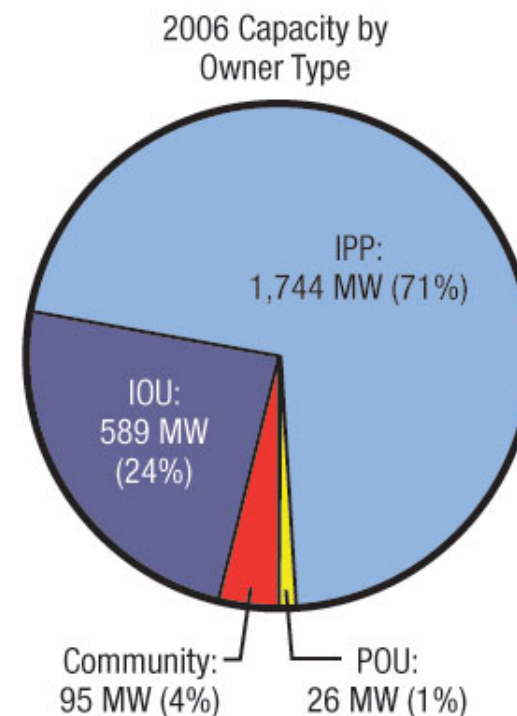
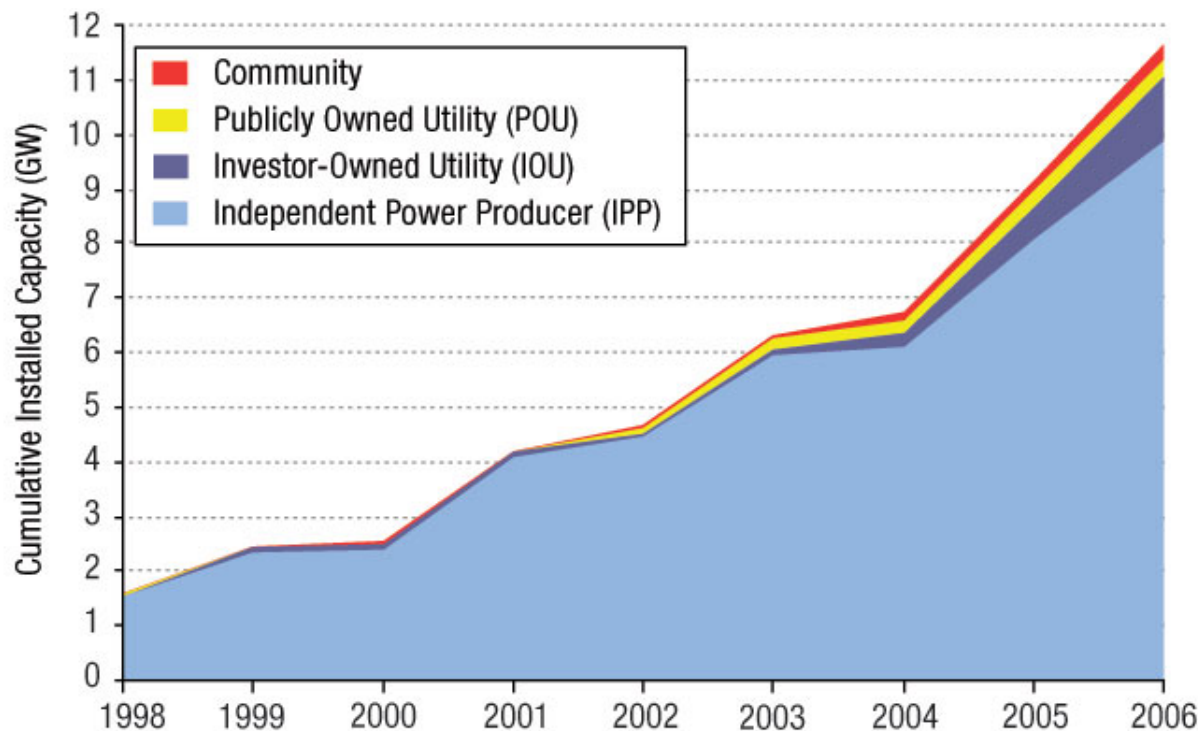


# Innovation and Competition in Non-Utility Wind Financing Persists

- A variety of innovative ownership/financing arrangements enable equity to access the federal production tax credit (PTC)
- Two most commonly used structures in 2006 were corporate balance-sheet finance and “flip” structures
- Continued expansion of debt and equity providers to wind market
  - At least 12 equity providers in 2006, up from just 3 a few years ago
  - 11 banks as lead debt arrangers, up from just a few several years ago
- Cost of capital continued to decline
  - Tax equity rates of return have declined by ~3% in past 4 years
  - Debt margins have declined by ~0.5% in past 4 years



# Utility Interest in Wind Asset Ownership Strengthens; Community Wind Grows

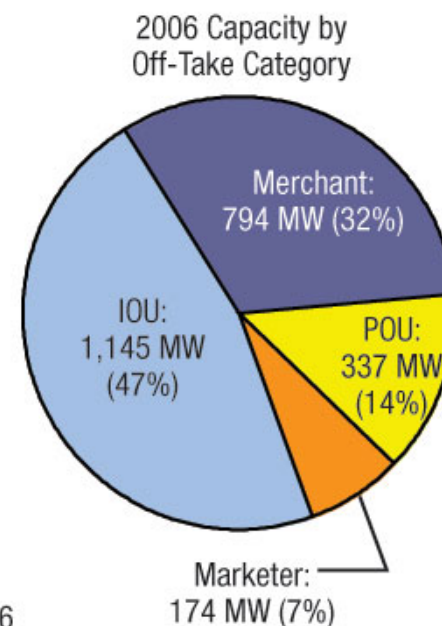
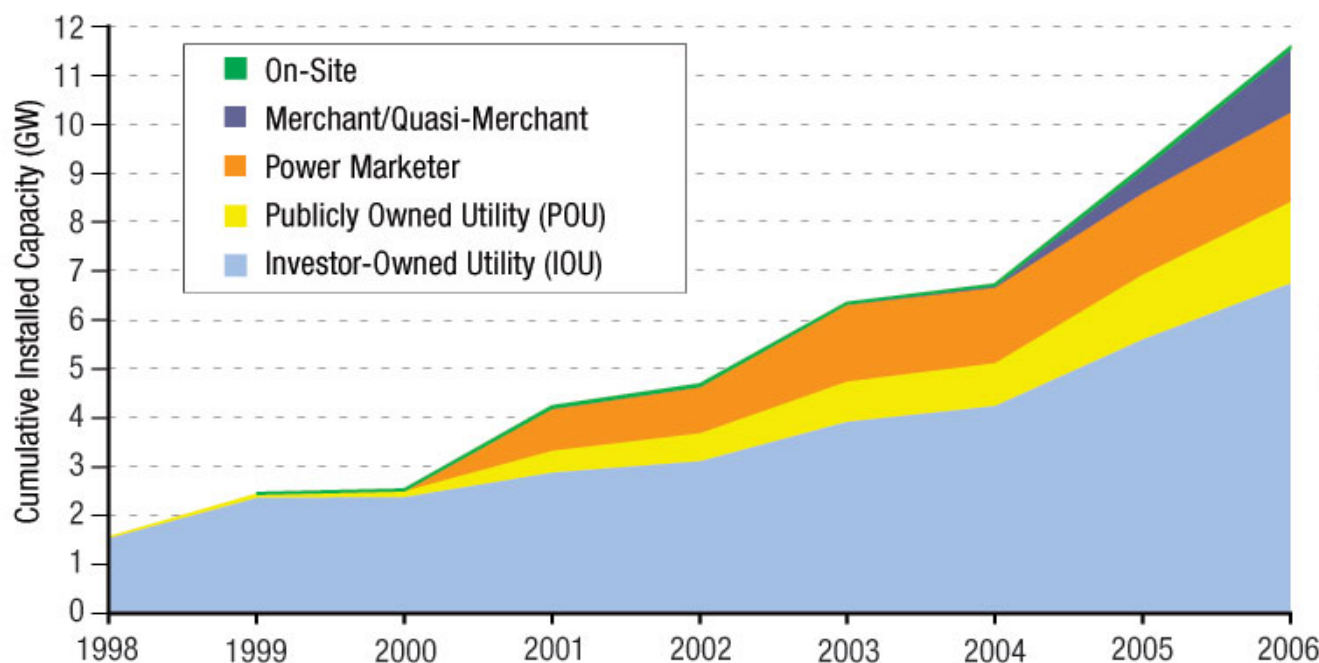


Source: Berkeley Lab estimates based on AWEA/GEC wind project database.

...but independent power producers continue to dominate ownership



# Merchant Plants and Sales to Power Marketers Are Significant



Source: Berkeley Lab estimates based on AWEA/GEC wind project database.

- Utilities continue to be the dominant purchasers of wind power
- Power marketers have become major buyers since 2000
- Merchant activity increased very recently, especially in TX and NY



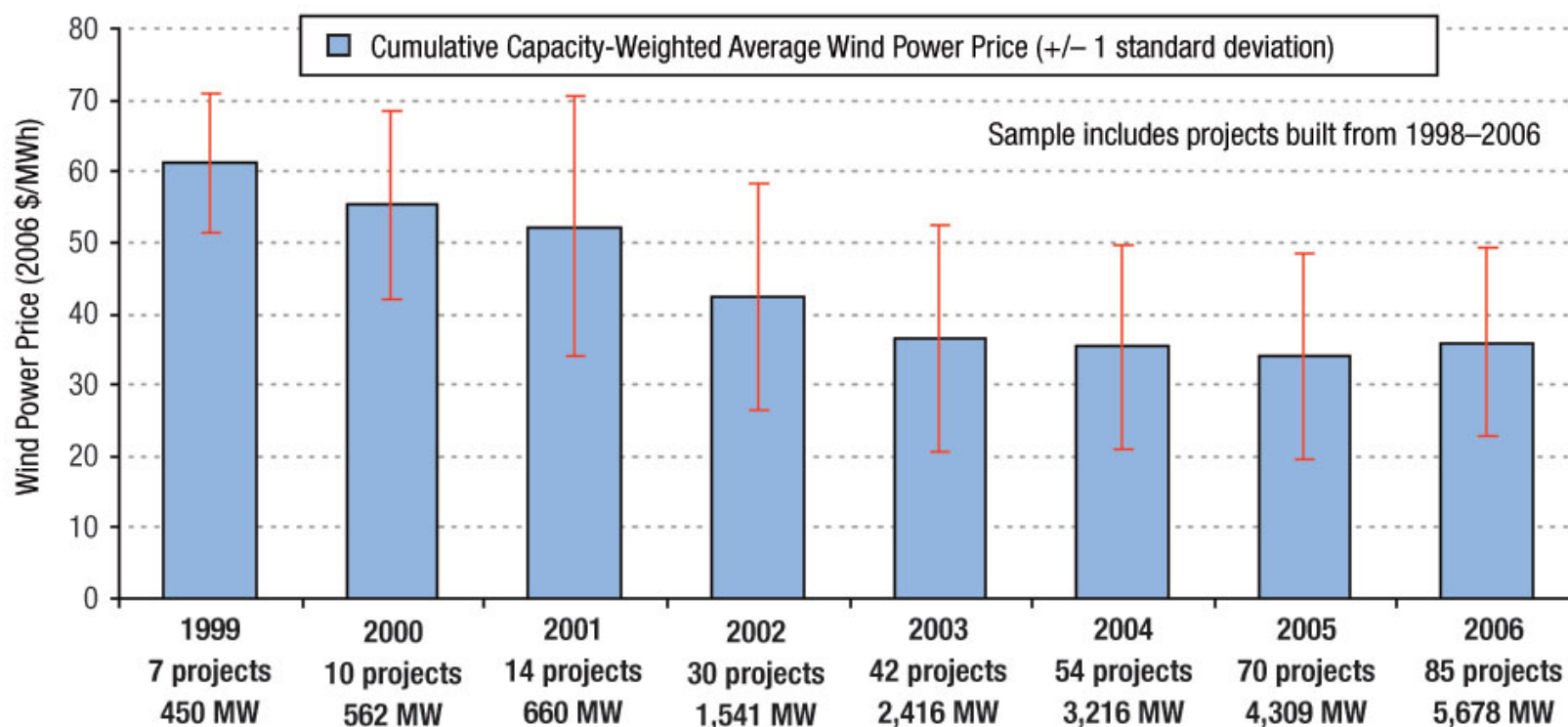


# Wind Power Prices Are Up in 2006

- Berkeley Lab maintains a database of wind power sales prices; next few slides present data from that database
- Sample includes 85 wind projects installed from 1998-2006, totaling 5,678 MW (58% of total added capacity over that timeframe)
- Prices reflect price of electricity as sold by project owner (i.e., busbar energy prices)
  - Prices reduced by receipt of state/federal incentives (e.g., the PTC) and by any value gained through separate sale of RECs (though only 9 of 85 projects appear to receive additional REC revenue)
  - As a result, prices do not reflect wind energy generation costs



# Cumulative Average Sales Price for Sample of Projects Built After 1997 Remains Low

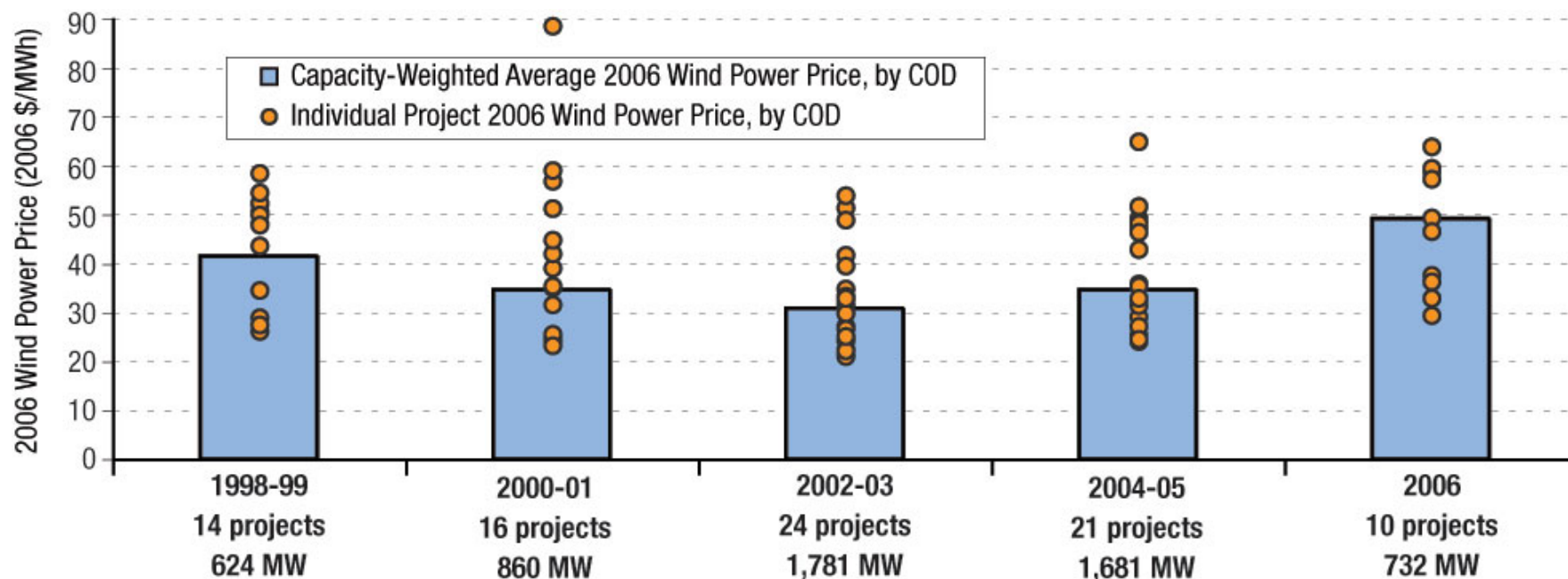


Source: Berkeley Lab database.

Small increase in 2006 due to rising prices of projects built in that year, but cumulative nature of graphic mutes degree of price increase



# Wind Prices Up for Projects Built in 2006, After Bottoming Out in 2002-03

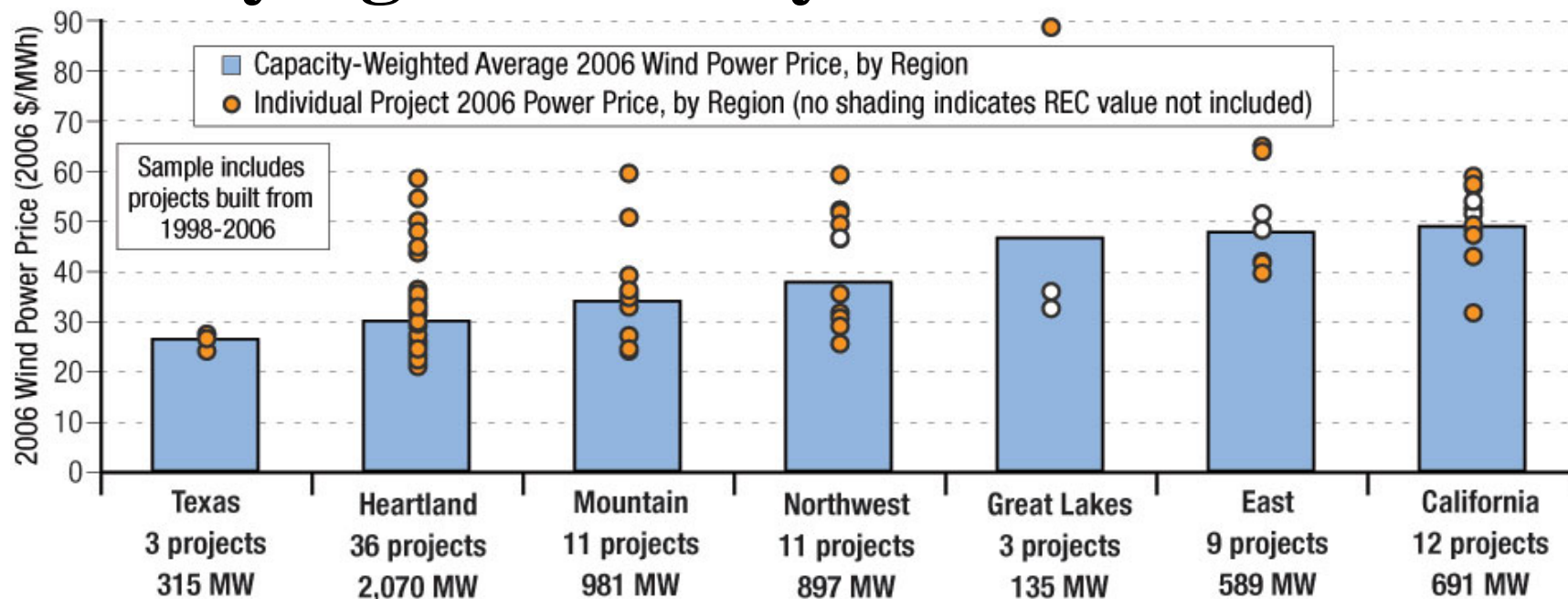


Source: Berkeley Lab database.

- Dramatic increase in avg. '06 price from **\$31/MWh** for projects built in '02-03, to **\$35/MWh** for projects built '04-05, and to **\$49/MWh** for '06 projects
- Prices will likely rise further to more fully reflect turbine price increases
- Graphic shows prices in 2006 from projects built from 1998-2006



# Regional Differences Explain Some of the Underlying Variability in Wind Sales Prices



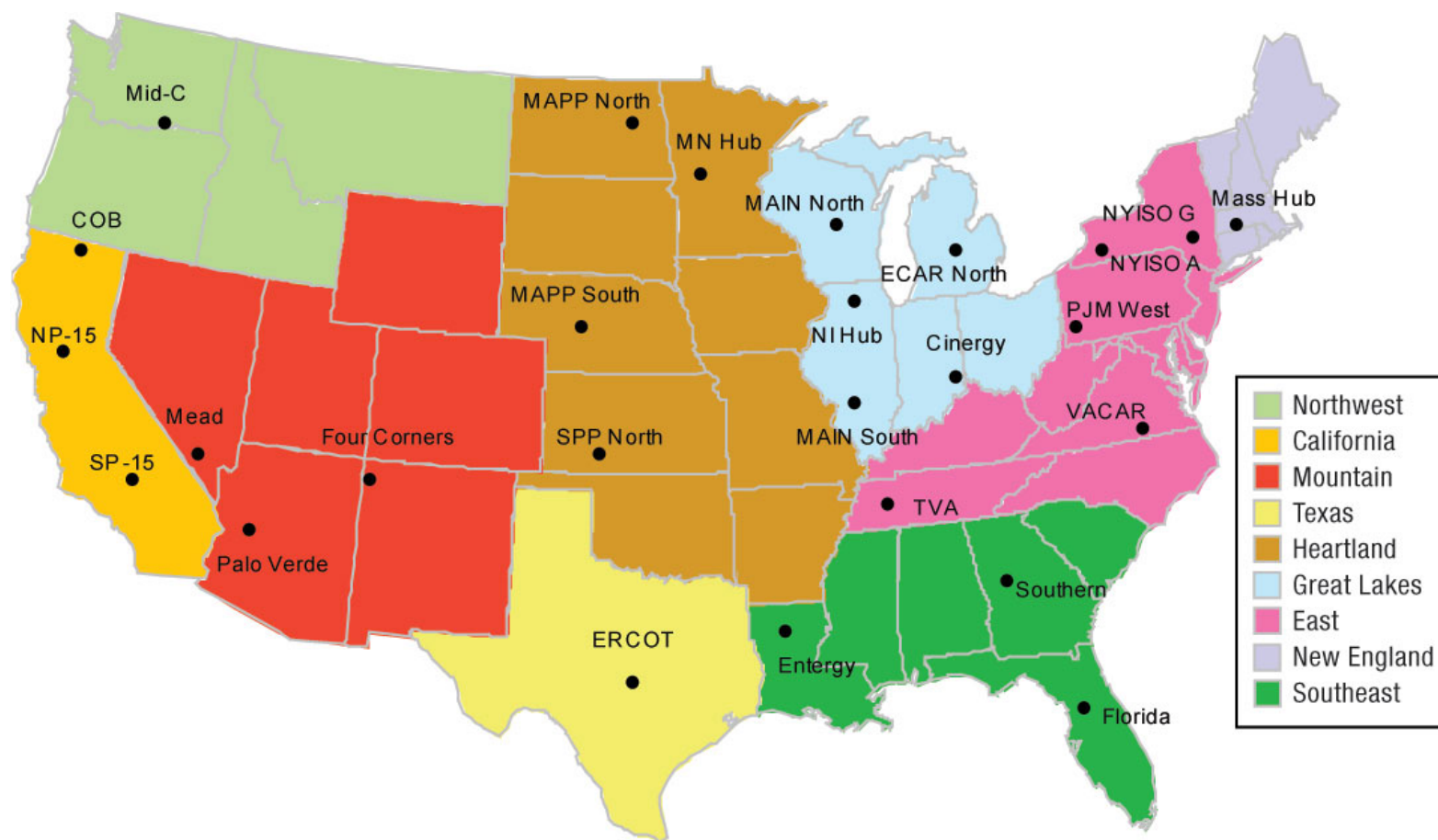
Source: Berkeley Lab database.

Texas and the Heartland are lower-price regions, while California and the East are higher-price regions

Higher cost regions would appear even costlier if additional REC revenue was included for small # of projects that receive it

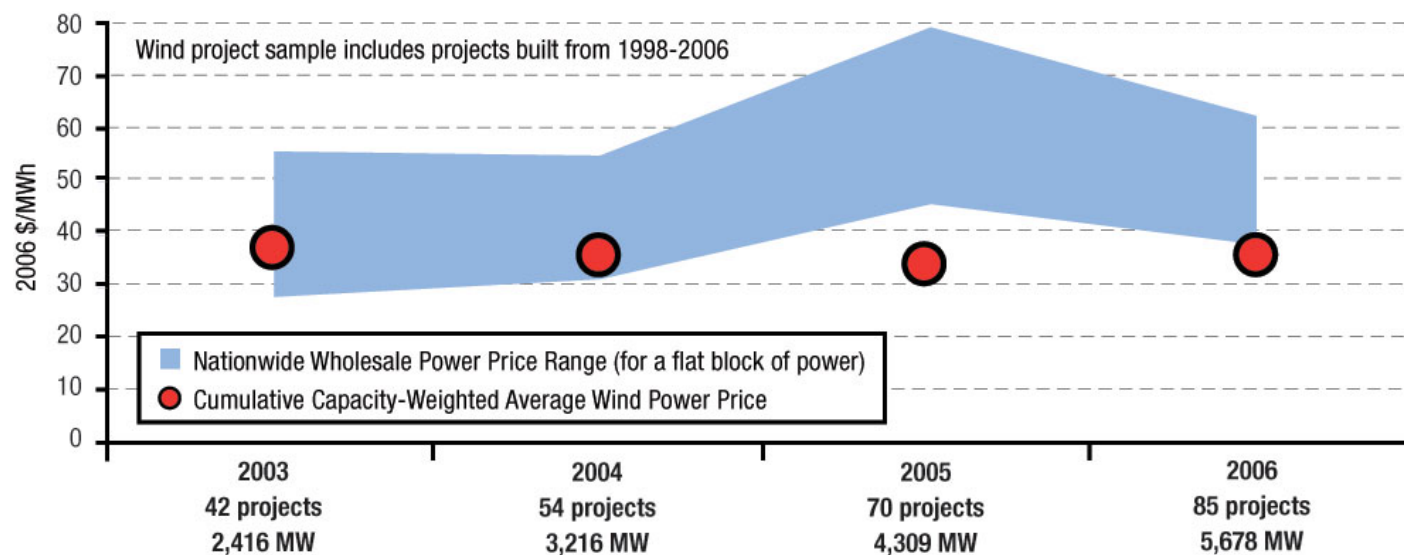


# Regional Definitions and Wholesale Price Hubs





# Nationally, Wind Has Been Competitive with Wholesale Power Prices in Recent Years

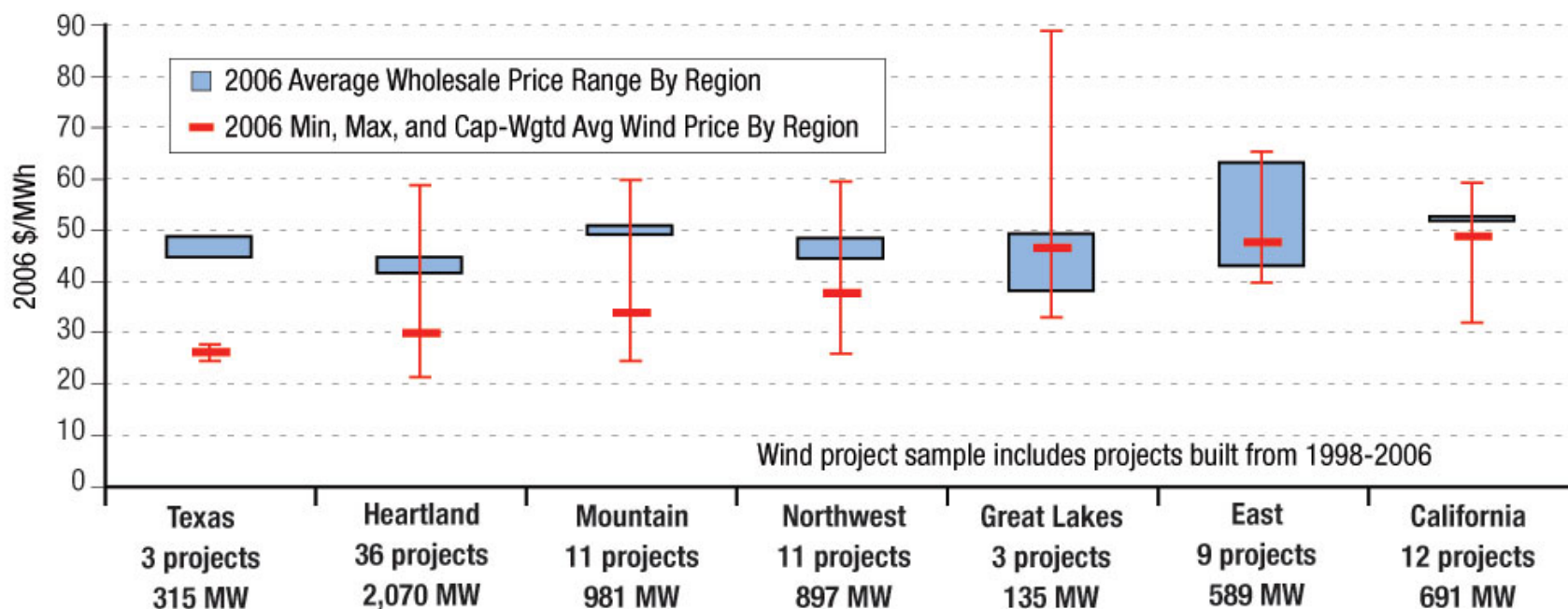


Source: FERC 2006 and 2004 "State of the Market" reports, Berkeley Lab database.

- Wind projects built from 1998-2006 have, in aggregate, been competitive relative to conventional wholesale prices over the 2003-06 timeframe
- Wholesale price range reflects a flat block of power across 26 pricing hubs in the U.S. (see map on previous slide)
- Wind costs represent capacity-weighted average price for wind power for entire sample of projects built from 1998-2006



# In 2006, Wind Projects Built Since 1997 Were Competitive with Wholesale Power Prices in Most Regions

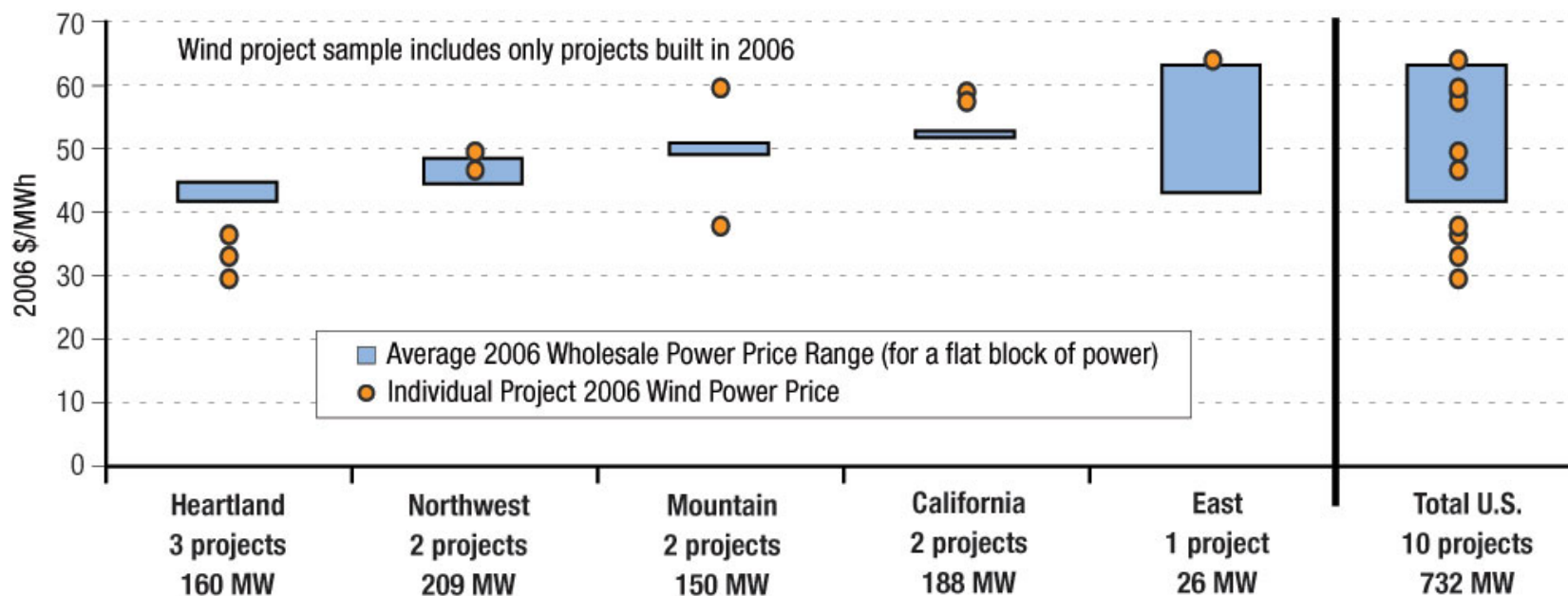


Source: FERC 2006 "State of the Market" report, Berkeley Lab database.

Note: Even within a region there are a range of wholesale power prices because multiple wholesale price hubs exist in each area (see previous map)



# Focusing Just on Wind Projects Built in 2006 Tells a More Cautious Story



Source: FERC 2006 "State of the Market" report, Berkeley Lab database.

- Wind projects built in 2006 were only marginally competitive with wholesale power prices in 2006
- The recent rise in wind prices is making wind less competitive in wholesale markets across the U.S.

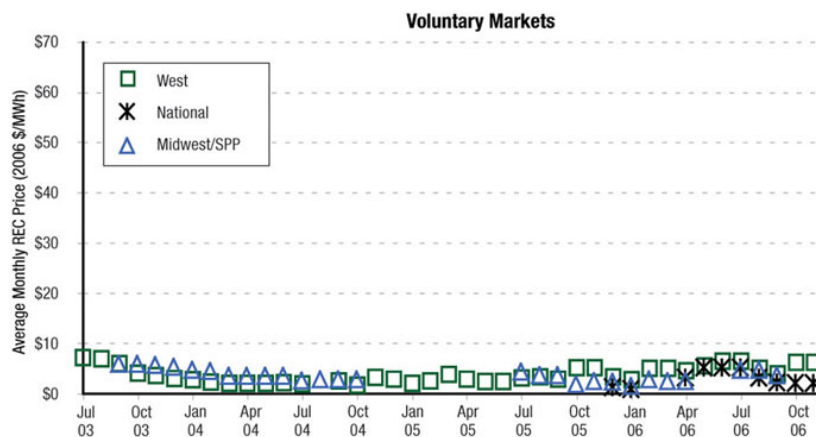
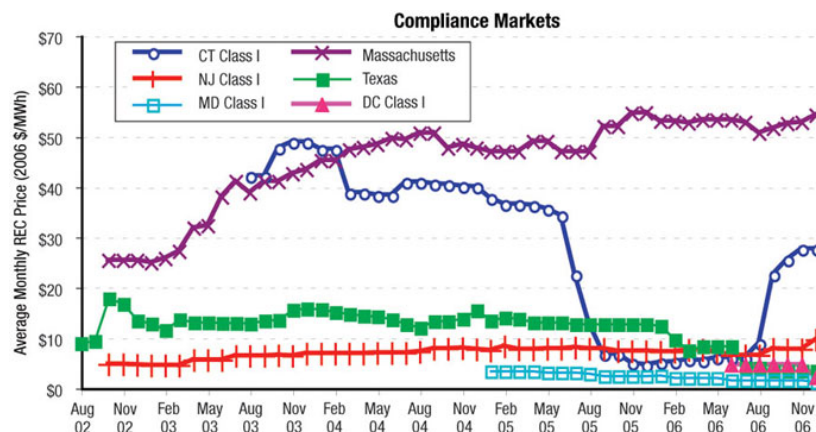




# Renewable Energy Certificate (REC) Markets Are Fragmented

Renewable energy certificate markets experience significant price variations by:

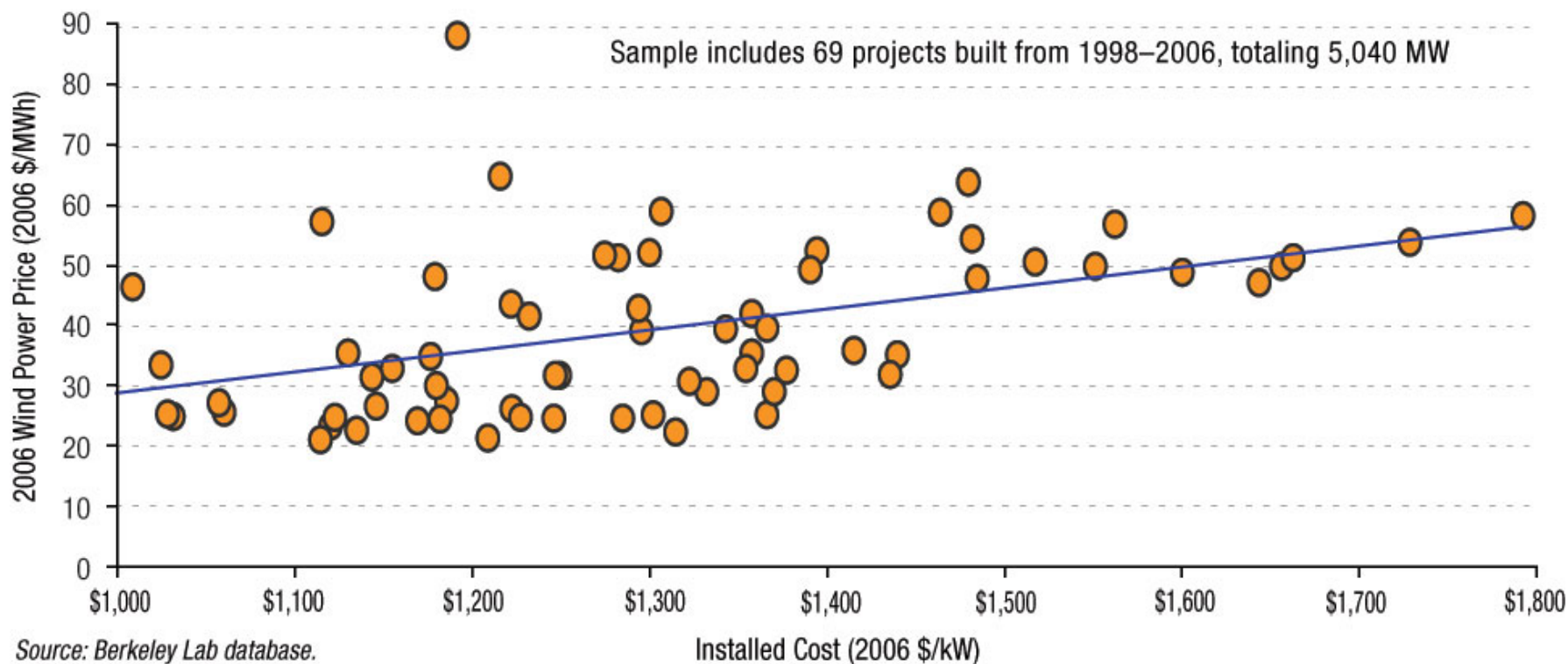
- geographic region;
- market type (compliance vs. voluntary); and
- Specific design of state RPS policies.



Source: Evolution Markets

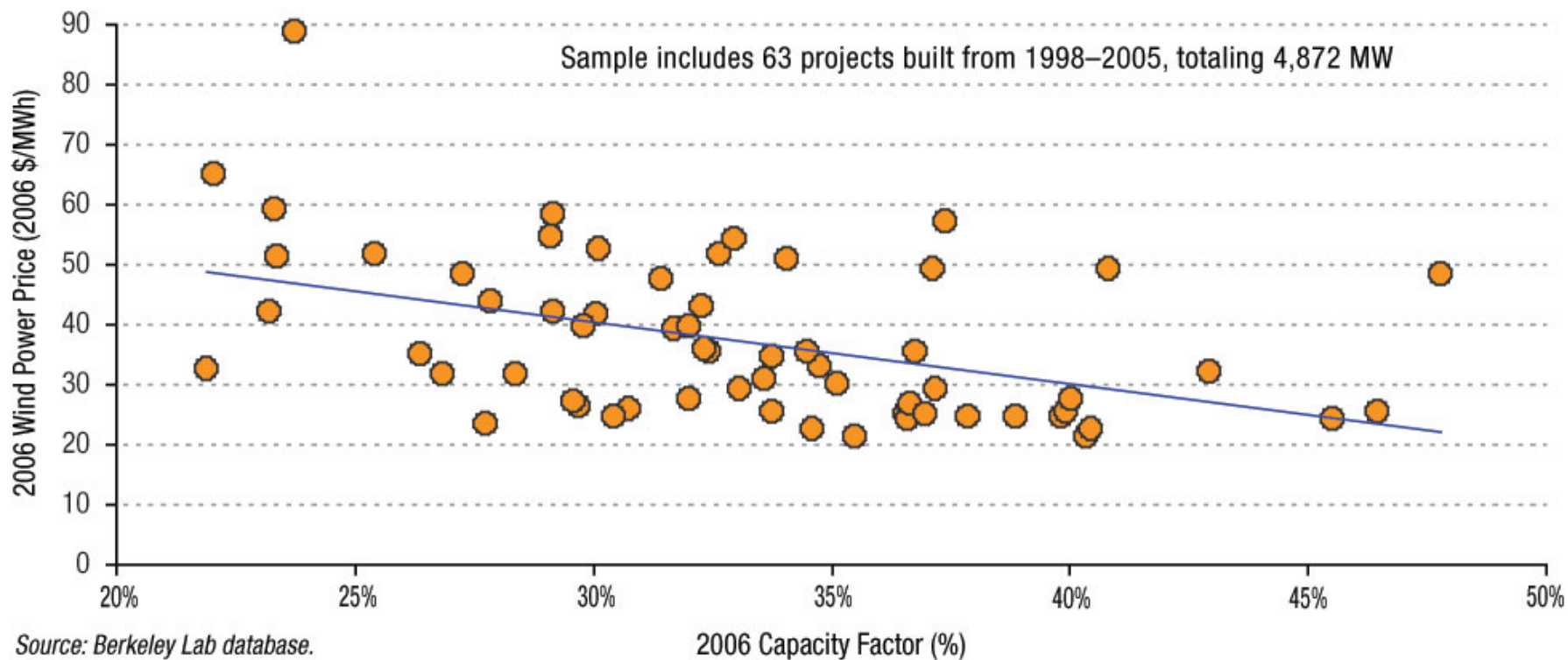


# Wind Power Sales Prices Are Affected by Installed Project Costs...



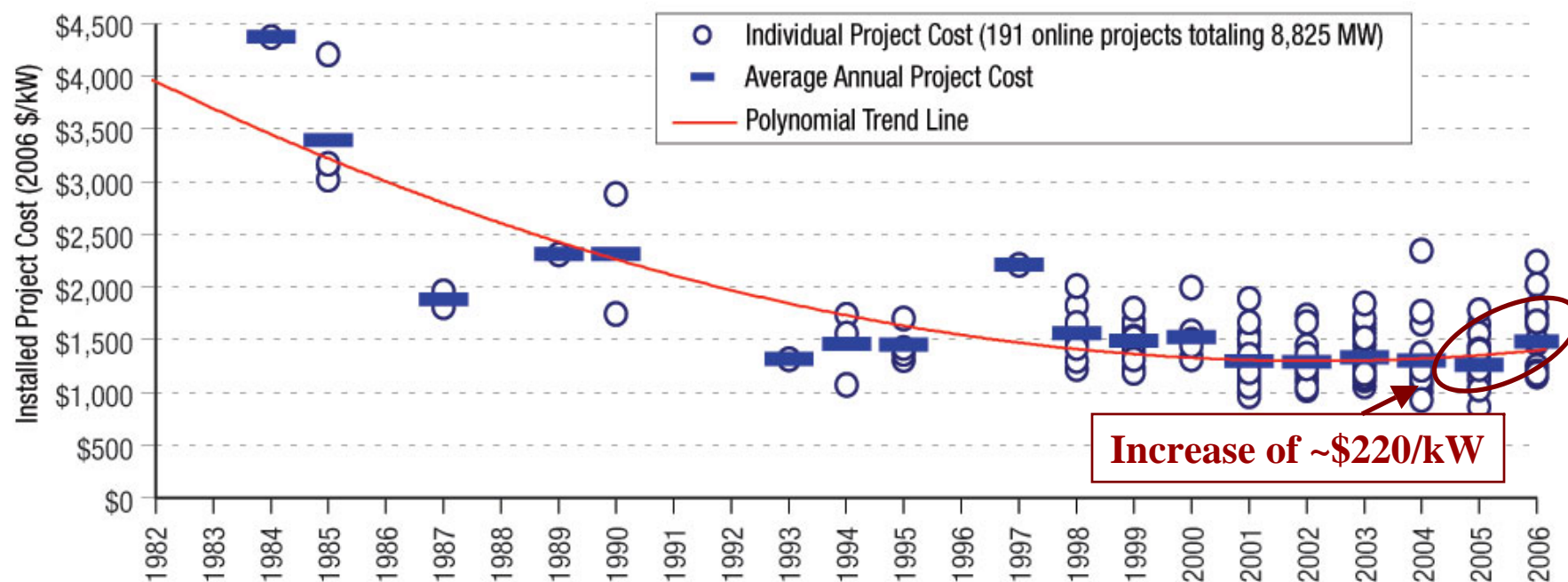


# ...and by Project Performance





# Installed Project Costs Are On the Rise, After a Long Period of Decline



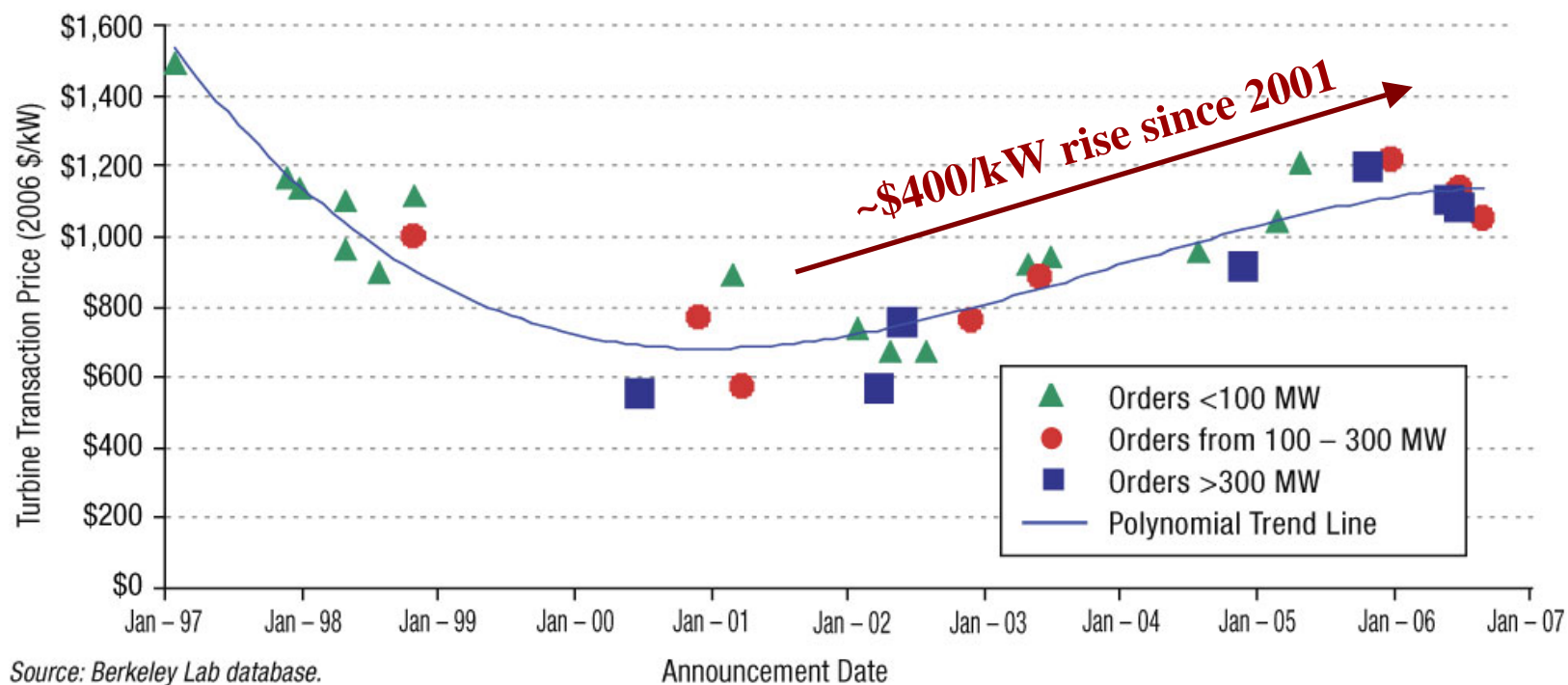
Source: Berkeley Lab database (some data points suppressed to protect confidentiality).

Projects proposed (but not yet built) in 2006 (not shown in graphic) are \$200/kW higher still (avg. ~\$1,680/kW)

Note: Sample of projects includes 191 online wind projects, totaling 8,825 MW (~76% of all wind capacity installed in the U.S. at the end of 2006)



# Project Cost Increases Are a Function of Wind Turbine Prices



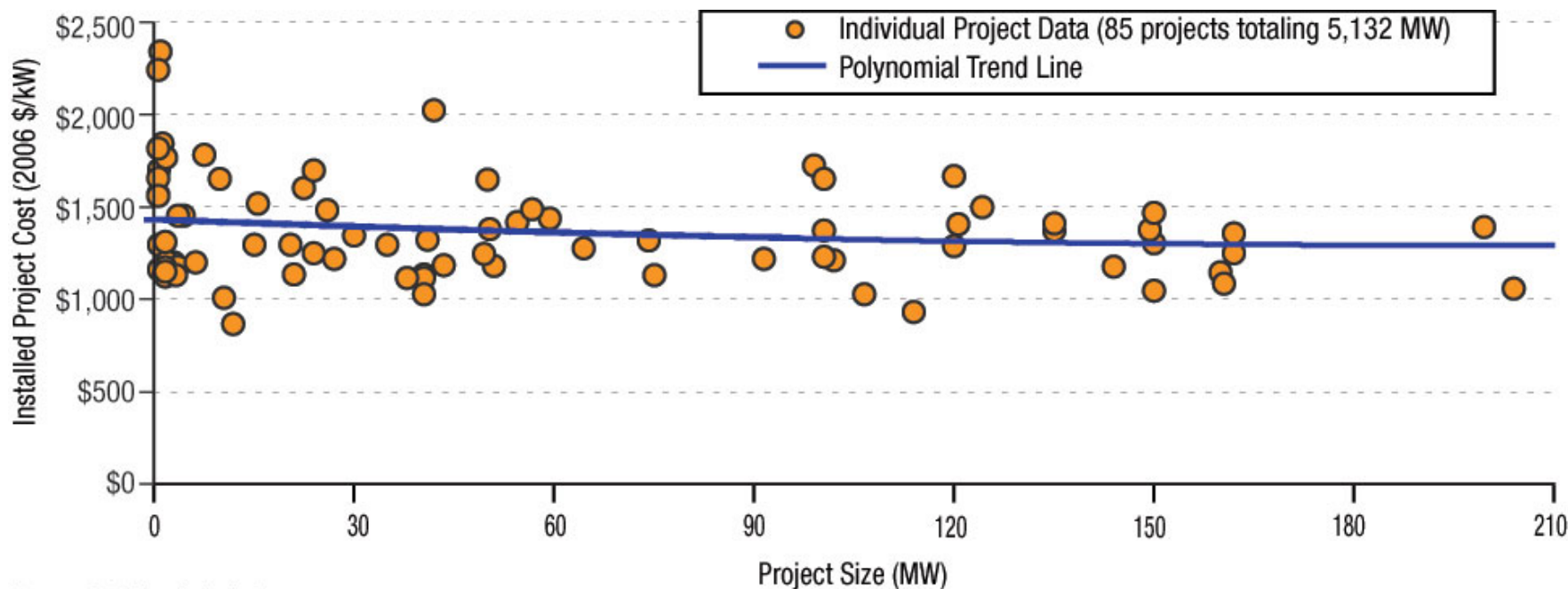
Source: Berkeley Lab database.

Since turbines are often ordered 12 or more months in advance, further project cost increases are expected

Note: Figure depicts reported transaction price data for 32 U.S. wind turbine orders totaling 8,986 MW and placed from 1997-2006



# Some Economies of Scale *May* Exist, at Least Among Smaller Wind Power Projects

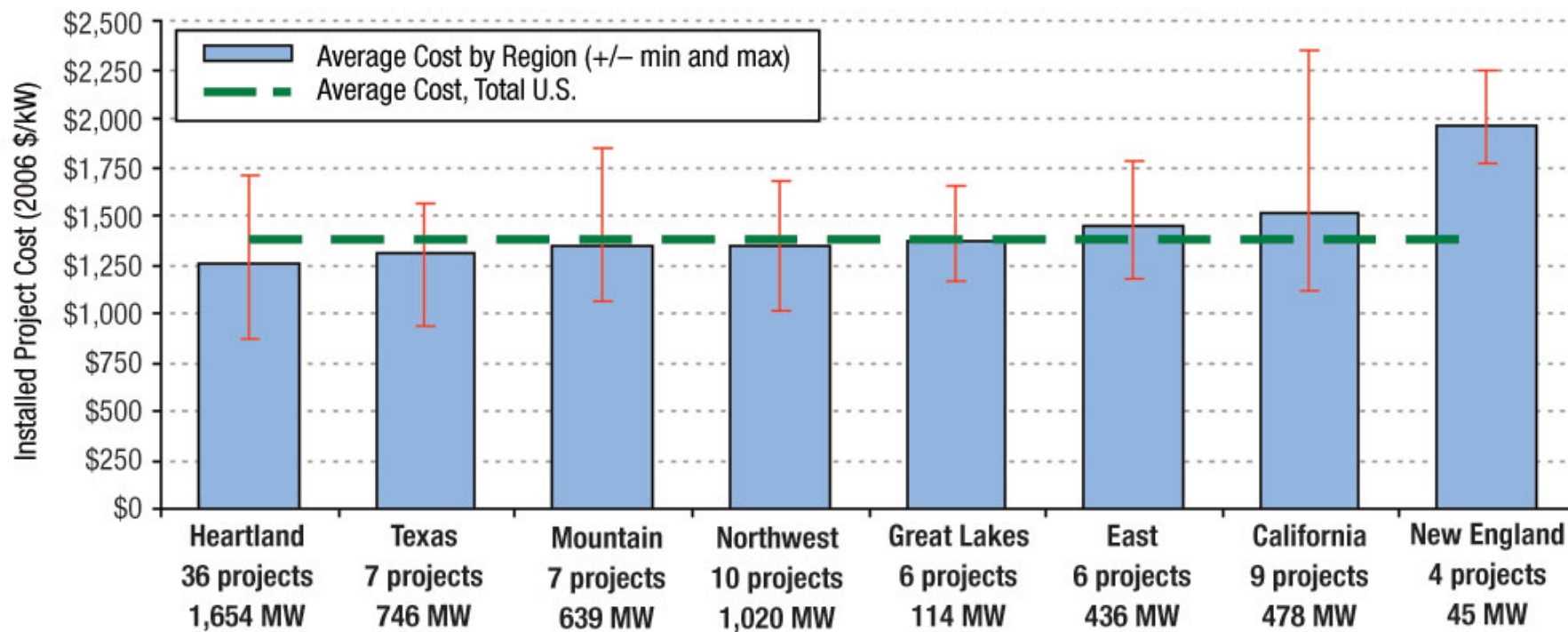


Source: Berkeley Lab database.

Note: Figure only includes projects that came online from 2003 through 2006



# Regional Differences in Wind Project Costs Are Apparent

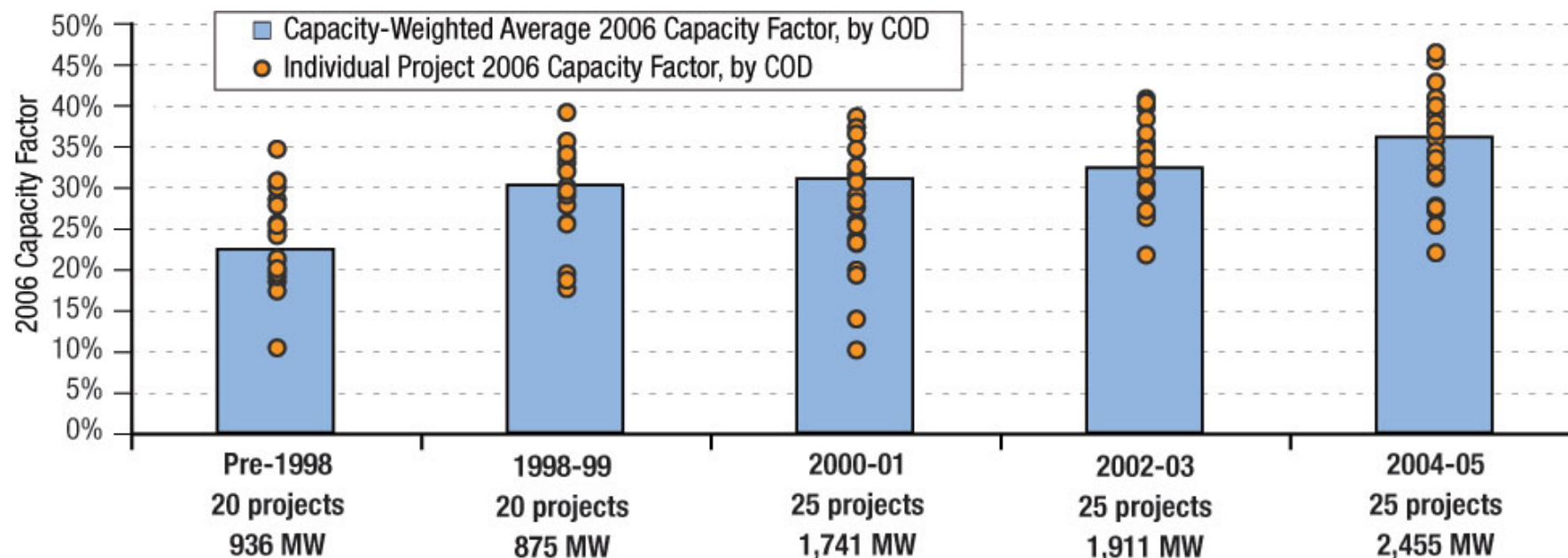


Source: Berkeley Lab database.

Note: Figure only includes projects that came online from 2003 through 2006



# Wind Project Performance Is Improving



Source: Berkeley Lab database.

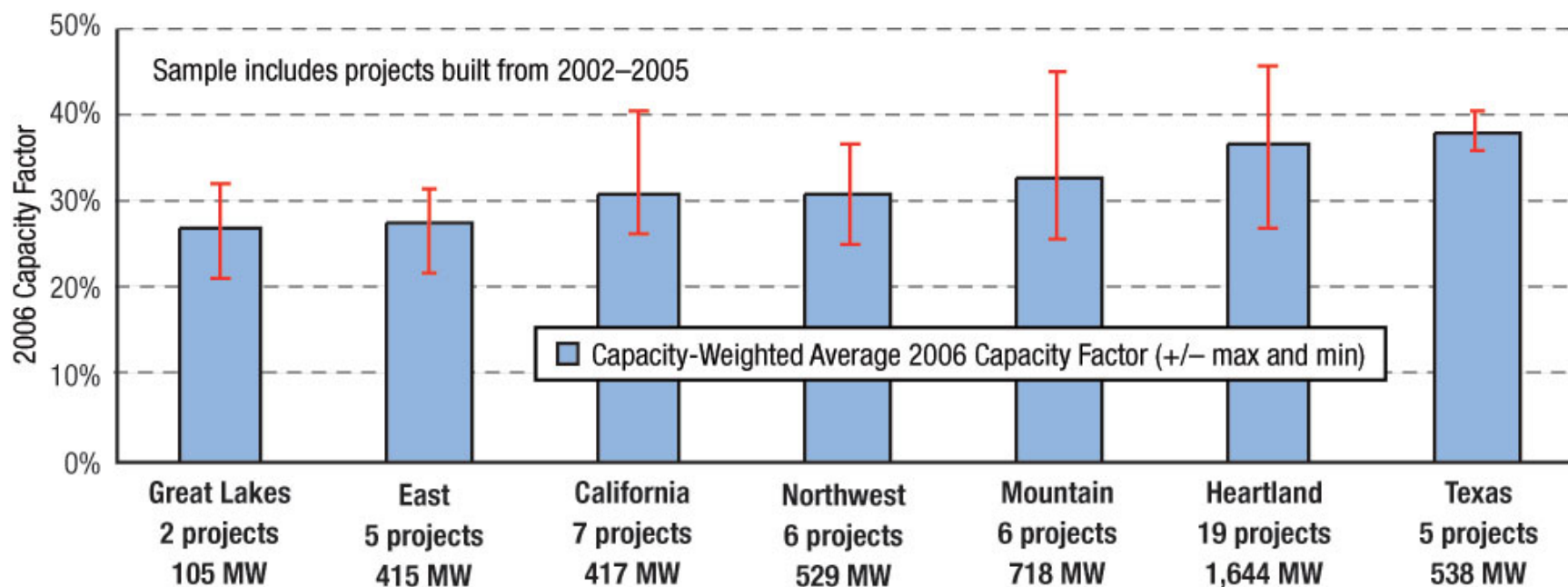
The average year-2006 capacity factor for projects built in 2004-05 (36%) is 20% greater than for projects built in 1998-99 (30%)

Note: Sample consists of 115 wind projects built from 1983-2005, totaling 7,918 MW (87% of nationwide capacity at end of 2005)





# Regional Performance Differences Are Apparent



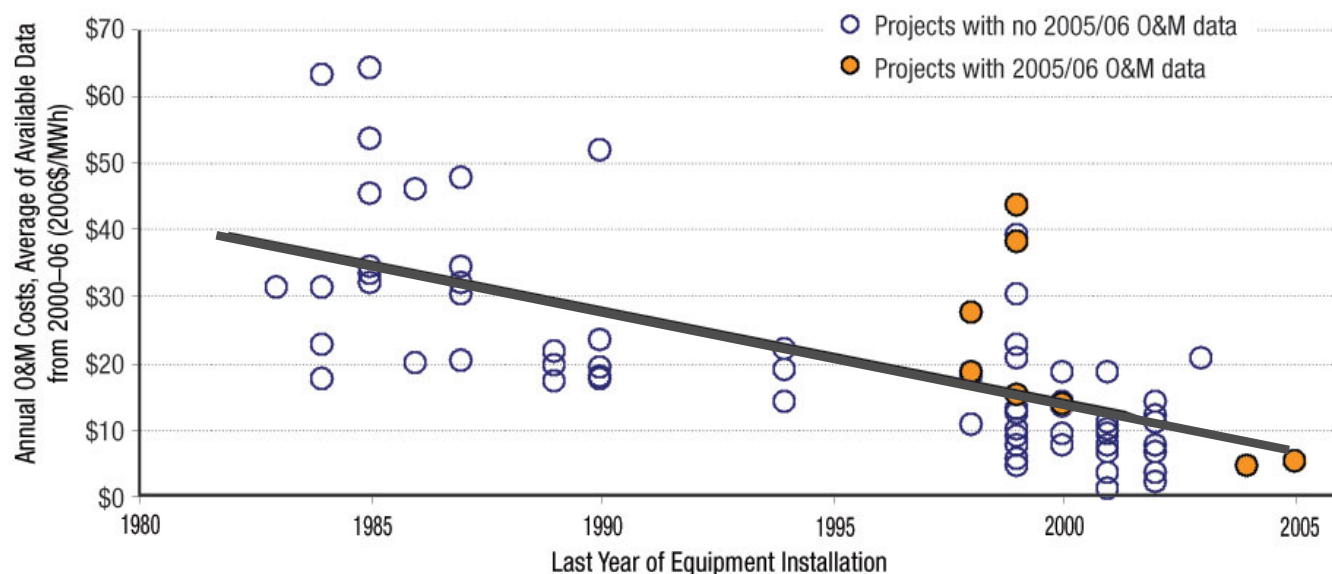
Source: Berkeley Lab database.

Capacity factors average more than 35% in Texas and the Heartland, and less than 30% in the East and Great Lakes

Note: Figure only includes projects that came online from 2002-05; note that sample size is problematic for several regions, including the Great Lakes



# Average Wind Project O&M Costs from 2000-06 Are Affected By Year of Installation



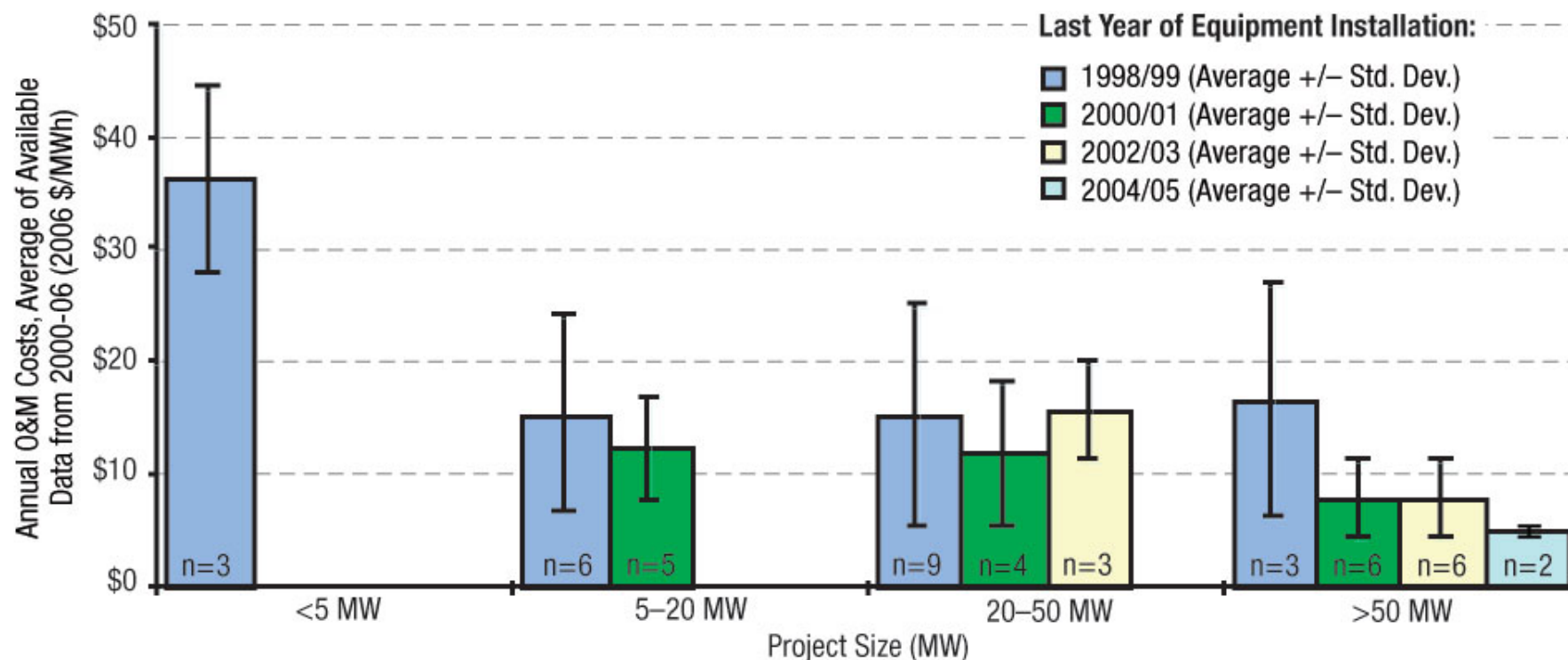
Source: Berkeley Lab database; five data points suppressed to protect confidentiality.

Capacity-weighted average 2000-06 O&M costs for projects built in 1980s equal **\$30/MWh**, dropping to **\$20/MWh** for projects built in 1990s, and to **\$8/MWh** for projects built in 2000s

Note: Sample is limited, and consists of 89 wind projects totaling 3,937 MW; few projects in sample have complete records of O&M costs from 2000-06



# Smaller Projects Appear to Experience Higher O&M Costs, on a \$/MWh Basis

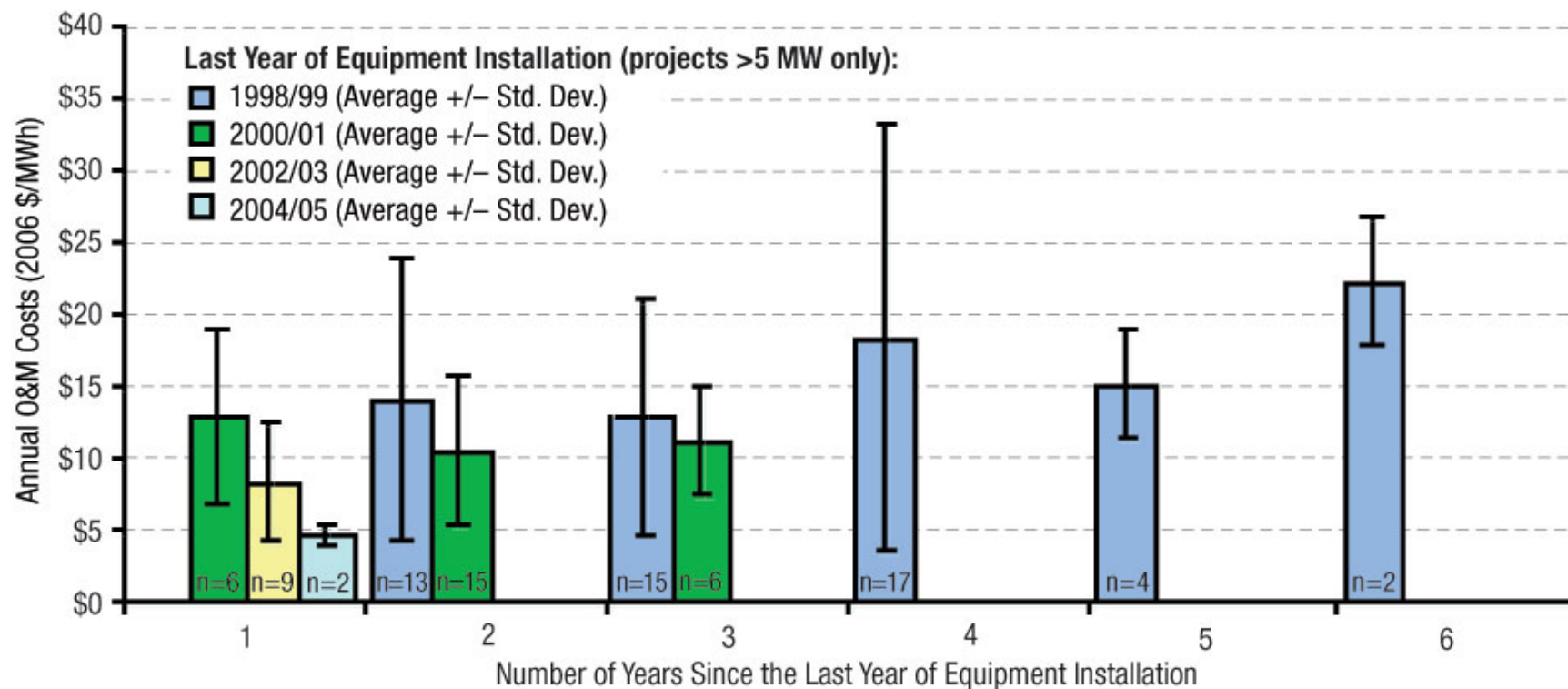


Source: Berkeley Lab database; averages shown only for groups of two or more projects.

Note: Sample is extremely limited; figure only includes projects built from 1998-2005



# O&M Appears to Increase with Project Age, Decrease with Recently Constructed Projects



Source: Berkeley Lab database; averages shown only for groups of two or more projects.

Note: Sample is extremely limited; figure only includes projects over 5 MW in size and built from 1998-2005



# Integrating Wind into Power Systems Is Manageable, But Not Costless

Table 6. Key Results from Major Wind Integration Studies Completed 2003-2006

Date	Study	Wind Capacity Penetration	Cost (\$/MWh)				
			Regulation	Load Following	Unit Commitment	Gas Supply	TOTAL
2003	Xcel-UWIG	3.5%	0	0.41	1.44	na	1.85
2003	We Energies	4%	1.12	0.09	0.69	na	1.90
2003	We Energies	29%	1.02	0.15	1.75	na	2.92
2004	Xcel-MNDOC	15%	0.23	na	4.37	na	4.60
2005	PacifiCorp	20%	0	1.6	3	na	4.60
2006	CA RPS (multi-year)	4%	0.45*	trace	na	na	0.45
2006	Xcel-PSCo	10%	0.2	na	2.26	1.26	3.72
2006	Xcel-PSCo	15%	0.2	na	3.32	1.45	4.97
2006	MN-MISO 20%	31%	na	na	na	na	4.41**

\* 3-year average

\*\* highest over 3-year evaluation period

Source: National Renewable Energy Laboratory.

- Considerable amount of analysis has been conducted in recent years on the potential impacts of wind on power systems
- Wind integration costs often found to average less than \$5/MWh for wind capacity penetrations up to ~15%



# Transmission Is a Significant Barrier to Wind; Solutions Continued to Emerge in 2006

- U.S. DOE national transmission congestion study
- FERC allowing additional profit incentives for transmission owners, potentially encouraging greater investment
- WGA's 30 GW clean energy goal, including recommendations for transmission expansion and more efficient use of existing transmission
- Several states beginning to proactively develop transmission infrastructure for wind: Texas (CREZ); California (Tehachapi); MidWest (CapX 2020)
- Large number of transmission projects planned that include wind
- 2007 development to date: (1) U.S. DOE draft designations of two National Interest Electric Transmission Corridors; (2) FERC Order 890; (3) FERC approval (in principal) of proposal from California ISO for new category of transmission to better serve wind



## **Federal and State Policy Efforts Continue to Drive Wind Development: 2006 Activities**

- Federal PTC extension through 2008
- \$270 million of Clean Renewable Energy Bonds to 112 wind projects (~200 MW)
- \$17 million of USDA 9006 grant awards to 14 wind projects (28 MW)
- One new state RPS (Washington), and several revisions to existing state RPS policies (Additional state RPS activity has occurred in 2007)
- State renewable funds, tax incentives, utility planning, green power, and growing interest in carbon regulation all also played a role in 2006



## Coming Up in 2007

- Lack of transmission availability, siting and permitting conflicts, and other barriers to wind development remain
- Nonetheless, 2007 expected to be another excellent year for the U.S. wind industry, with 25-30% growth projected
- With PTC continued through 2008, strong growth should extend at least through that year
- U.S. DOE and wind industry evaluating possible costs, benefits, and challenges of meeting 20% of nation's electricity supply with wind





## For More Information...

See full report for additional findings, a discussion of the sources of data used, etc.

- <http://www1.eere.energy.gov/windandhydro/>

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