U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Land-Based Wind Market Report: 2023 Edition

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Land-Based Wind Market Report: 2023 Edition

Purpose and Scope:

- Summarize data on key trends in the U.S. wind power sector
- Focus on land-based wind turbines over 100 kW in size
  - Separate DOE-funded data collection efforts on distributed and offshore wind
  - Note that the *Installation Trends*, *Industry Trends*, and *Future Outlook* sections include data on both land-based and offshore wind; other chapters focus solely on land-based
- Focus on historical data, with some emphasis on the previous year

Funding:

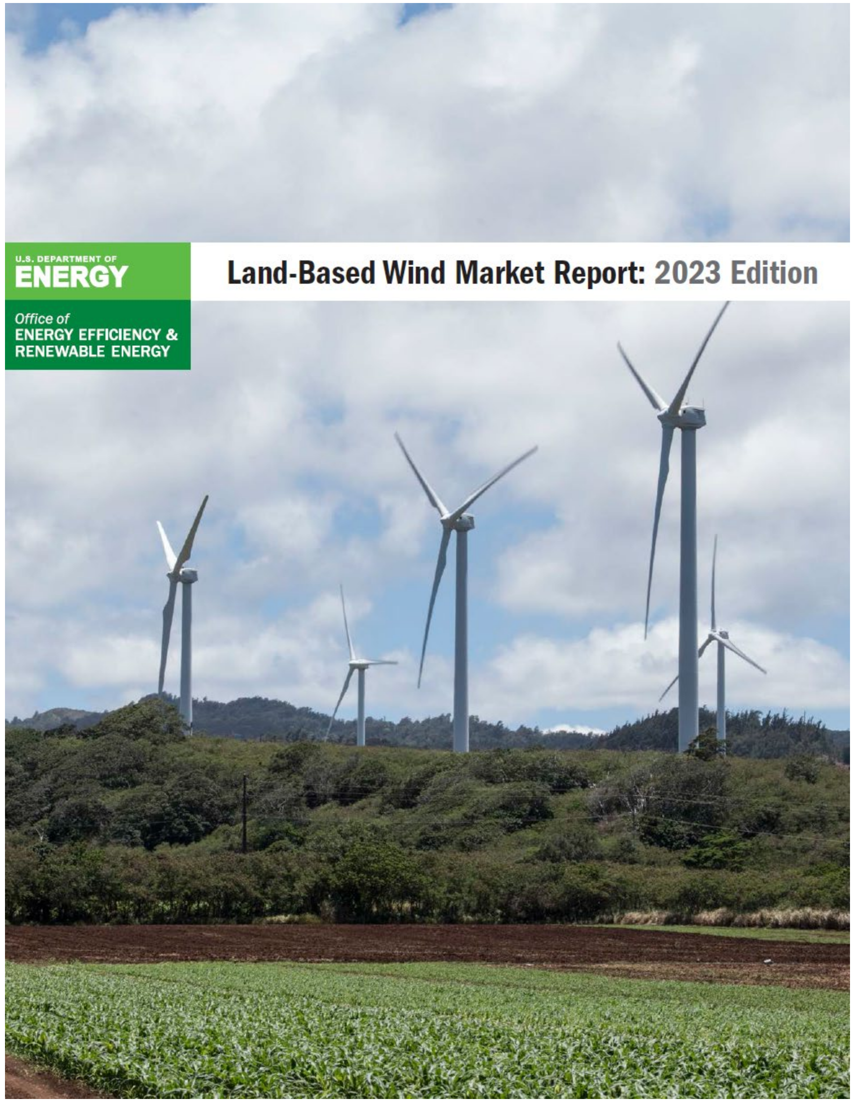
- U.S. Department of Energy's Wind Energy Technologies Office

Products and Availability:

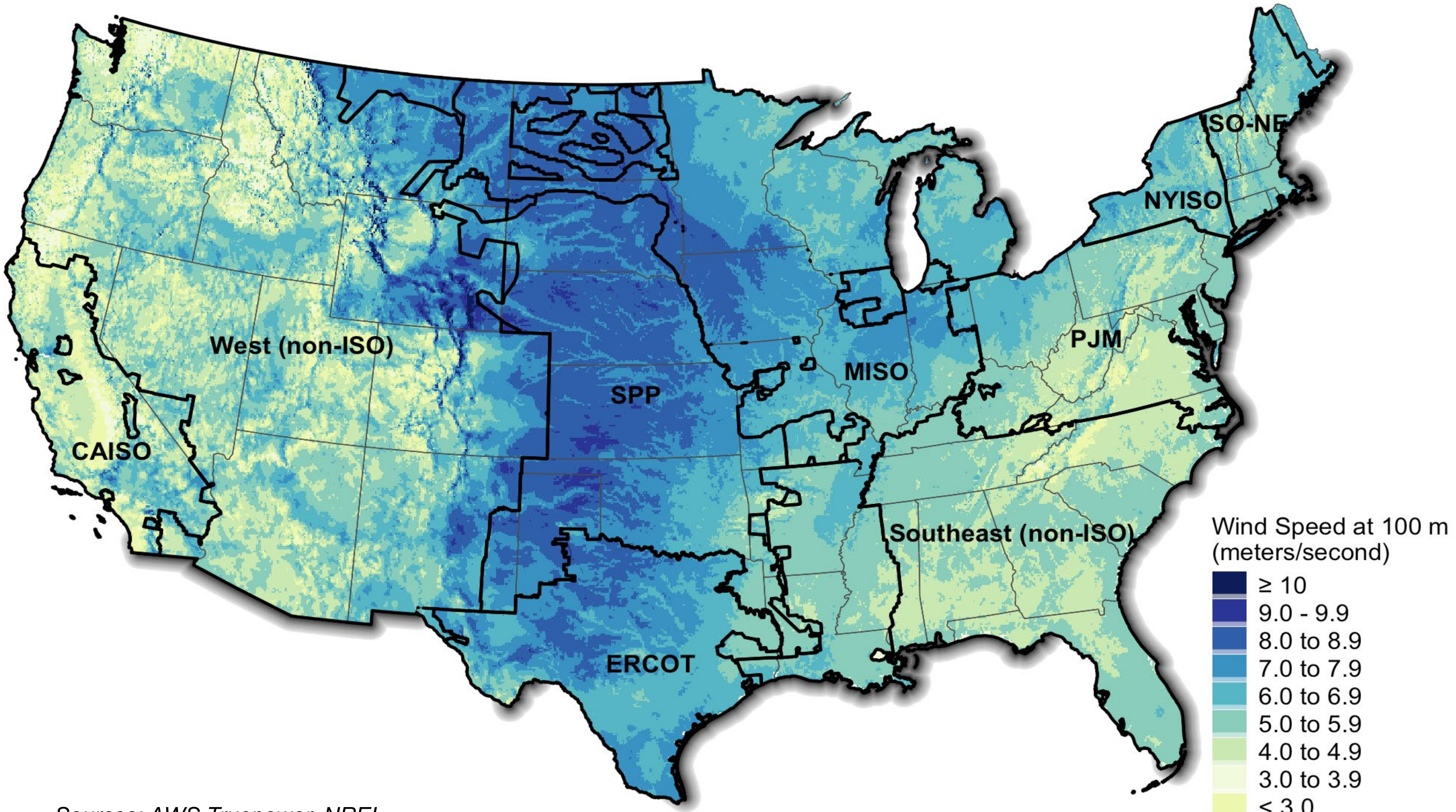
- This briefing is complemented with underlying report, data file, and visualizations
- All products available at: windreport.lbl.gov

Presentation Contents

- Installation trends
- Industry trends
- Technology trends
- Performance trends
- Cost trends
- Power sales price and levelized cost trends
- Cost and value comparisons
- Future outlook



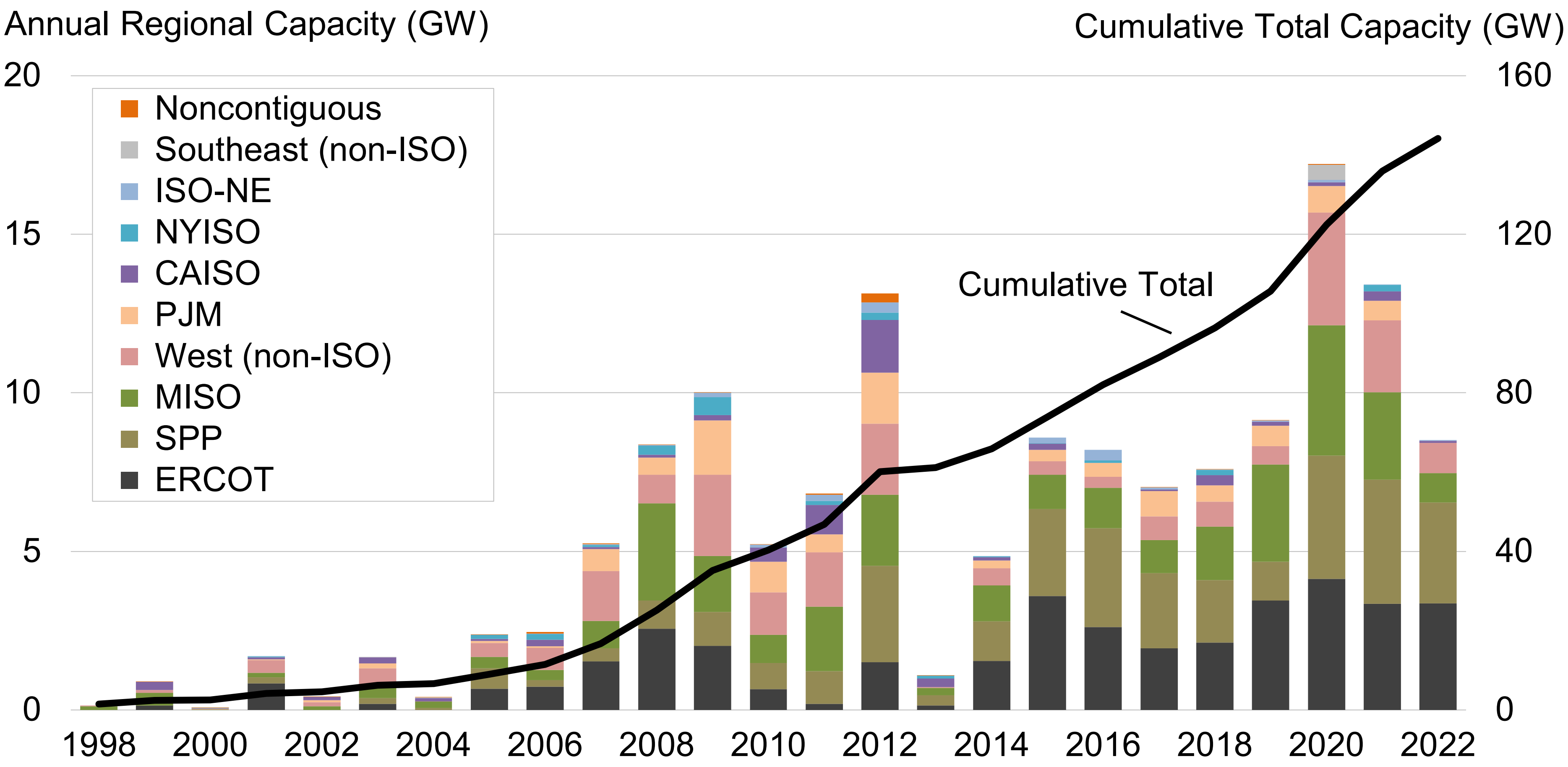
Regional boundaries applied in this analysis include the seven independent system operators (ISO) and two non-ISO regions



Sources: AWS Truepower, NREL

Installation Trends

Total U.S. wind capacity additions equaled 8.5 GW in 2022, representing $12 billion in capital investment



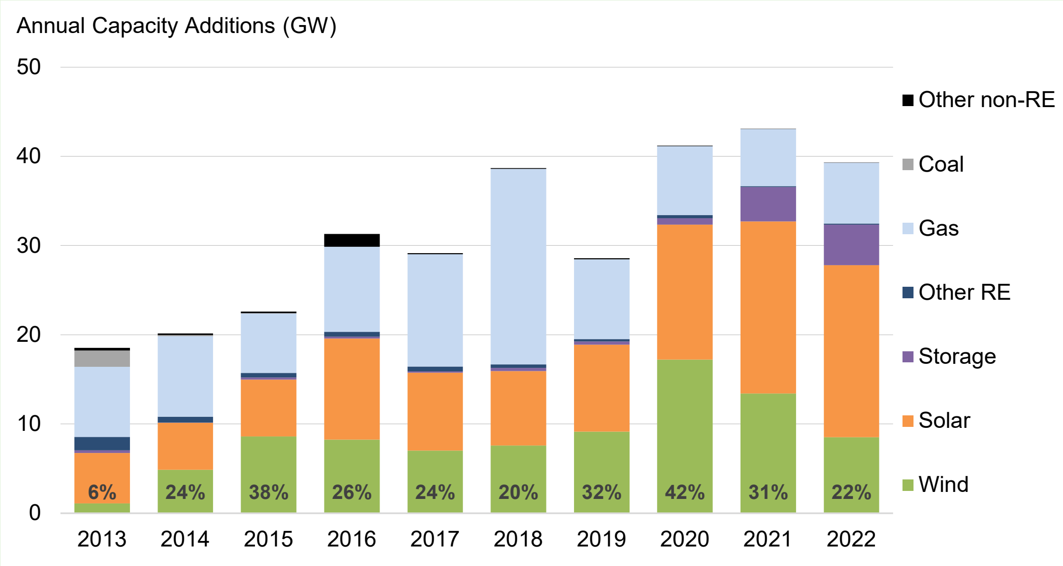
Source: ACP

- 77% of new capacity in ERCOT and SPP
- Partial repowering: 1.7 GW of turbines retrofitted in 2022
- 144 GW of total installed capacity at end of 2022

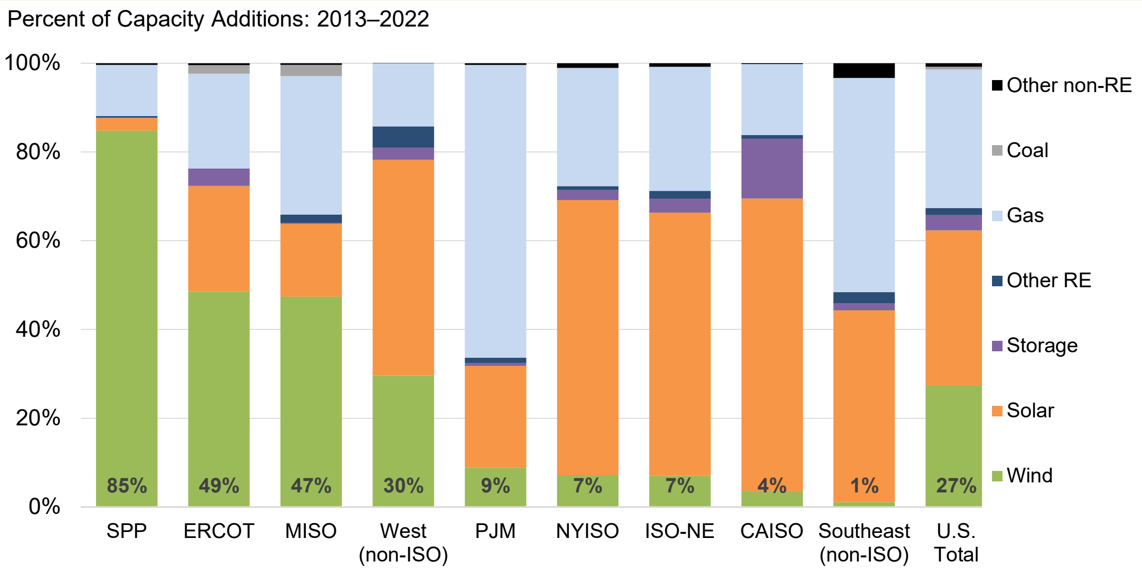
Interactive data visualization: https://emp.lbl.gov/wind-energy-growth

Wind power represented the second largest source of U.S. electric-capacity additions in 2022, at 22%, behind solar's 49%

Relative contribution of resource types in annual capacity additions



Resource capacity additions by region: 2013-2022



Sources: Hitachi, ACP, EIA, Berkeley Lab

Over the last decade, wind has comprised 27% of total capacity additions, and a much higher proportion in SPP, ERCOT, and MISO

Globally, the United States ranked 2nd in annual and cumulative total wind power capacity additions in 2022

Annual Capacity (2022, GW)	
China	37.6
United States	**8.5**
Brazil	4.1
Germany	2.7
Sweden	2.4
Finland	2.4
France	2.1
India	1.8
United Kingdom	1.7
Spain	1.7
Rest of World	12.4
TOTAL	**77.5**

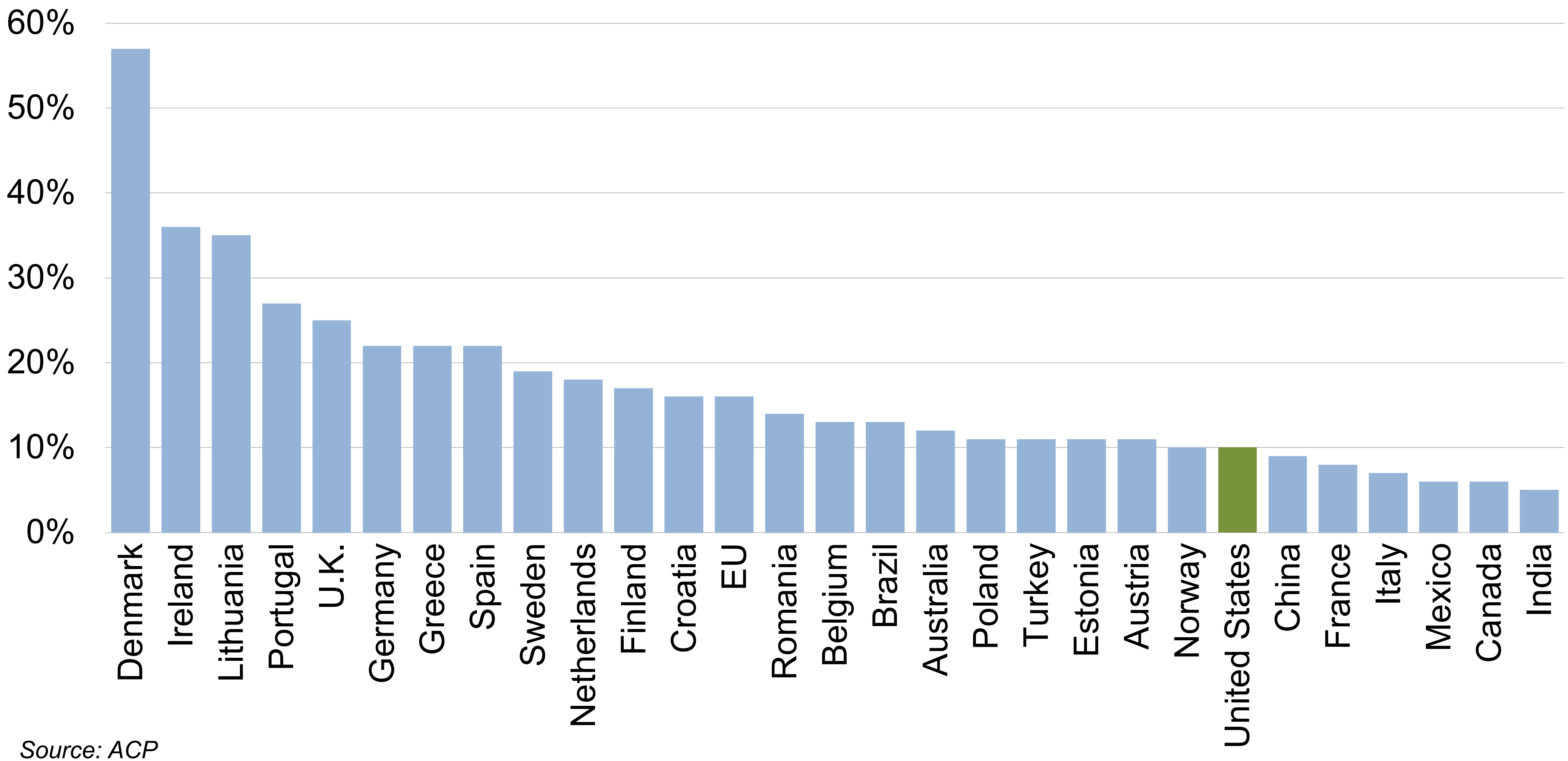
Cumulative Capacity (end of 2022, GW)	
China	365
United States	**144**
Germany	67
India	42
Spain	30
United Kingdom	28
Brazil	26
France	21
Canada	15
Sweden	15
Rest of World	153
TOTAL	**906**

- Global wind additions totaled over 77 GW of newly added capacity
- U.S. remains a distant second to China in annual and cumulative capacity

Sources: GWEC, ACP

The United States ranks lower than many other countries in terms of wind energy as a share of total generation

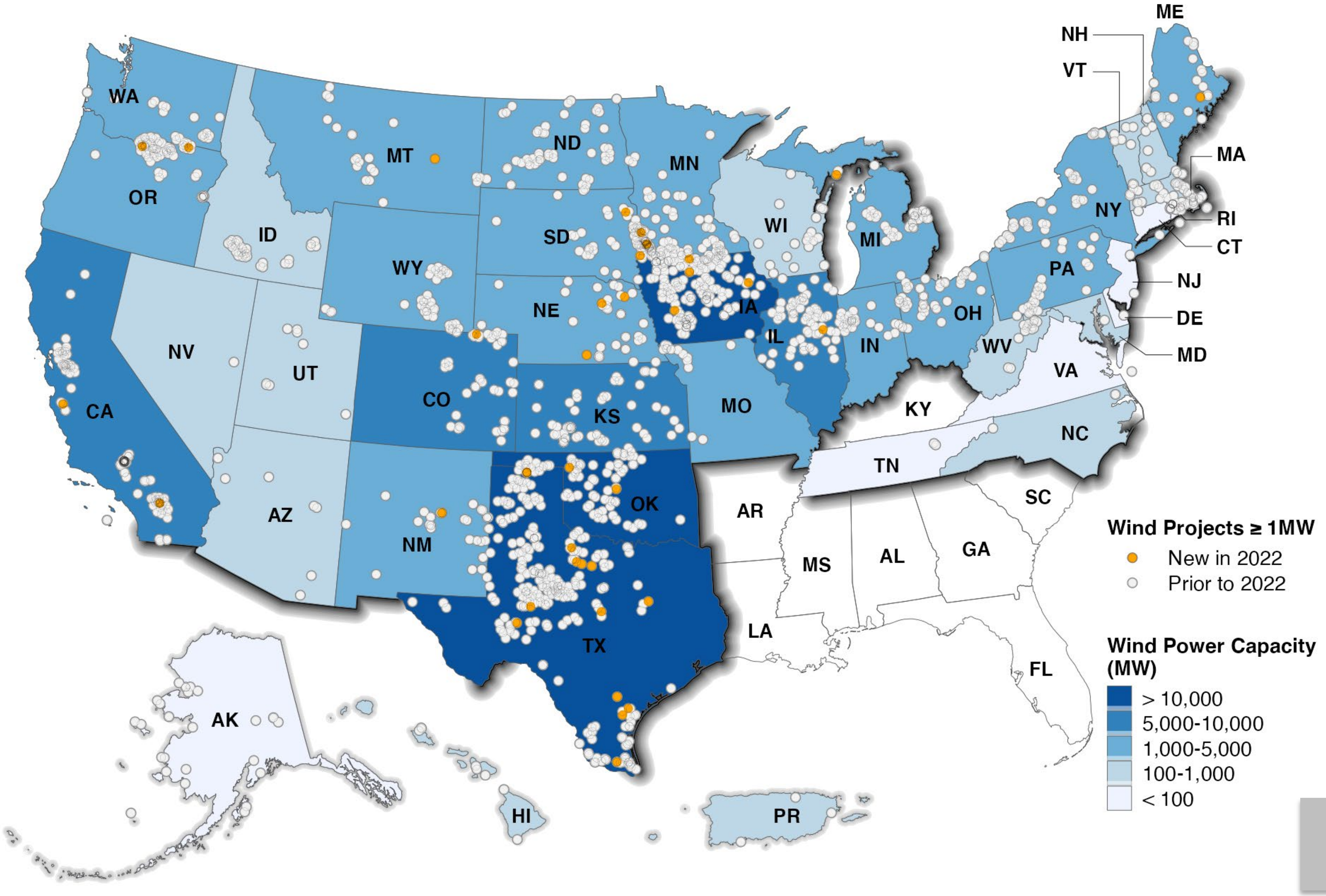
Wind as Percentage of Total Generation in 2022



Source: ACP

Note: Figure includes a subset of the top global wind markets

The geographic spread of wind power projects across the United States is broad, with the exception of the Southeast



Interactive data visualization:
https://emp.lbl.gov/wind-energy-growth

Source: ACP, Berkeley Lab

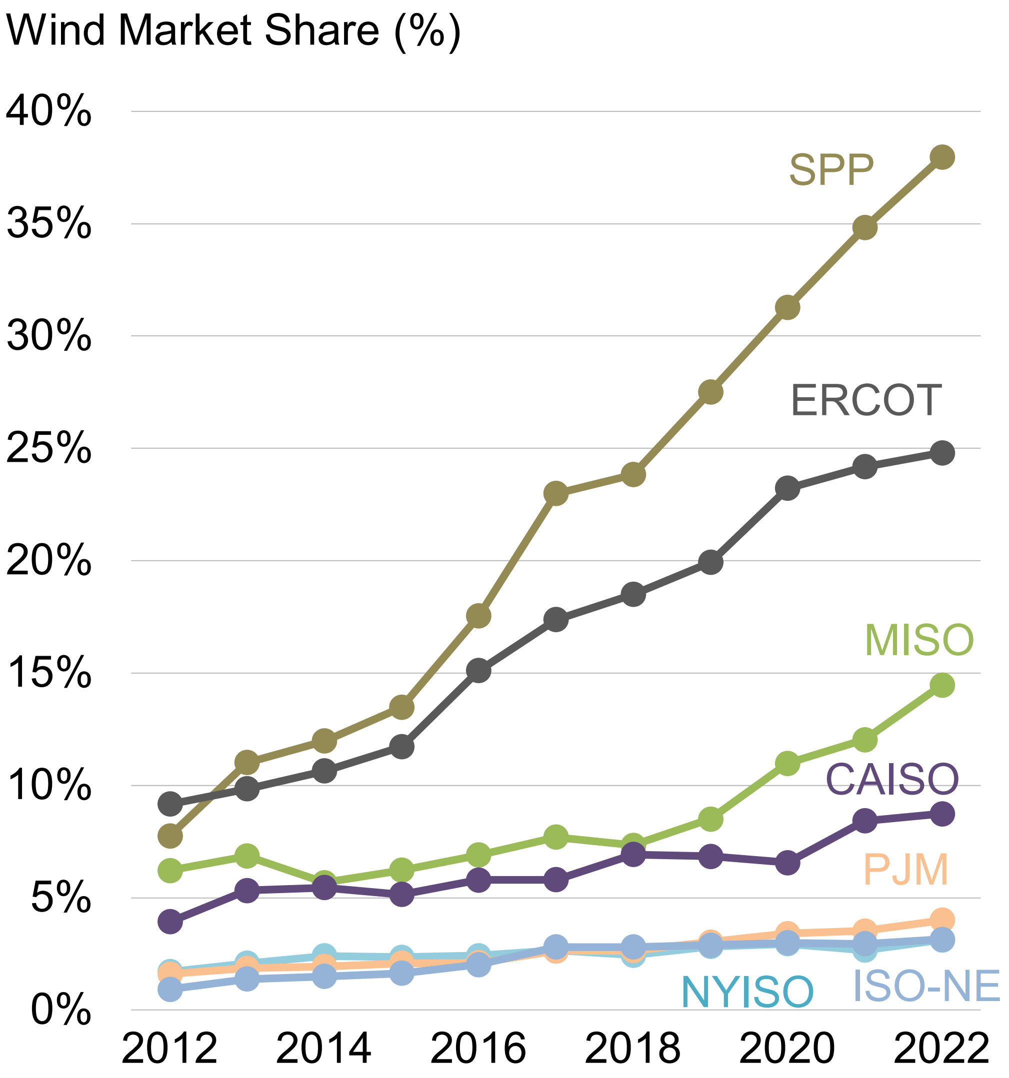
Texas installed the most wind power capacity in 2022; 12 states exceeded 20% wind as a fraction of in-state generation

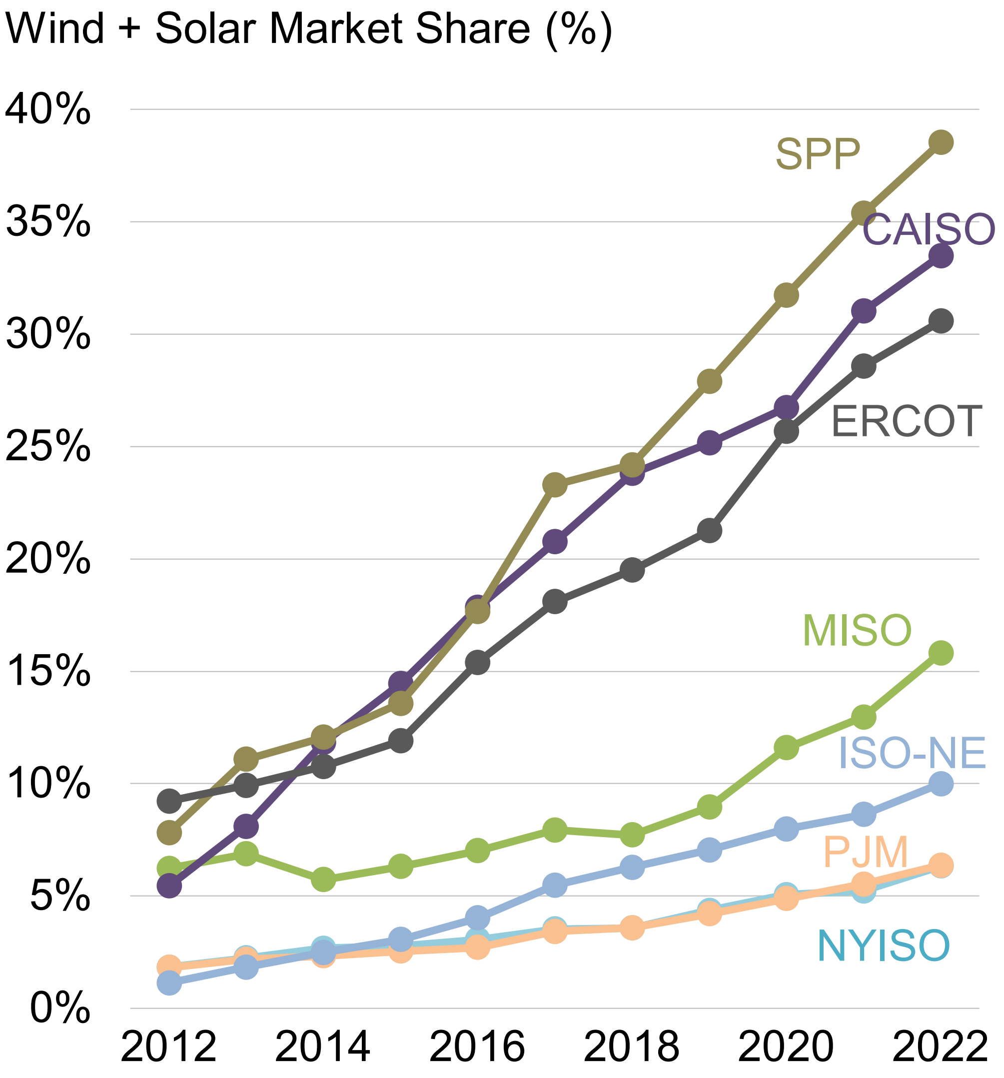
Installed Capacity (MW)				2022 Wind Generation as a Percentage of:			
Annual (2022)		Cumulative (end of 2022)		In-State Generation		In-State Sales	
Texas	4,028	Texas	40,151	Iowa	62.4%	Iowa	81.9%
Oklahoma	1,607	Iowa	12,783	South Dakota	54.8%	South Dakota	76.9%
Nebraska	602	Oklahoma	12,222	Kansas	47.0%	Kansas	69.9%
Iowa	484	Kansas	8,240	Oklahoma	43.5%	North Dakota	65.5%
Montana	366	Illinois	7,129	North Dakota	36.7%	Wyoming	60.4%
South Dakota	304	California	6,118	New Mexico	34.9%	Oklahoma	54.0%
Minnesota	245	Colorado	5,194	Nebraska	31.0%	New Mexico	52.6%
New Mexico	235	Minnesota	4,749	Colorado	28.0%	Nebraska	37.7%
Oregon	210	New Mexico	4,327	Minnesota	23.5%	Colorado	29.2%
Colorado	145	North Dakota	4,302	Maine	22.8%	Montana	25.9%
Illinois	120	Oregon	4,055	Wyoming	21.8%	Texas	25.3%
Michigan	72	Nebraska	3,519	Texas	21.6%	Maine	23.3%
California	72	Indiana	3,468	Vermont	18.2%	Minnesota	21.5%
Maine	20	Washington	3,407	Idaho	16.6%	Oregon	17.1%
		Michigan	3,231	Montana	14.8%	Illinois	16.9%
		South Dakota	3,219	Oregon	14.3%	Idaho	11.1%
		Wyoming	3,176	Illinois	12.1%	Washington	10.1%
		Missouri	2,435	Indiana	9.9%	Indiana	9.7%
		New York	2,192	Missouri	9.4%	Missouri	9.3%
		Montana	1,487	Michigan	7.8%	Michigan	9.1%
Rest of U.S.	*0*	*Rest of U.S.*	*8,769*	*Rest of U.S.*	*1.7%*	*Rest of U.S.*	*1.5%*
Total	**8,511**	**Total**	**144,173**	**Total**	**10.1%**	**Total**	**11.2%**

Interactive data visualization: https://emp.lbl.gov/wind-energy-growth

Source: ACP, EIA

Wind penetration by ISO/RTO is highly variable; in 2022, it was highest in SPP at 38% and ERCOT at 25%

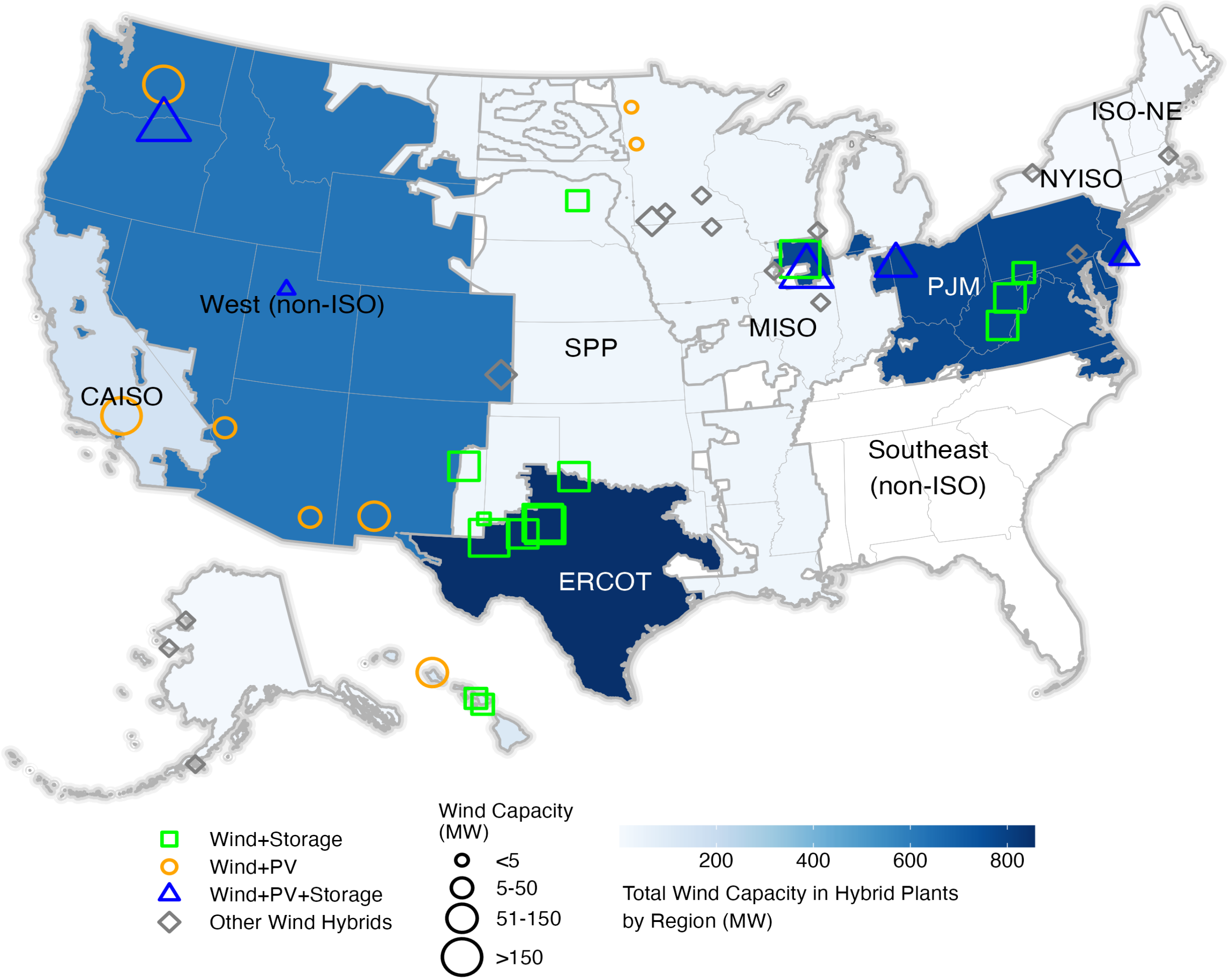




Sources: SPP, ERCOT, MISO, CAISO, PJM, ISO-NE, NYISO

Hybrid wind plants that pair wind with storage, solar, or other resources saw limited growth in 2022; only one new project

Online Wind Hybrid / Co-located Projects



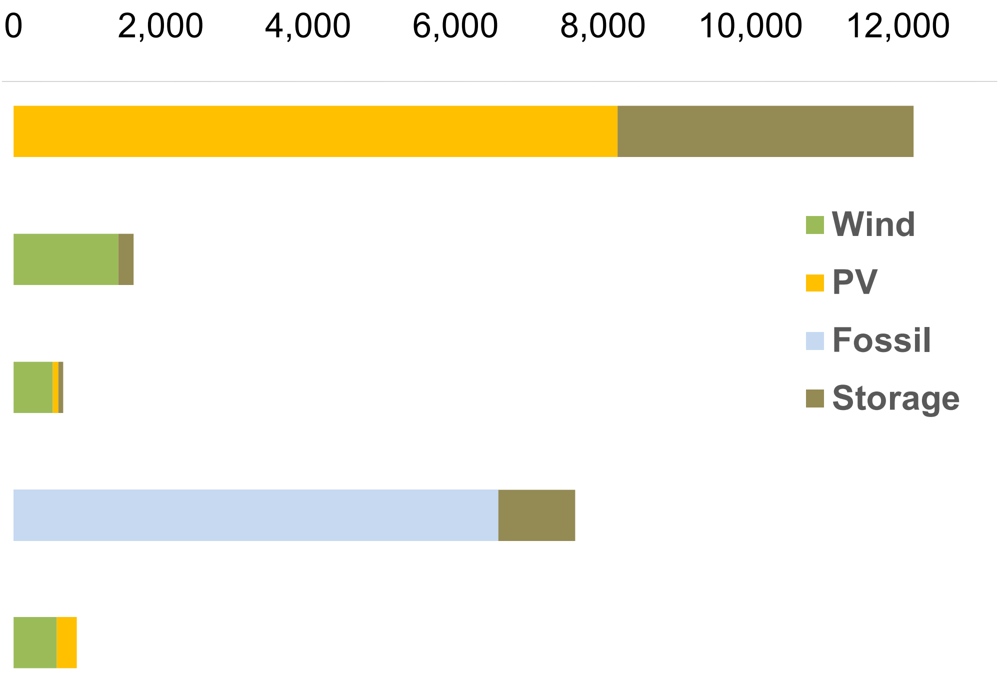
- 41 hybrid wind power plants in operation at the end of 2022
- Represent 2.6 GW of wind power and 0.8 GW of co-located resources
- Most common wind hybrid project combines wind+storage; other combinations include wind+PV; wind+PV+storage; wind+gas
- ERCOT, PJM, non-ISO West host largest amount of wind hybrid capacity

Interactive data visualization:
https://emp.lbl.gov/online-hybrid-and-energy-storage-projects

Sources: EIA-860 Early Release, Berkeley Lab

Comparing the frequency and design of a subset of the hybrid / co-located project configurations: end of 2022

	# projects	Total capacity (MW)	Storage ratio	Duration (hrs)
PV+Storage	213		49%	3.1
Wind+Storage	14		14%	0.6
Wind+PV+Storage	5		11%	2.0
Fossil+Storage	26		16%	2.3
Wind+PV	8		n/a	n/a



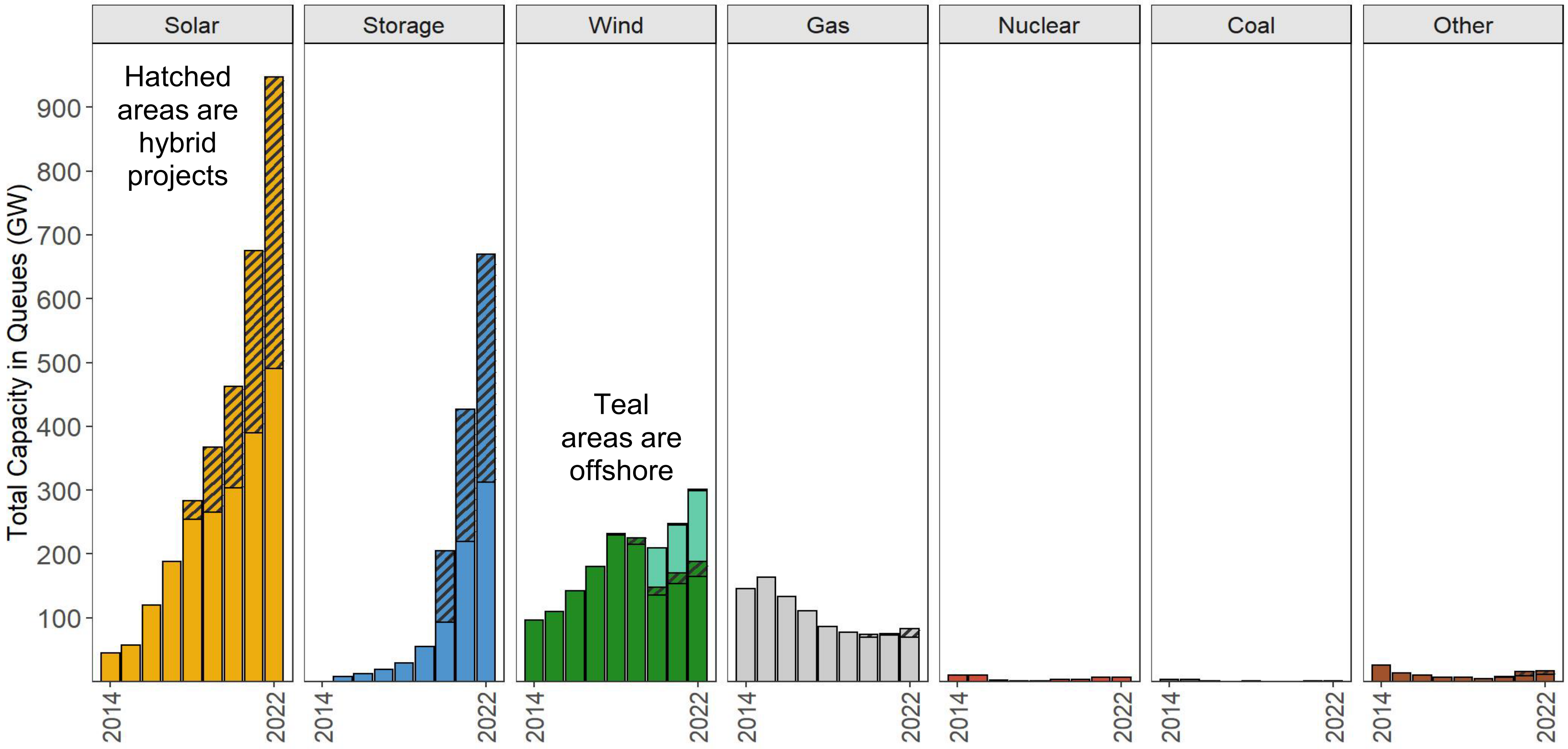
Notes: Not included in the figure are many other hybrid projects with other configurations. Storage ratio defined as total storage capacity divided by total generator capacity for a given project type.

Sources: EIA 860 Early Release, Berkeley Lab

Most wind hybrids are Wind+Storage, with limited storage duration to serve ancillary services markets

Interactive data visualization: https://emp.lbl.gov/online-hybrid-and-energy-storage-projects

A record-high 300 GW of wind exists in transmission interconnection queues, but solar and storage are expanding much more rapidly



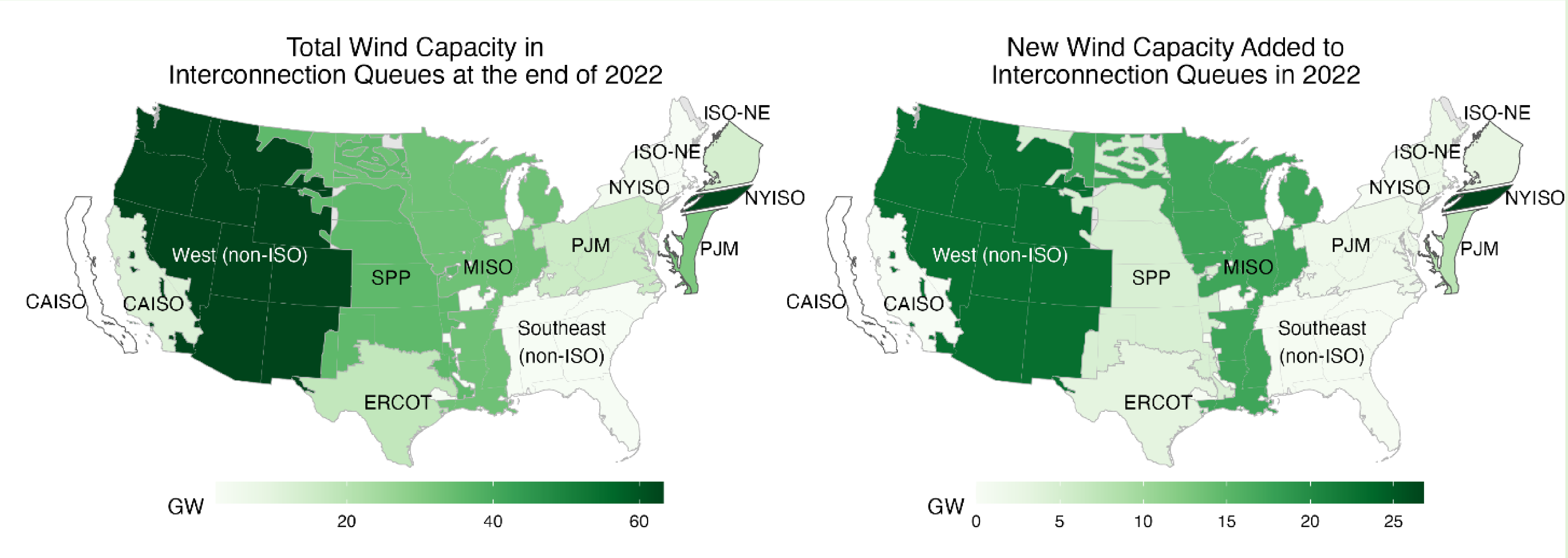
Not all this capacity will be built: <25% historical completion rate

Note: Storage capacity in hybrids was not estimated for years prior to 2020; offshore wind was not separately identified prior to 2020

Source: Berkeley Lab review of interconnection queues

Interactive data visualization: https://emp.lbl.gov/generation-storage-and-hybrid-capacity

Larger amounts of wind capacity in NYISO, non-ISO West, and PJM queues; 38% (113 GW) of wind capacity in queues is offshore

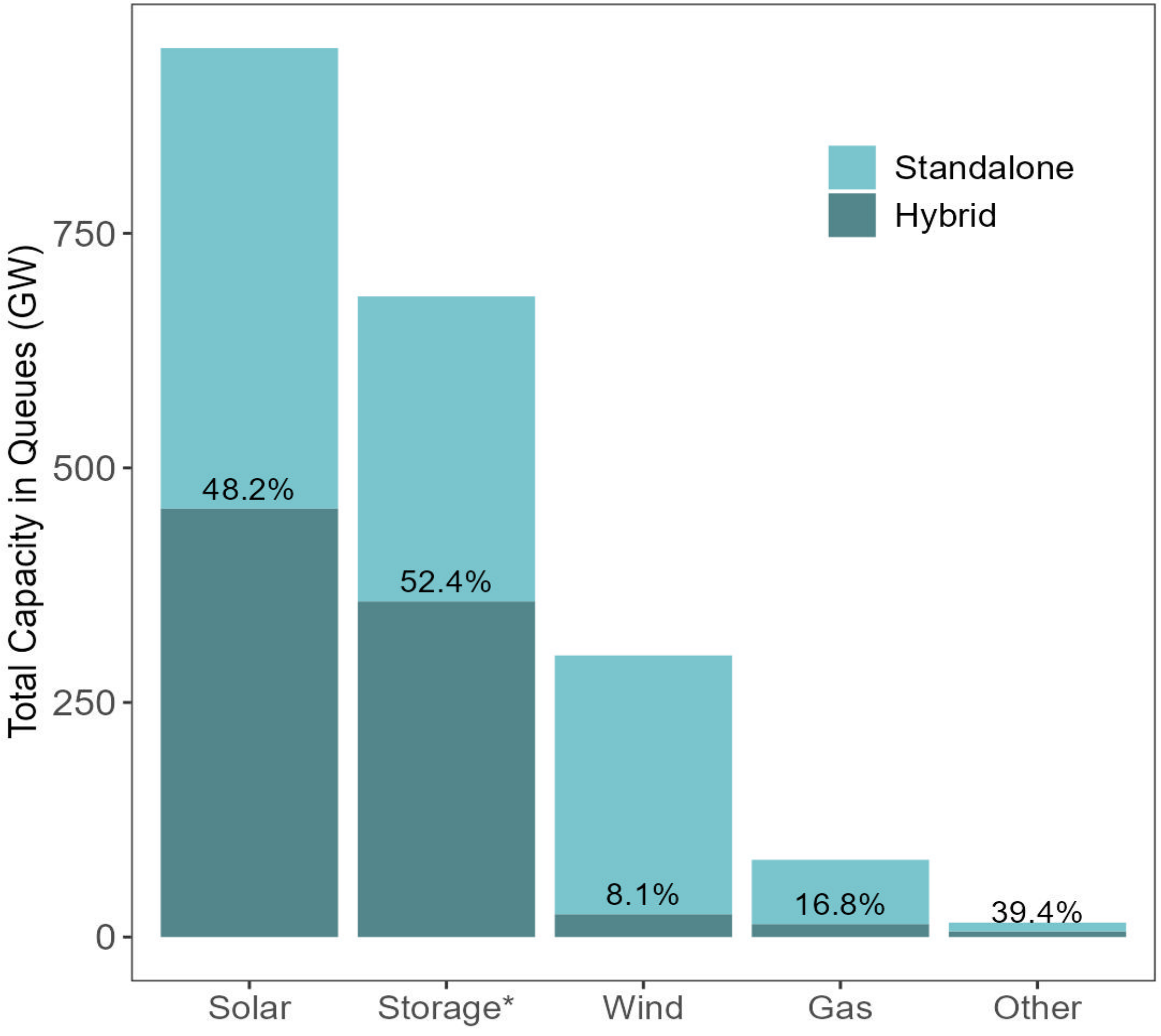


Source: Berkeley Lab review of interconnection queues

Note: Offshore areas reflect the amount of offshore wind in the interconnection queues of each region.

Interactive data visualization: https://emp.lbl.gov/generation-storage-and-hybrid-capacity

Hybrid plants: 8% of wind proposed as hybrids (24 GW); much larger fraction of solar proposed as hybrids, at 48%



Source: Berkeley Lab review of interconnection queues

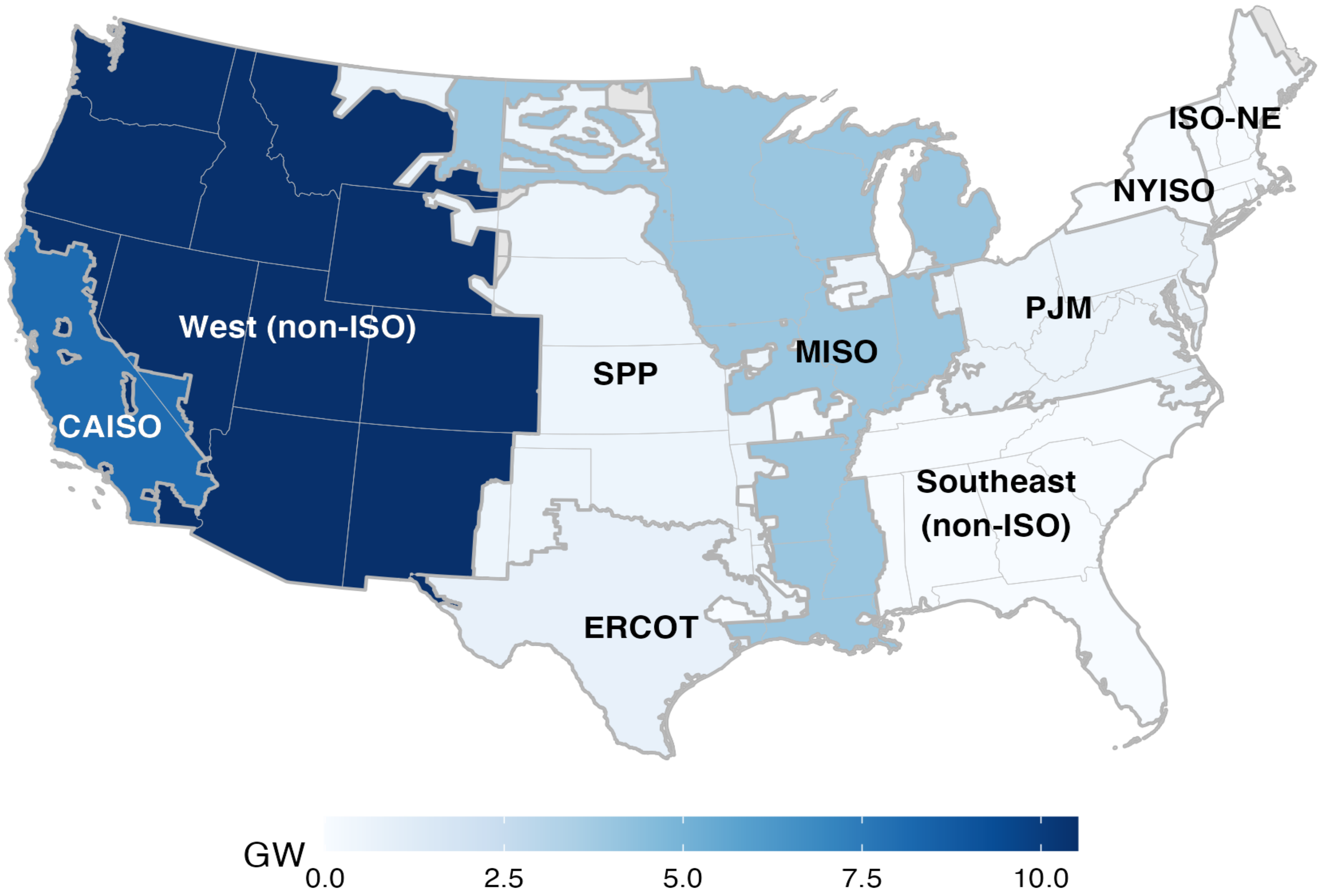
Greater historical commercial interest in solar hybrids is partly due to policy design—until recently, the investment tax credit for solar could be used for paired storage, whereas the production tax credit regularly used by wind plants had no such storage allowance; the Inflation Reduction Act changes these parameters, with storage or all configurations now benefiting from the investment tax credit

Notes: (1) Not all of this capacity will be built; (2) Hybrid plants involving multiple generator types (e.g., wind+PV+ storage, wind+PV) show up in all generator categories, presuming the capacity is known for each type; (3) hybrid storage capacity is estimated in some cases.

Interactive data visualization: https://emp.lbl.gov/generation-storage-and-hybrid-capacity

Proposed wind hybrids are primarily located in California and the non-ISO Western regions

Wind Hybrid Capacity in Queues at the end of 2022



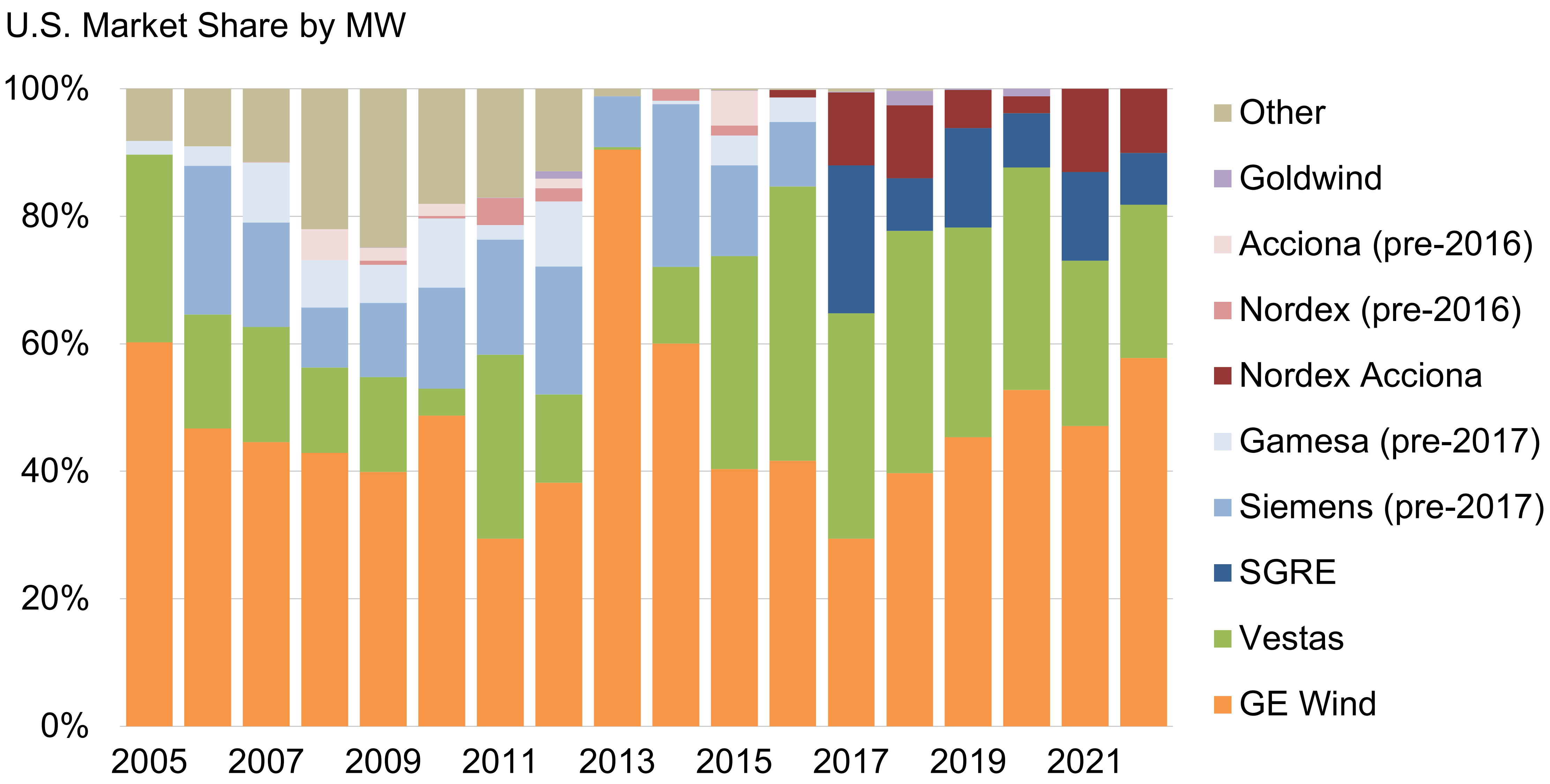
Source: Berkeley Lab review of interconnection queues

Interactive data visualization:
https://emp.lbl.gov/generation-storage-and-hybrid-capacity

Industry Trends

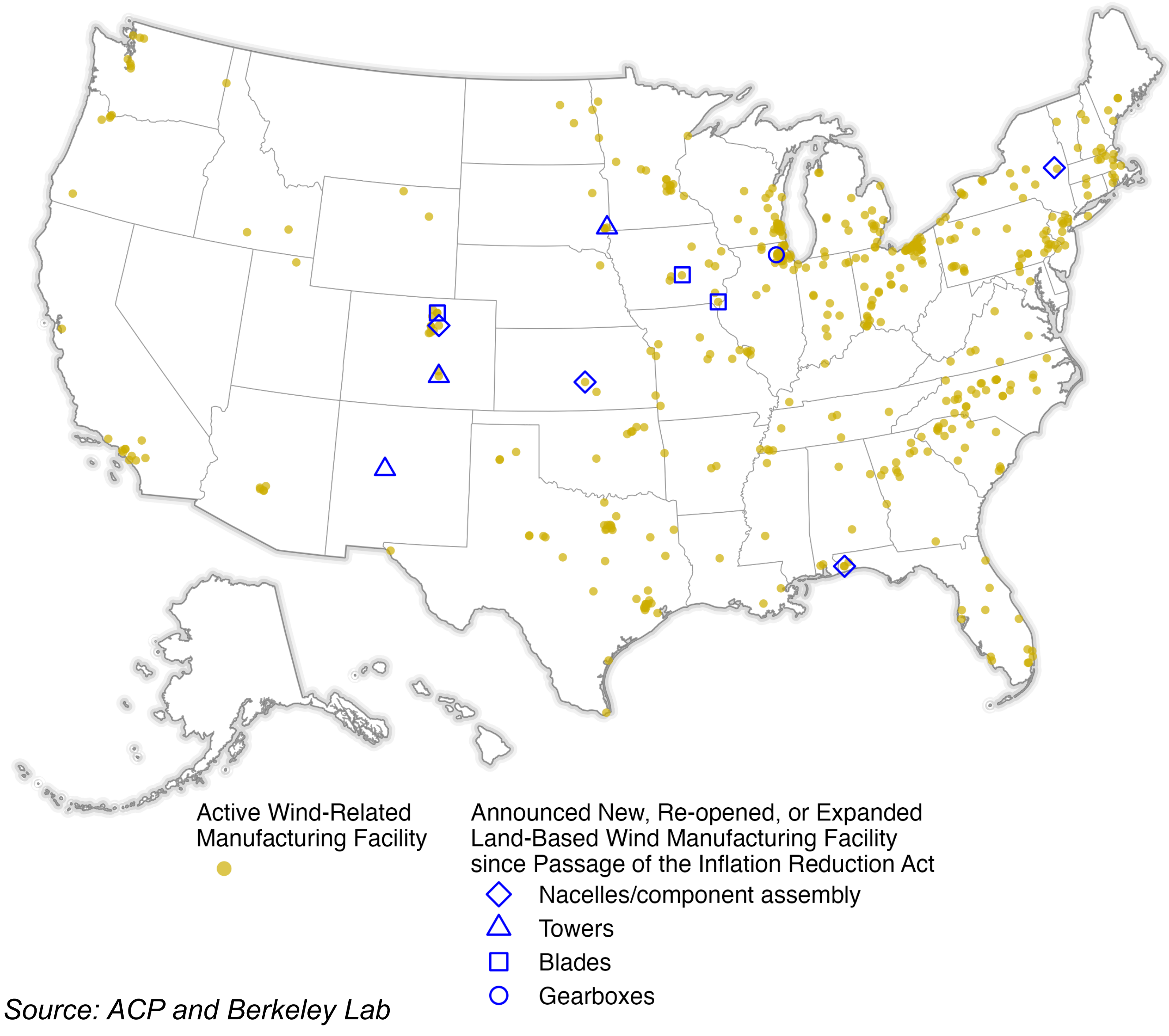
Industry Trends

Four turbine manufacturers, led by GE, supplied all the U.S. wind power capacity installed in 2022



Source: ACP

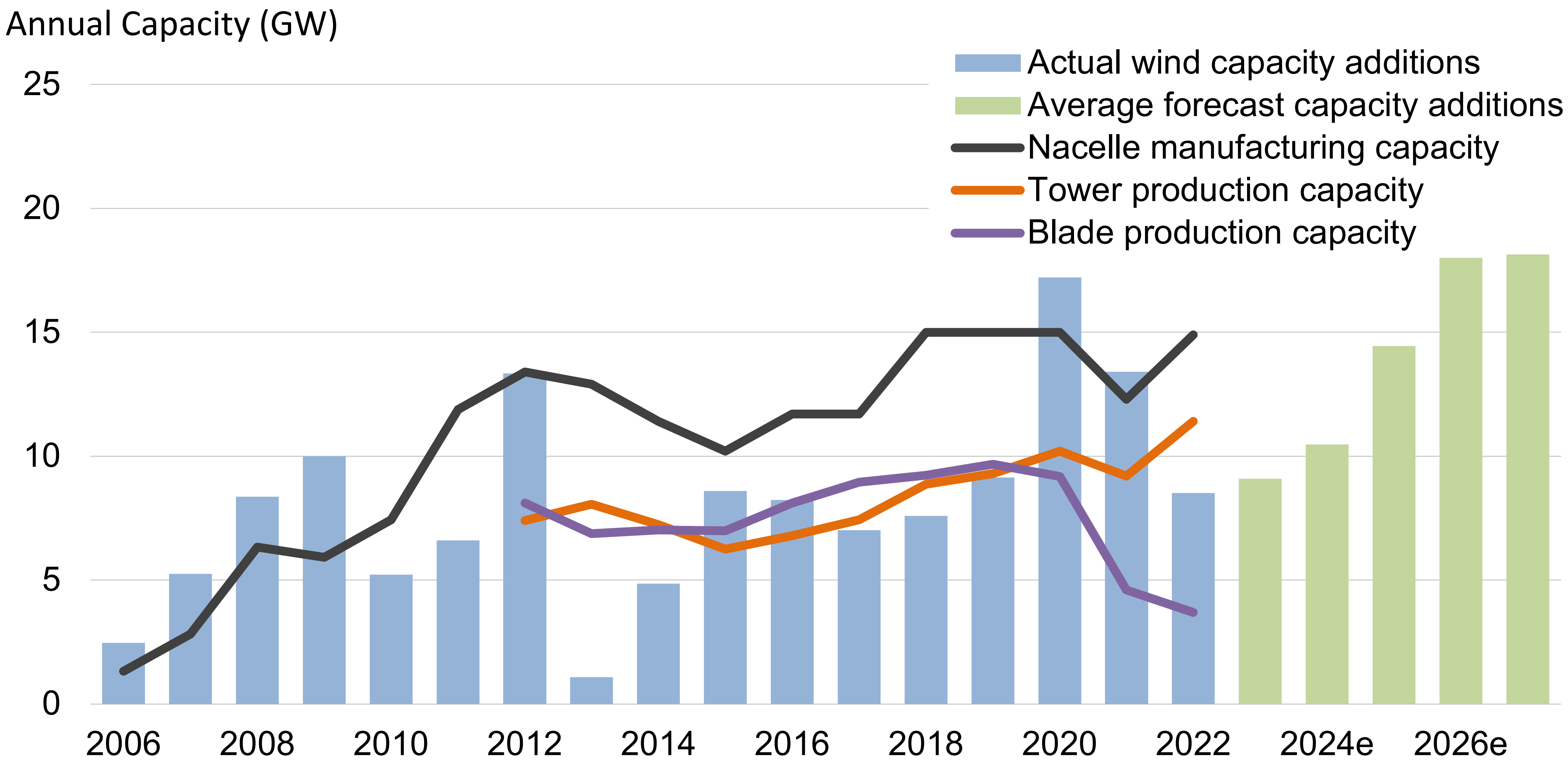
The domestic supply chain began 2022 in decline, but passage of the Inflation Reduction Act has created renewed optimism



Source: ACP and Berkeley Lab

- Wind equipment manufacturing is spread across the country
- Blade manufacturing capacity continued to decline in 2022
- Manufacturers have announced plans for **at least 11** new, re-opened or expanded manufacturing plants after passage of the *Inflation Reduction Act*
    - Production-based tax credit for nacelle, blade, and tower manufacturing
    - PTC bonus for wind projects that meet domestic content requirements
- Wind-related jobs increased 4.5% in 2022, to 125,580 full-time workers
- Jobs include those in construction (44,088) & manufacturing (23,543)

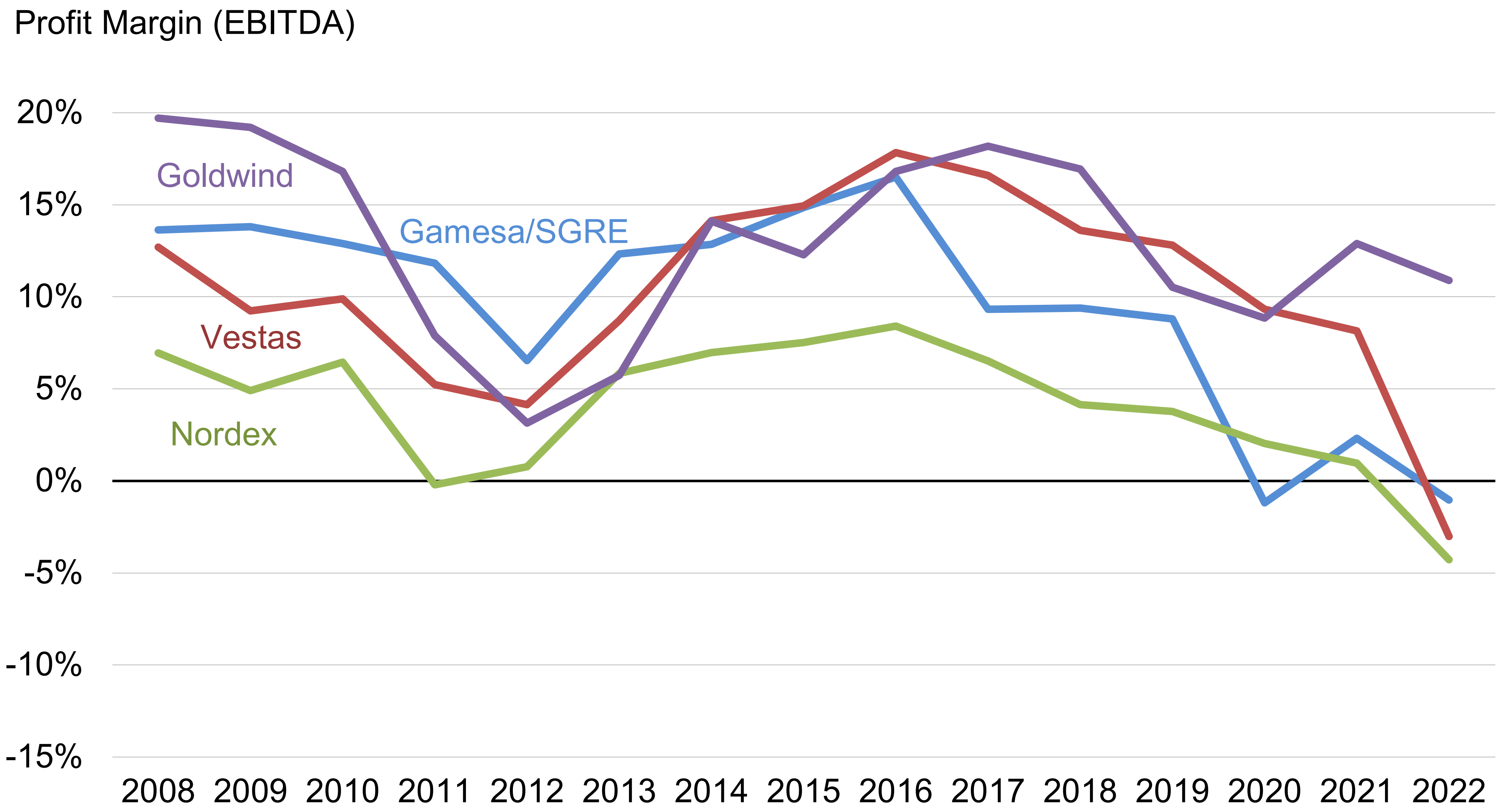
Blade manufacturing capability has fallen in recent years, while tower manufacturing and nacelle assembly capability has largely held steady



Sources: ACP, independent analyst projections, Berkeley Lab

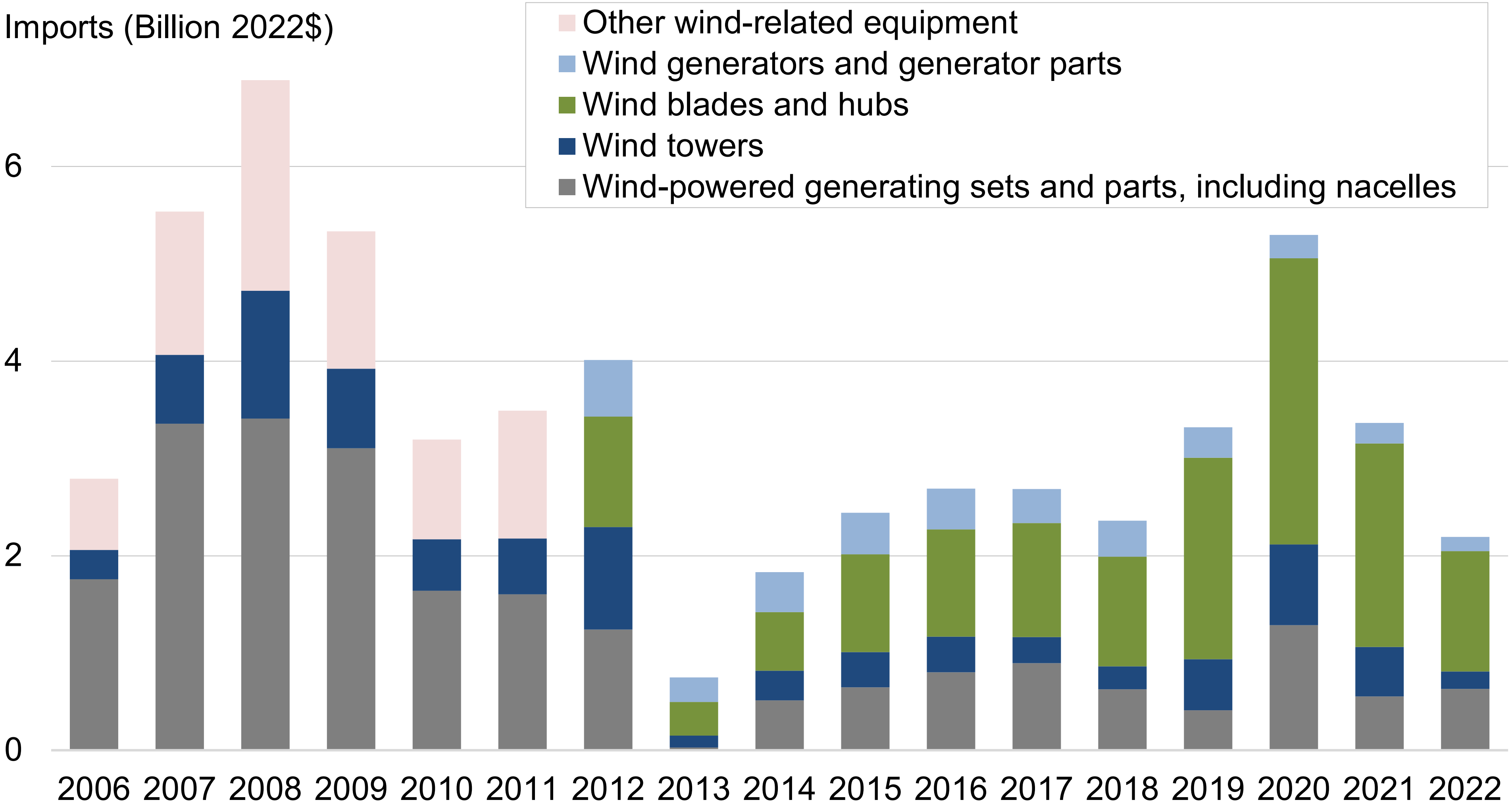
Note: Actual nacelle assembly, tower production, and blades production would be expected to be below maximum production capacity.

The profitability of global wind turbine manufacturers has generally declined over the last several years



Sources: OEM annual reports and financial statements

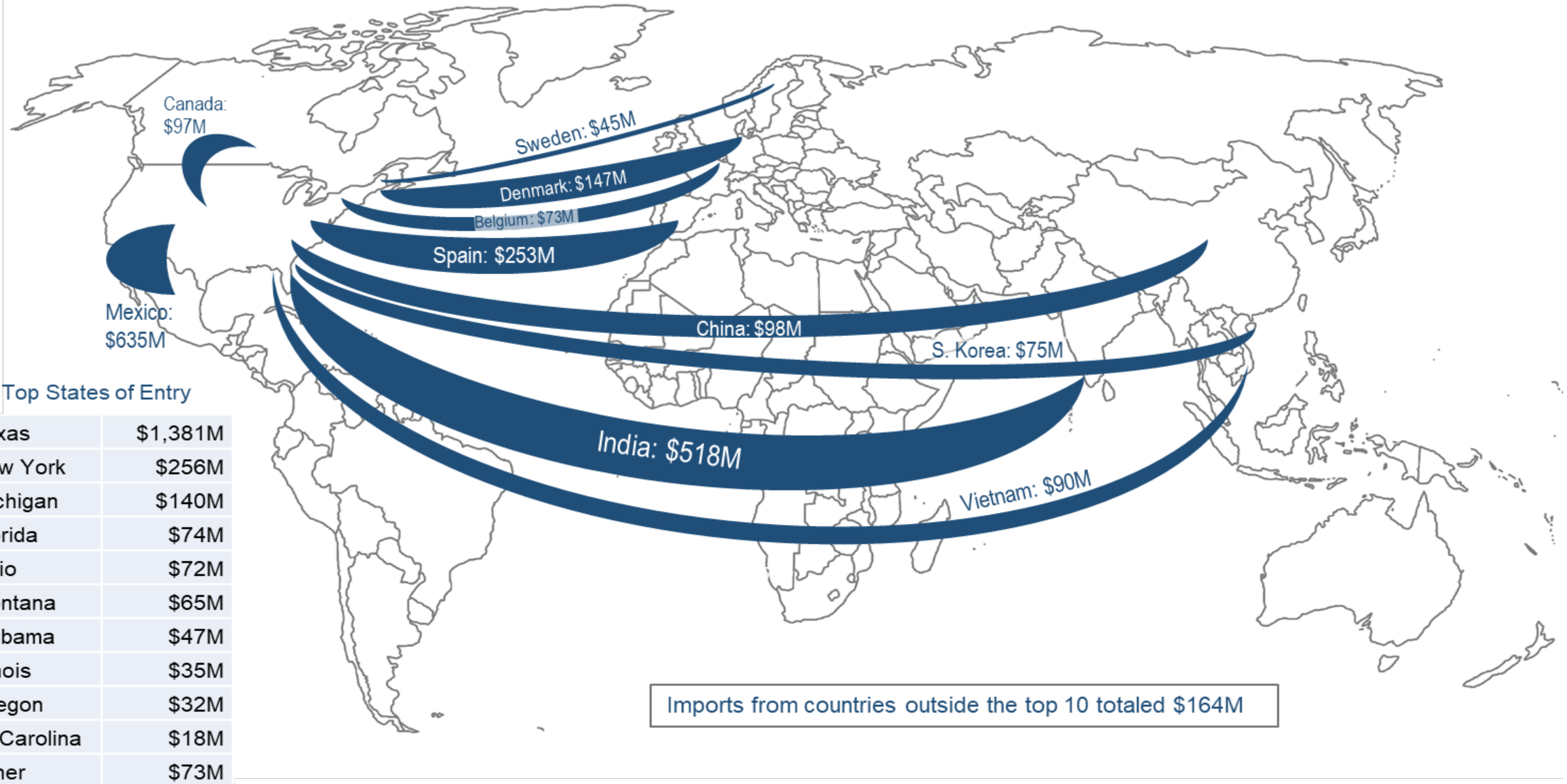
Imports of wind equipment are sizable, but have fluctuated over time; generally increasing wind import shares over last five to ten years



Source: Berkeley Lab analysis of data from USA Trade Online, https://usatrade.census.gov

Notes: Figure only includes tracked trade categories, misses other wind-related imports; wind-related trade codes and definitions are not consistent over the full time period; see full report for the assumptions used to generate the figure.

Tracked wind equipment imports into the United States in 2022 came from multiple regions of the world



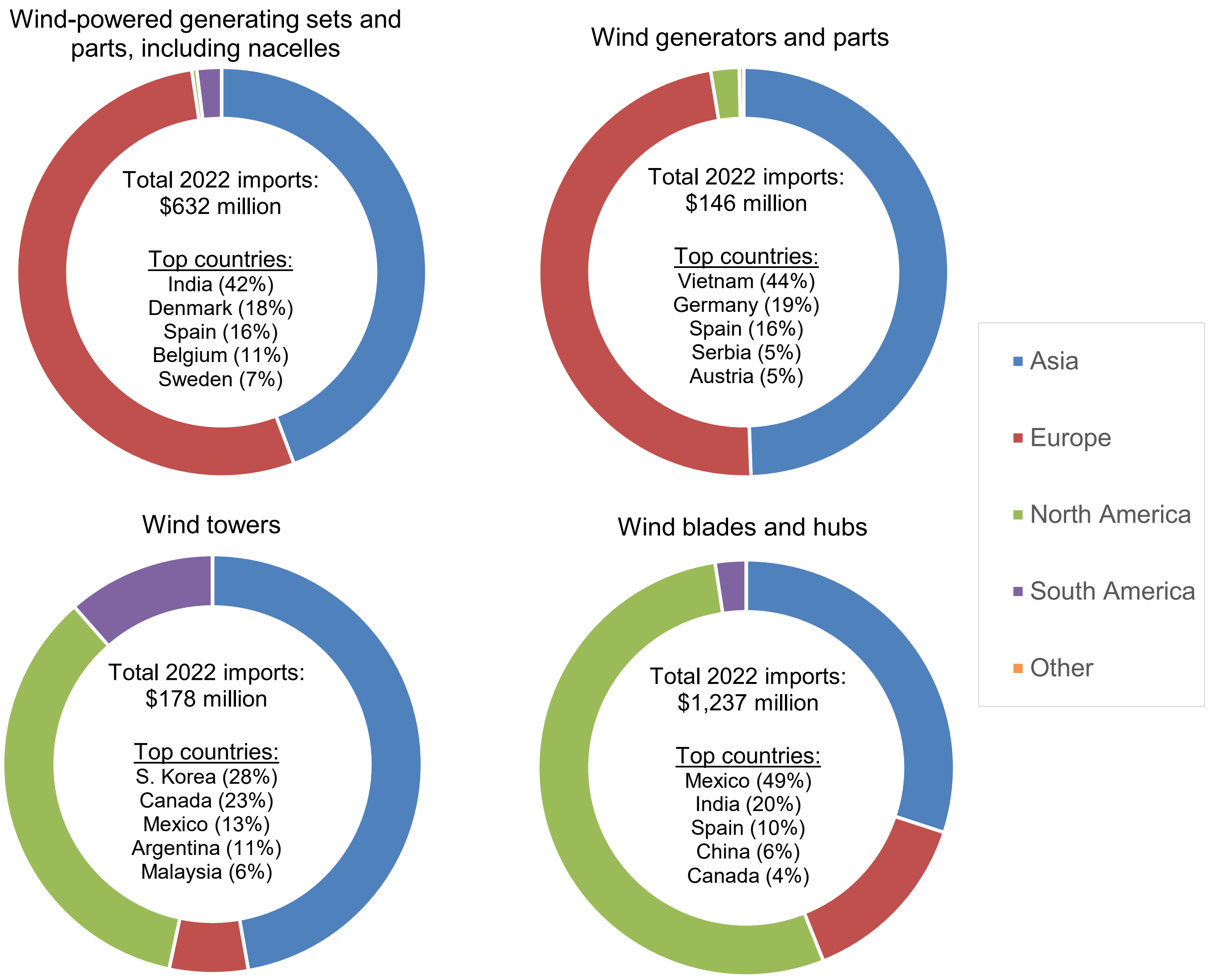
Top States of Entry

Texas	$1,381M
New York	$256M
Michigan	$140M
Florida	$74M
Ohio	$72M
Montana	$65M
Alabama	$47M
Illinois	$35M
Oregon	$32M
N. Carolina	$18M
Other	$73M

Source: Berkeley Lab analysis of data from USA Trade Online, https://usatrade.census.gov

Notes: Line widths are proportional to amount of imports, by country. Figure does not intend to depict the destination of these imports, by state. Tracked wind-specific equipment includes: wind-powered generating sets and parts, towers, generators and generator parts, blades and hubs, and nacelles

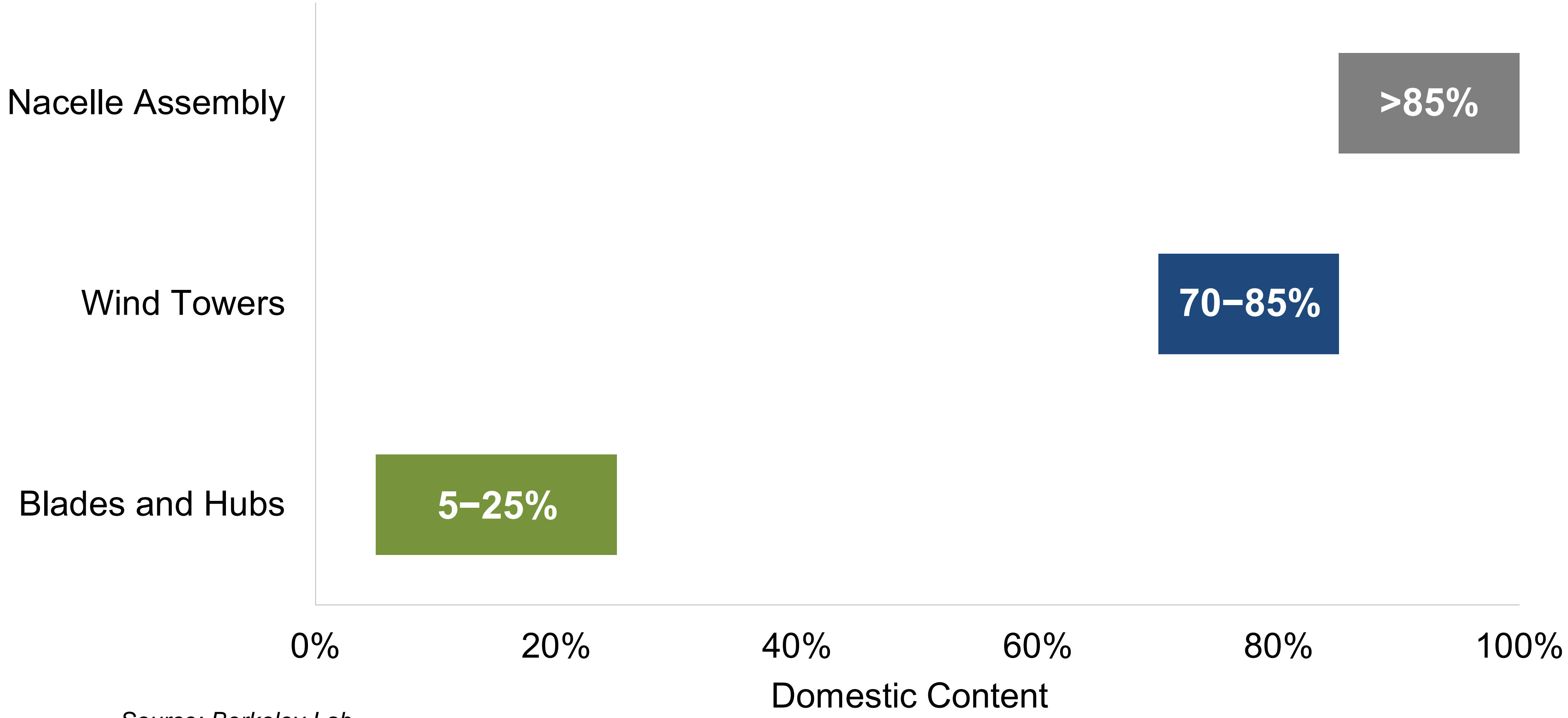
Source markets for 2022 wind equipment imports vary by type of wind equipment



- India, followed by Denmark, Spain, Belgium, and Sweden, were the primary source countries for wind-powered generating sets and parts, including nacelles, in 2022
- Tower imports came from a mix of countries near and far—South Korea, Canada, Mexico, Argentina, and Malaysia
- With regard to blades and hubs, Mexico and India accounted for almost 70% of imports, with Spain, China, and Canada the next largest source countries
- Almost 80% of wind-related generators and generator parts in 2022 came from Vietnam, Germany, and Spain, the rest primarily coming from Serbia and Austria

Source: Berkeley Lab analysis of data from USA Trade Online, https://usatrade.census.gov

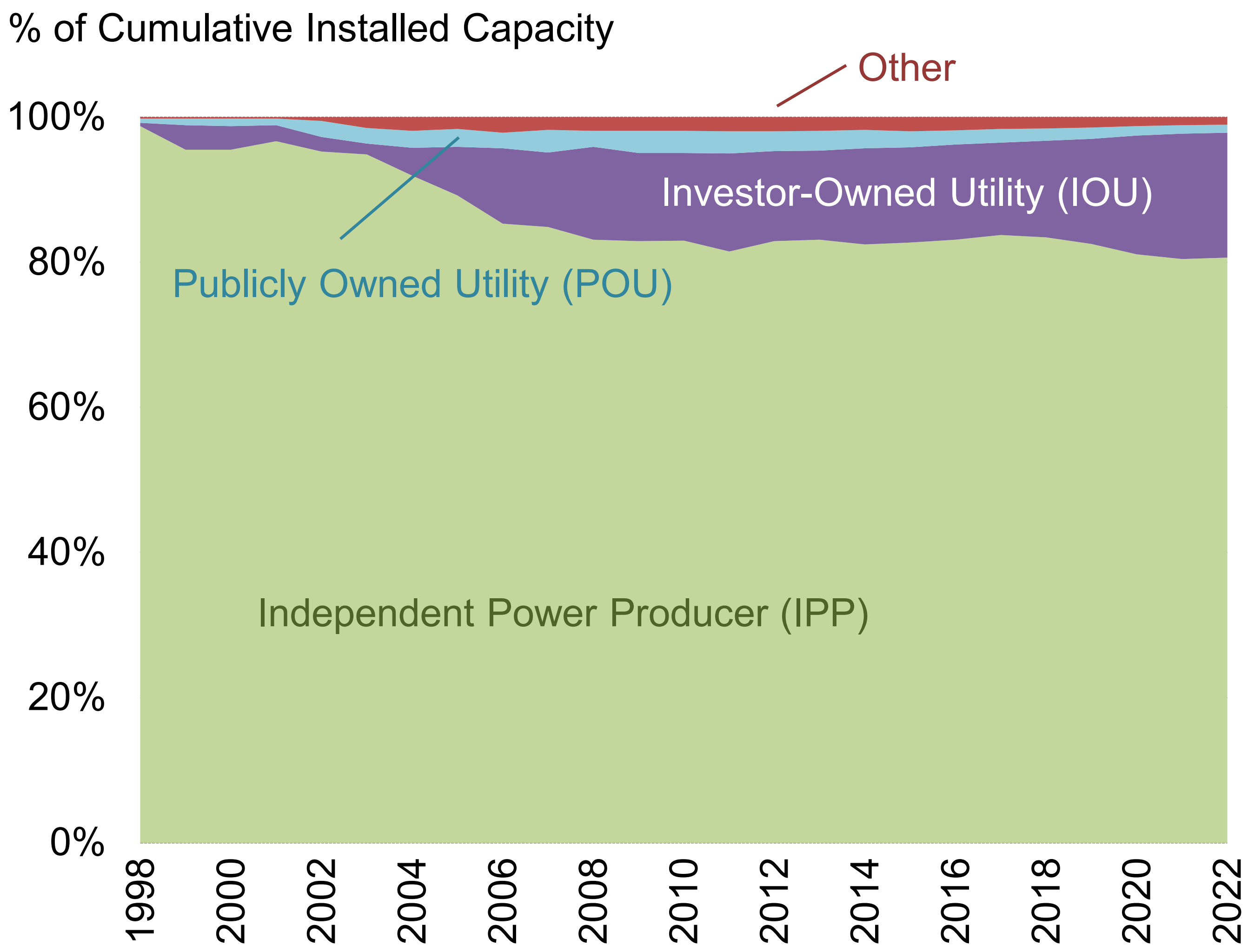
Domestic manufacturing content in 2022 was strong for nacelle assembly and towers, with blade production having declined rapidly

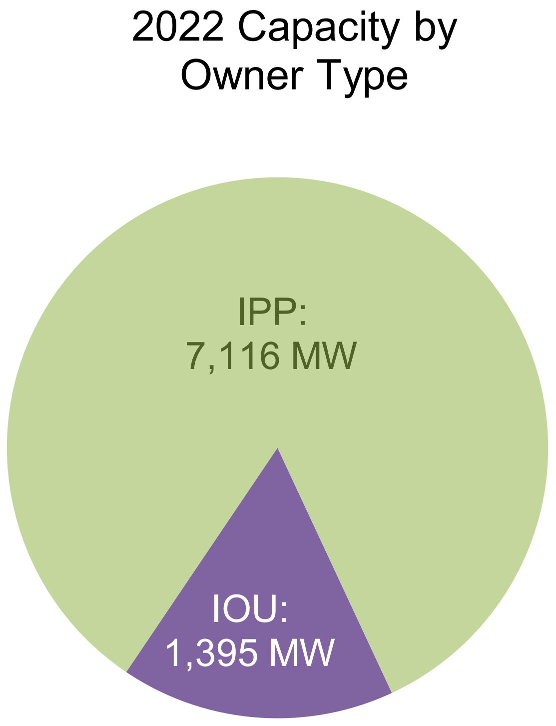


Source: Berkeley Lab

Imports occur in untracked trade categories not included above, including many nacelle internals. Incentives in the Inflation Reduction Act are anticipated to alter this picture in the years ahead.

Independent Power Producers own most wind assets built in 2022, extending historical trends

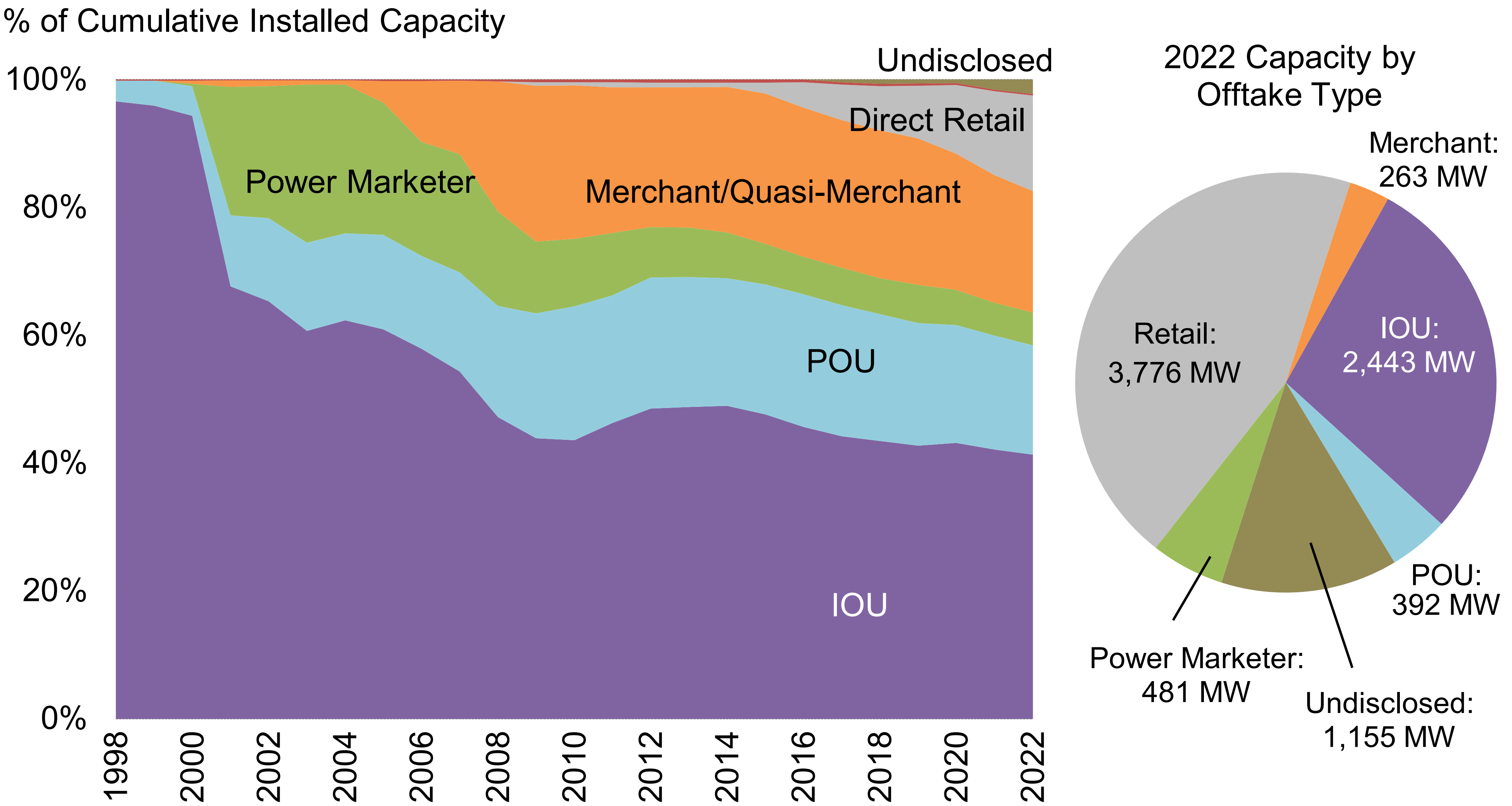




Source: Berkeley Lab estimates based on ACP

Note: Graphic on left shows distribution among growing cumulative fleet of projects installed. Pie chart shows distribution only among those projects built in 2022.

For the first time, non-utility buyers entered into more contracts to purchase wind than did utilities in 2022

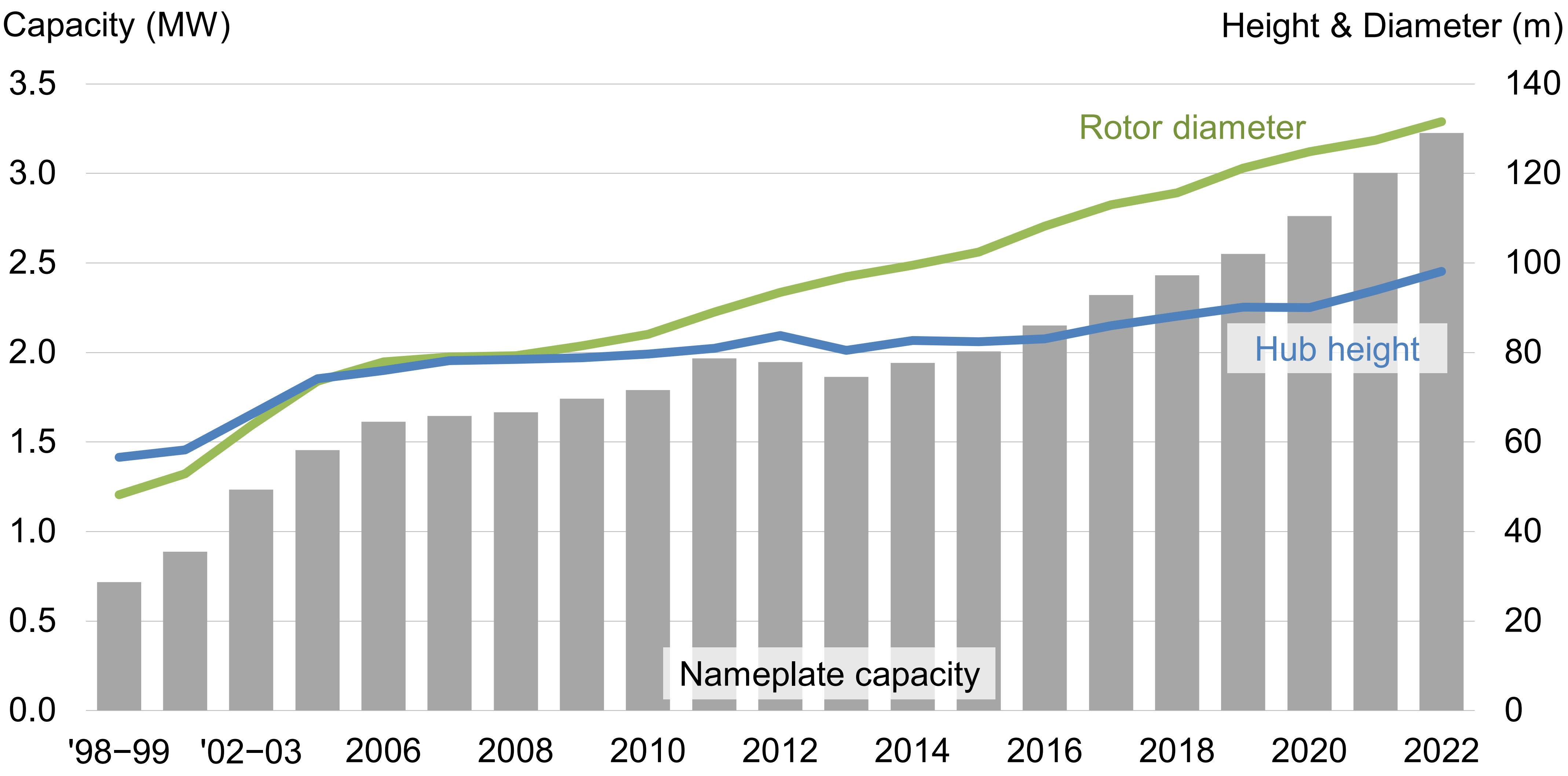


Source: Berkeley Lab estimates based on ACP

Note: Graphic on left shows distribution among growing cumulative fleet of projects installed. Pie chart shows distribution only among those projects built in 2022.

Technology Trends

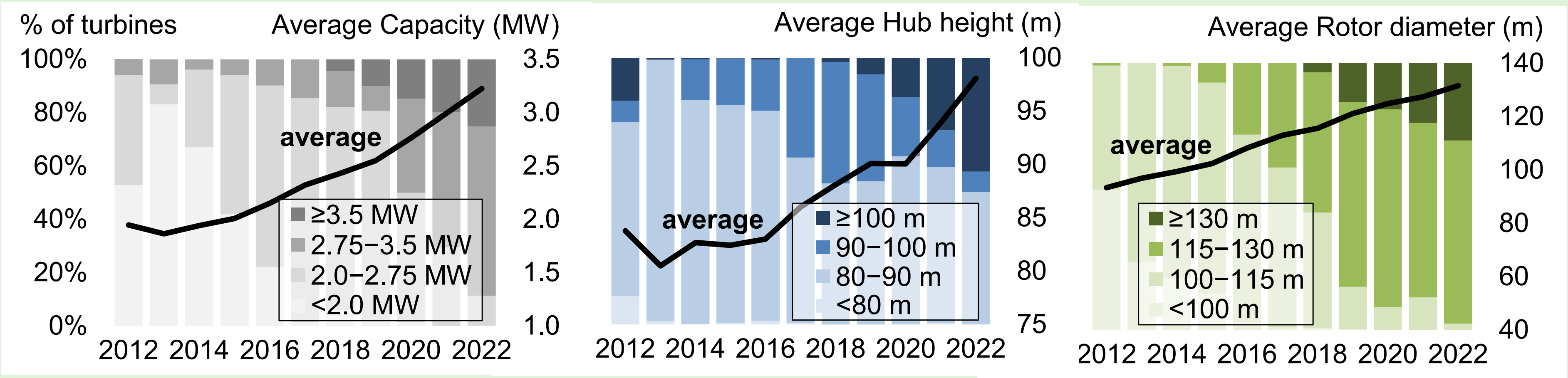
Turbine capacity, rotor diameter, and hub height have all increased significantly over the long term



Sources: ACP, Berkeley Lab

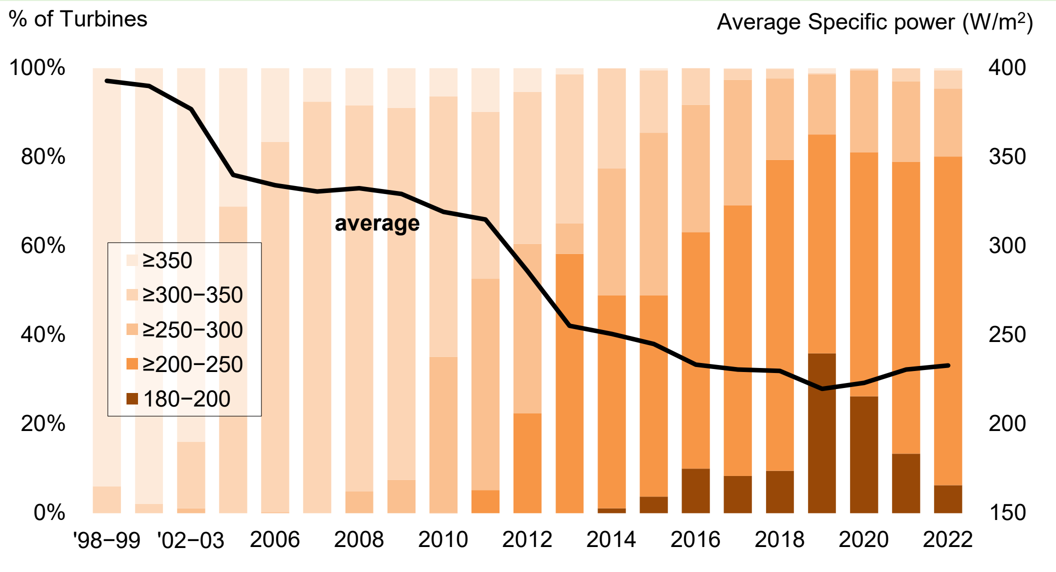
Interactive data visualization: https://emp.lbl.gov/wind-power-technology-trends

Turbine size maintains upward trajectory; turbines originally designed for lower wind speeds dominate the market



Specific power: turbine capacity divided by swept rotor area; lower specific power leads to higher capacity factors, as shown later

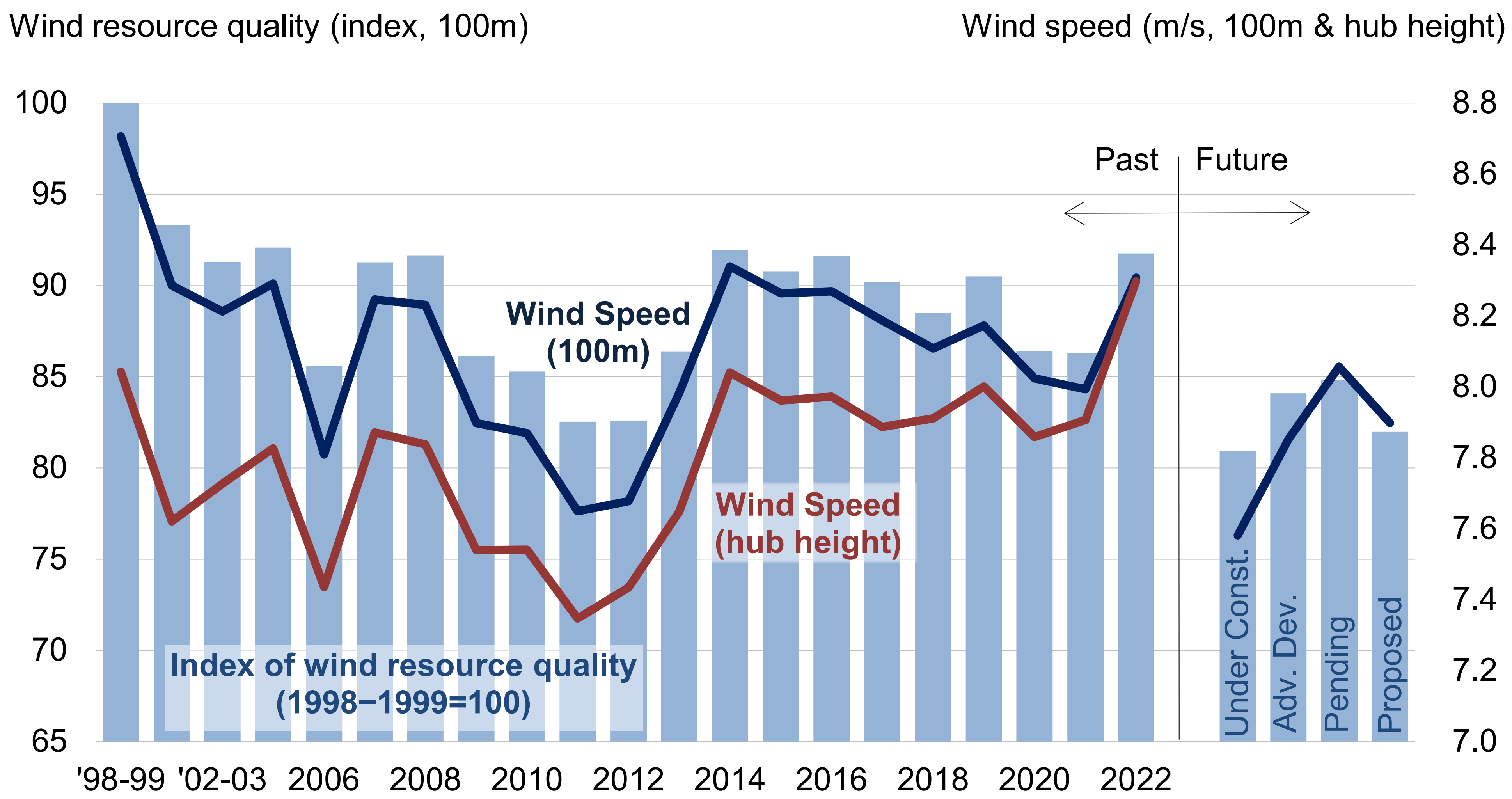
2022 average = 233 W/m^2



Sources: ACP, Berkeley Lab

Interactive data visualization: https://emp.lbl.gov/specific-power

Wind turbines were deployed in higher wind-speed sites in 2022, but general trend toward lower-quality wind sites is expected to continue

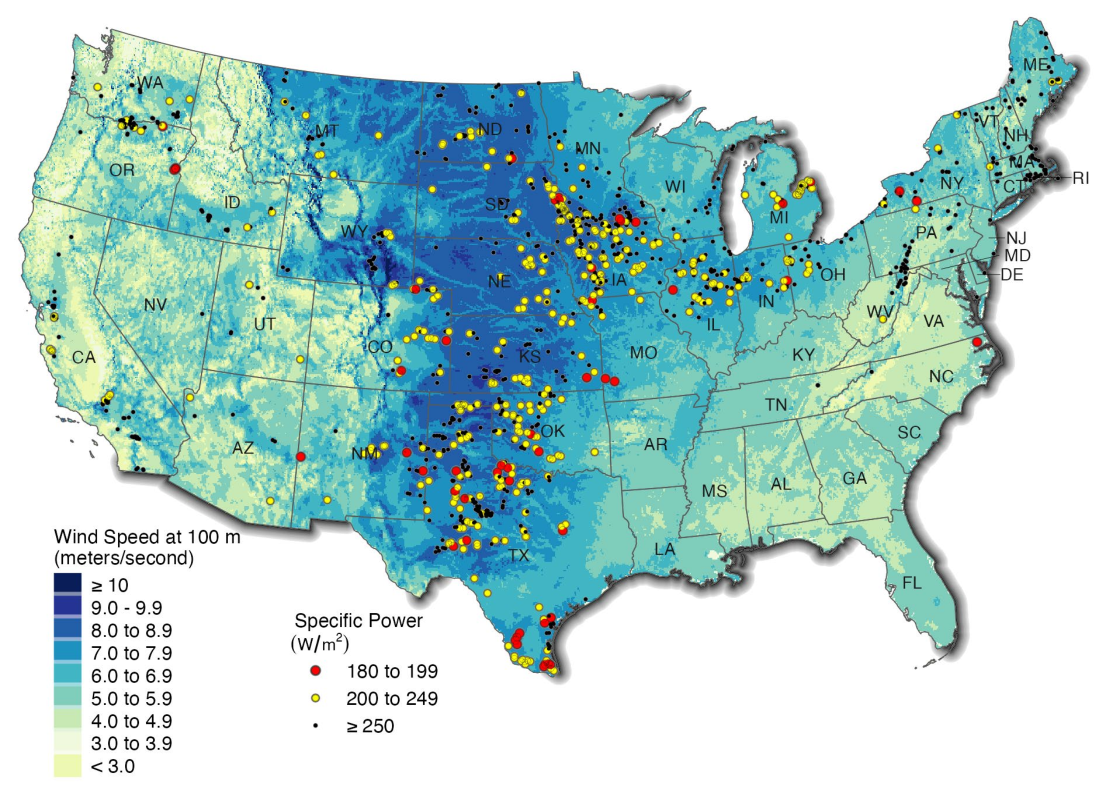


Sources: ACP, Berkeley Lab, AWS Truepower, FAA files

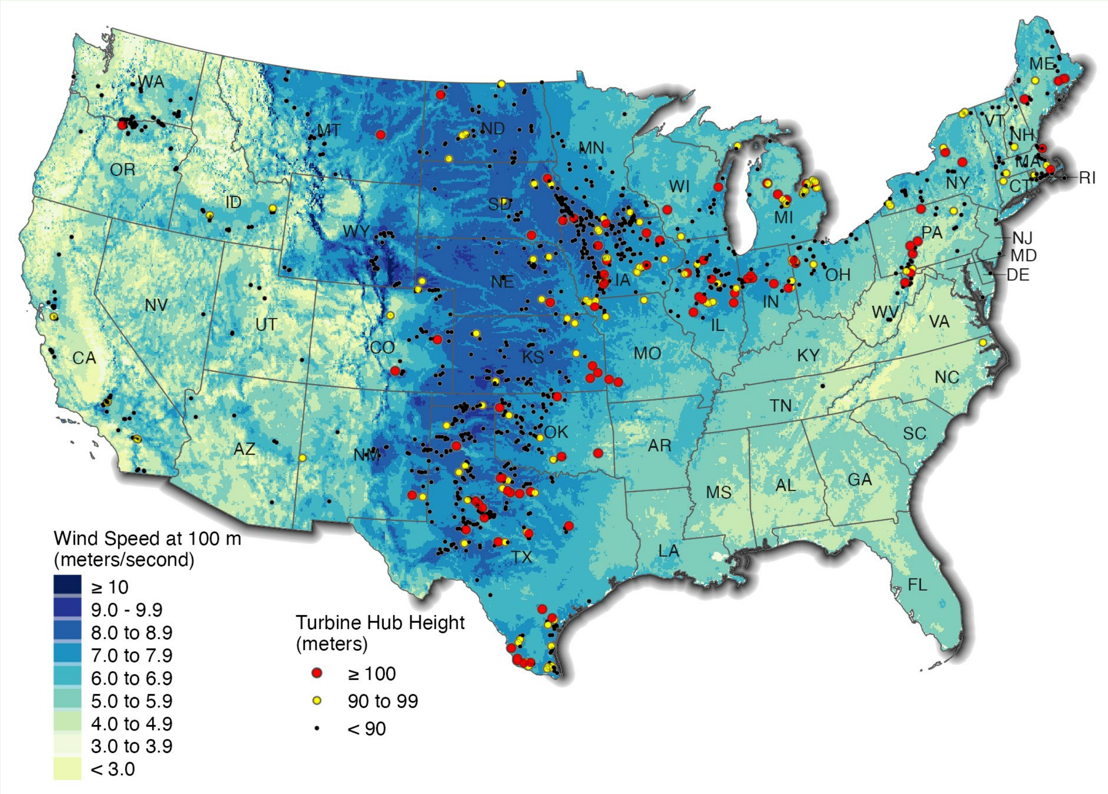
Note: Wind resource quality index is based on site estimates of gross capacity factor at 100 meters by AWS Truepower. A single, common wind-turbine power curve is used across all sites and timeframes, and no losses are assumed. Values are indexed to those projects built in 1998—1999.

Low specific power turbines are deployed on widespread basis; taller towers are seeing increased use in wider variety of sites

Specific Power



Hub Height

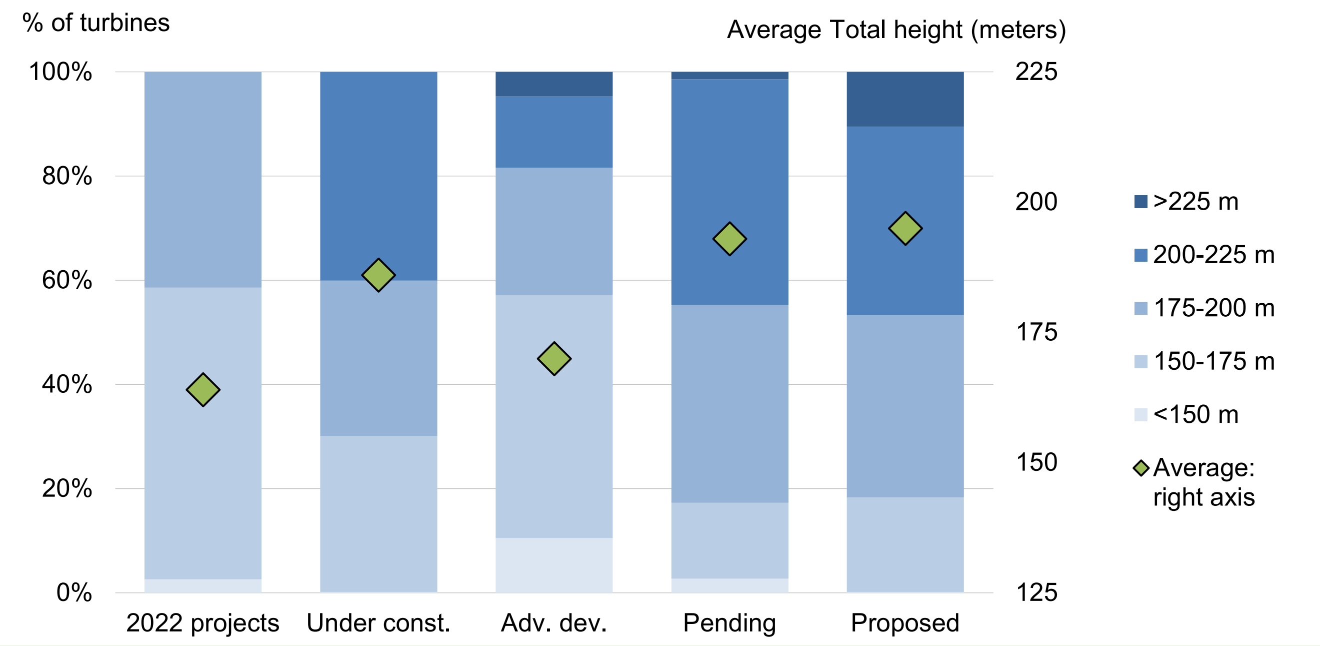


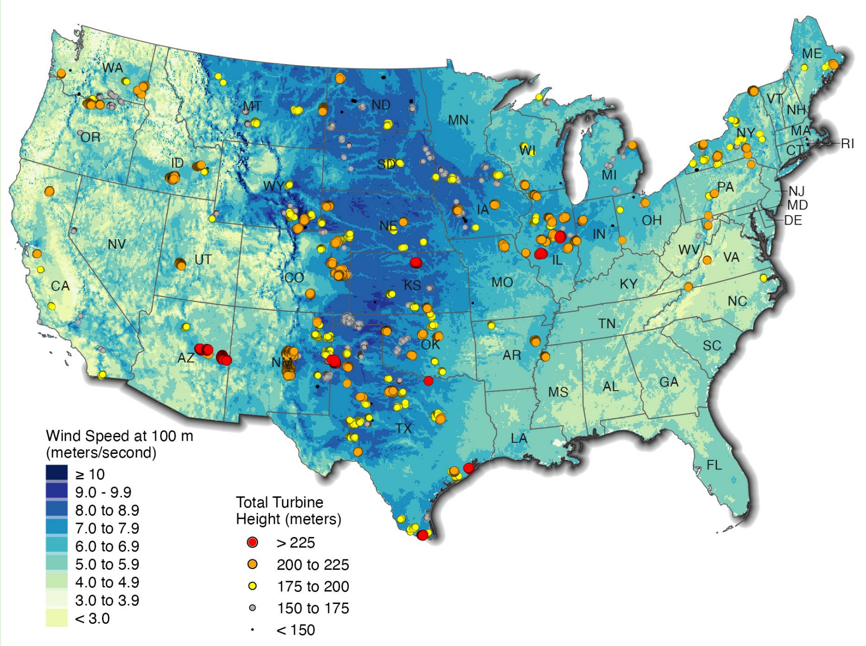
Sources: ACP, U.S. Wind Turbine Database, AWS Truepower, Berkeley Lab

Interactive data visualization: https://emp.lbl.gov/wind-power-technology-trends

Wind projects planned for the near future are poised to continue the trend of taller turbines

Proposed turbines show significant growth in total turbine height, compared to projects that entered commercial operation in 2022





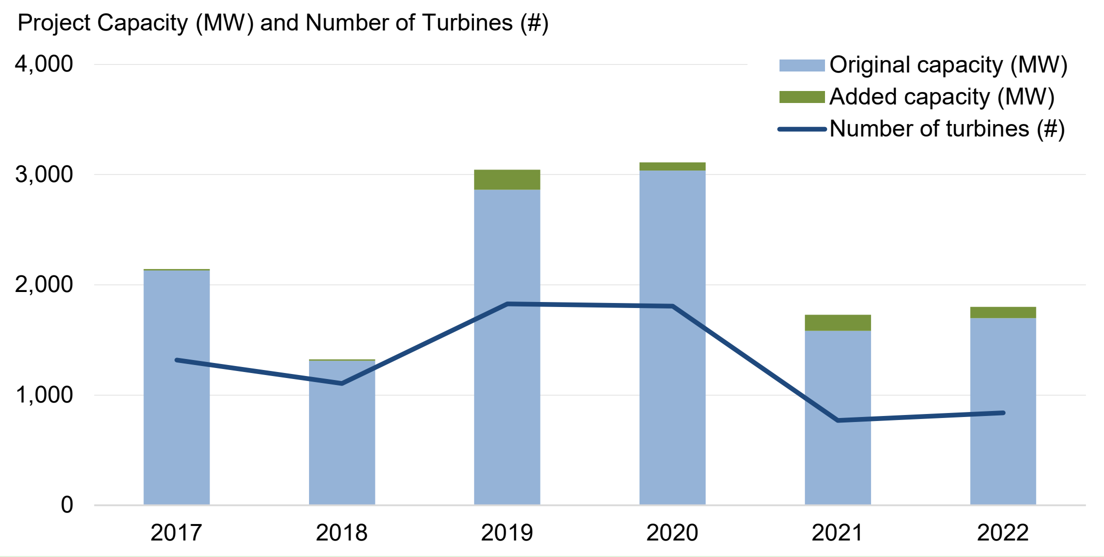
FAA = Federal Aviation Administration

Sources: ACP, FAA files, AWS Truepower, Berkeley Lab

In 2022, 13 wind projects were partially repowered, most of which now feature significantly larger rotors and lower specific power ratings

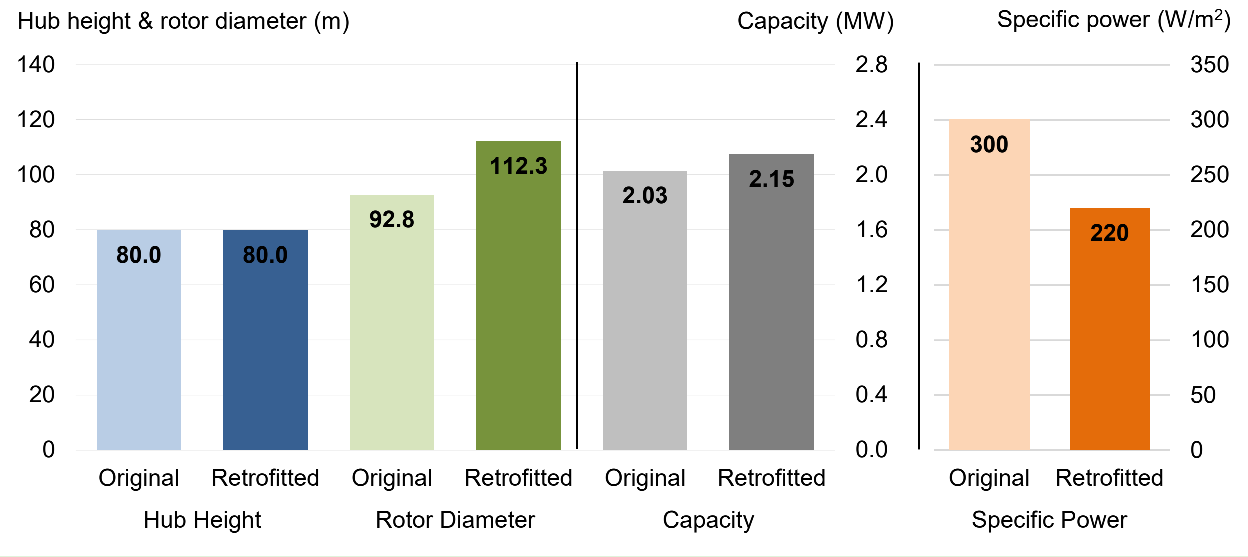
Partial Repowering by Year

(Figure shows wind project capacity repowered each year)



Technology Change with Partial Repowering

(Figure shows average technology change for wind turbines repowered in 2022)

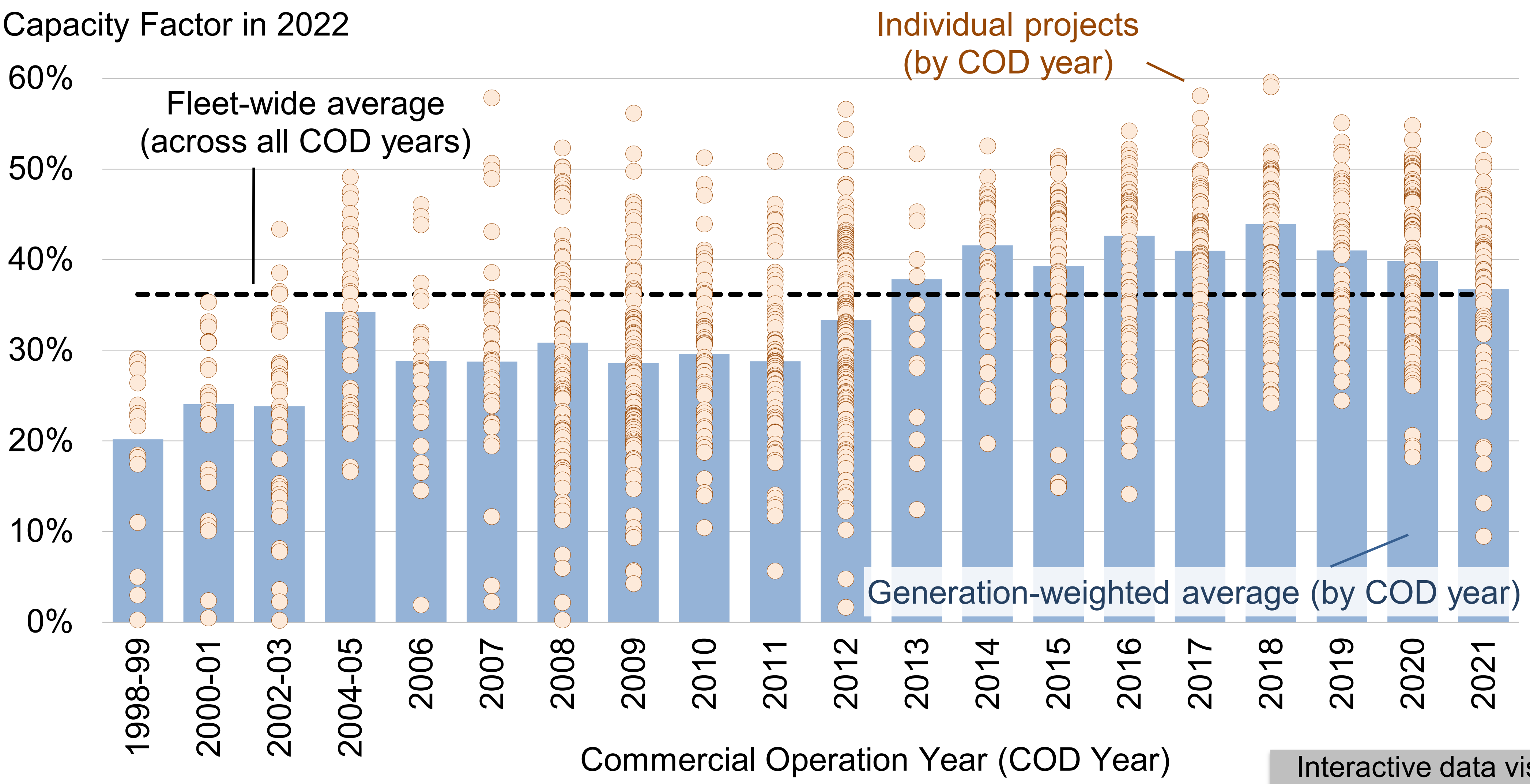


Sources: ACP, Berkeley Lab, turbine manufacturers

The mean age of turbines retrofitted in 2022 was just 11 years

Performance Trends

Average capacity factor was 36% on a fleet-wide basis and 37% among projects built in 2021; trending lower in most recent years

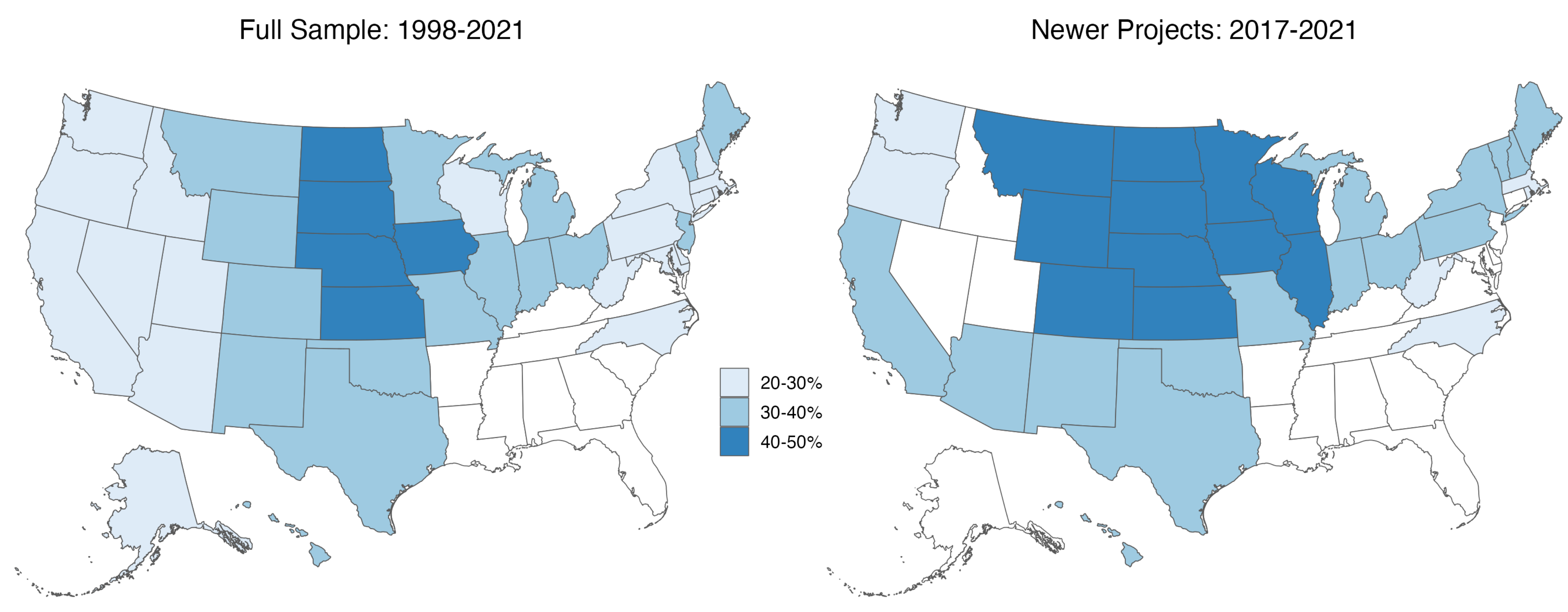


Interactive data visualization: https://emp.lbl.gov/wind-power-performance

Source: EIA, FERC, Berkeley Lab

The central part of the country features the highest capacity factors, in part reflecting the strength of the wind resource

Newer projects (right figure) have higher capacity factors than the full sample of projects (left figure)

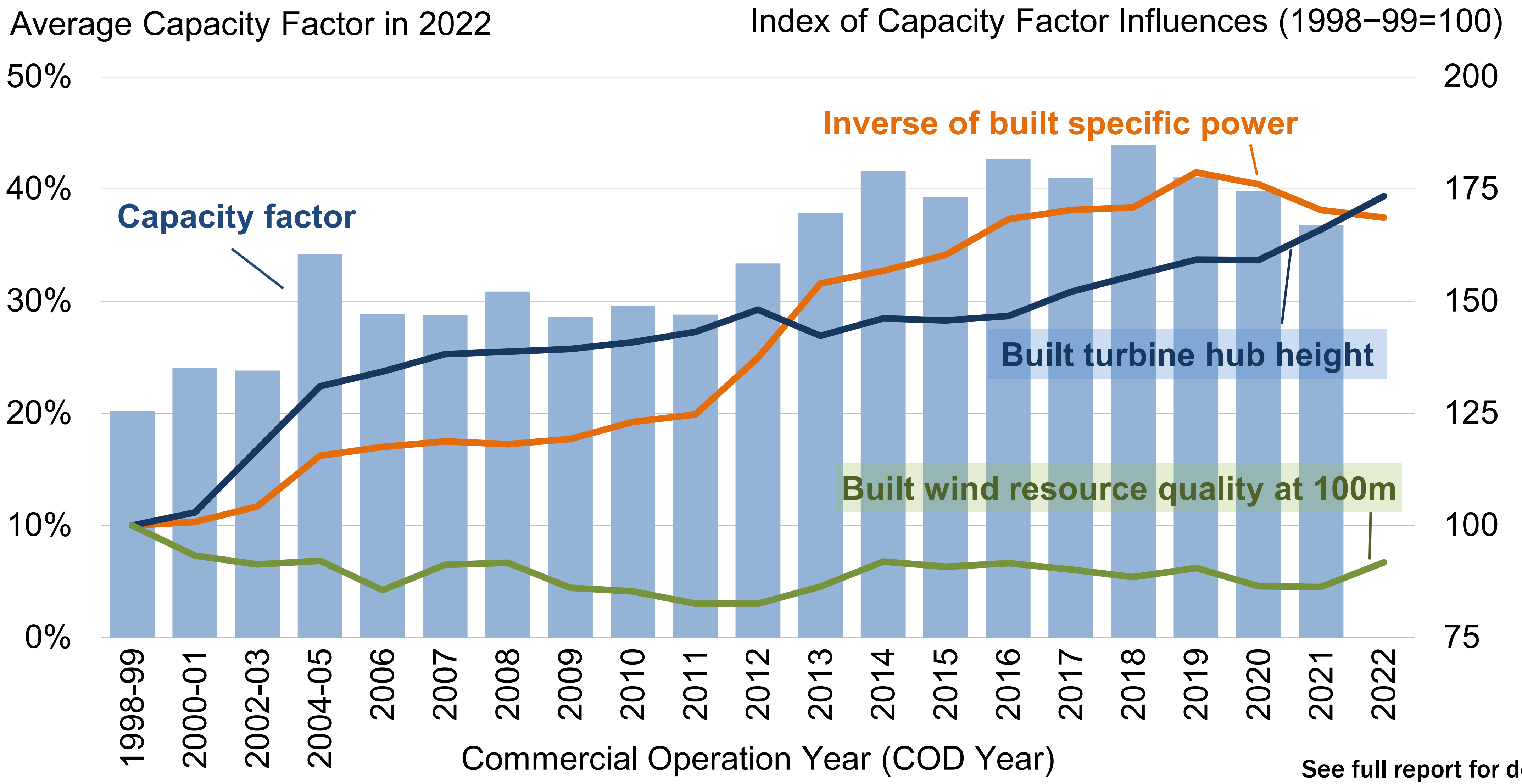


Source: EIA, FERC, Berkeley Lab

Note: States shaded in white have no projects in full sample (left) or in newer sample (right)

Interactive data visualization: https://emp.lbl.gov/wind-power-performance

Turbine design and site characteristics influence performance; 2022 projects impacted by recent specific power and resource quality trends

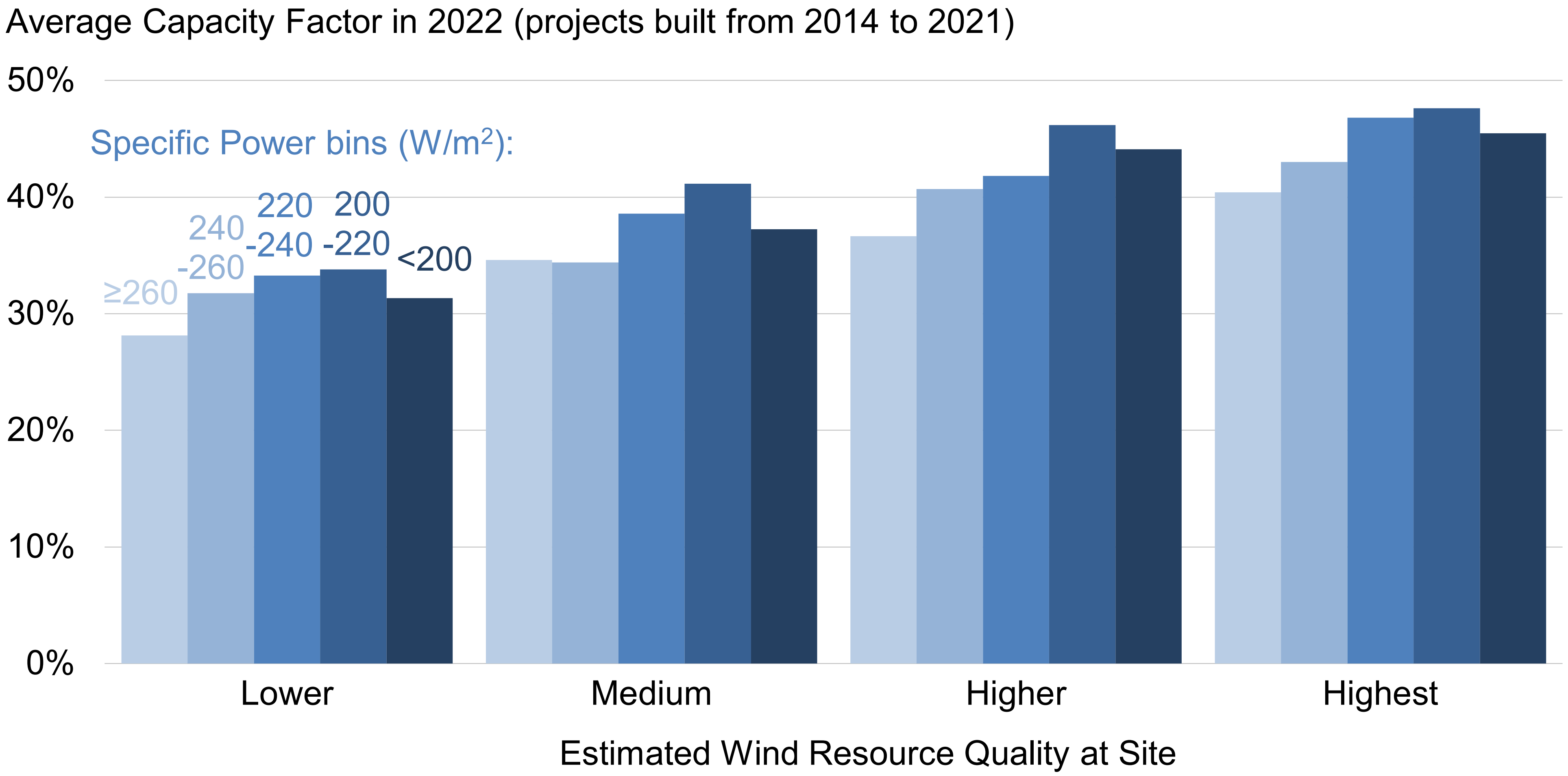


Source: EIA, FERC, Berkeley Lab

See full report for details on and interpretation of figure

Controlling for wind resource quality and specific power demonstrates impact of turbine evolution

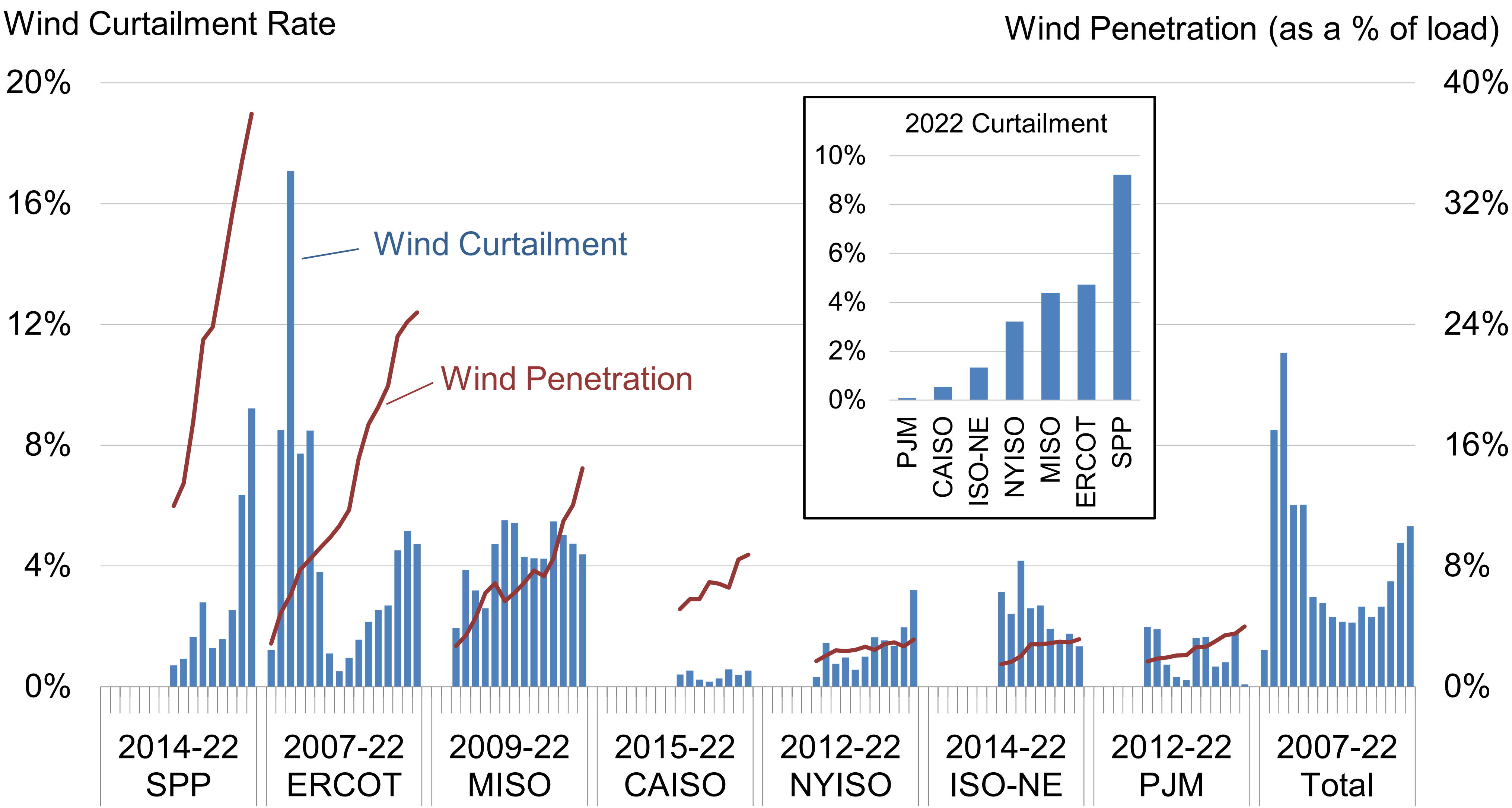
Low specific power turbines have generally driven capacity factors higher for projects located in given wind resource regimes



Note: See full report for a description of this categorization of wind resource quality

Source: EIA, FERC, Berkeley Lab

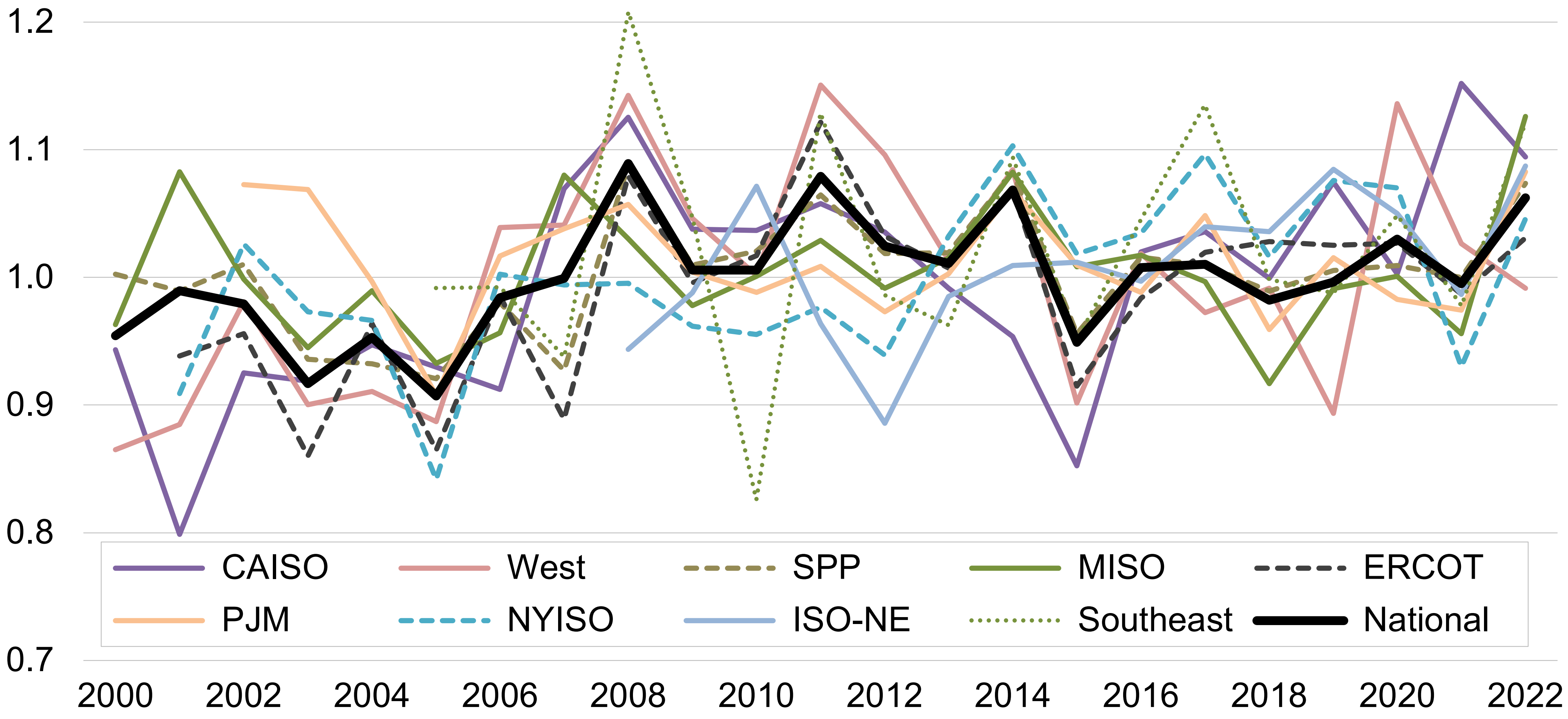
Wind power curtailment in 2022 across seven regions averaged 5.3%, up from a low of 2.1% in 2016



Sources: ERCOT, MISO, CAISO, NYISO, PJM, ISO-NE, SPP

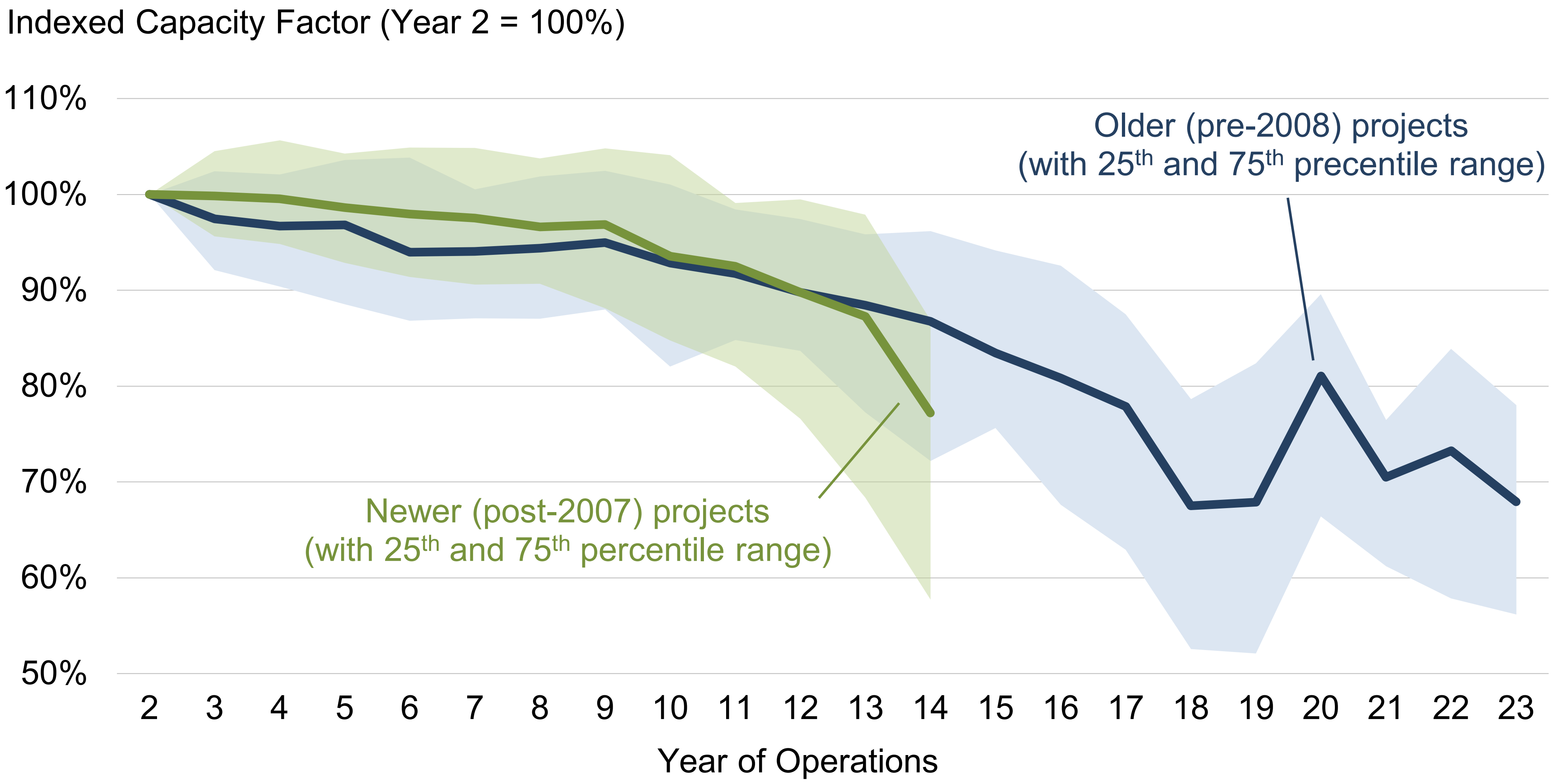
Yearly variations in average wind speed impact project performance; 2022 speeds were higher than the long-term average for most regions

Average Annual Wind Resource Indices (Long-Term Average = 1.0)



Source: ERA, Berkeley Lab; methodology behind the index of inter-annual variability is explained in report appendix

Wind project performance degradation with project age also contributes to lower performance of older projects in 2022



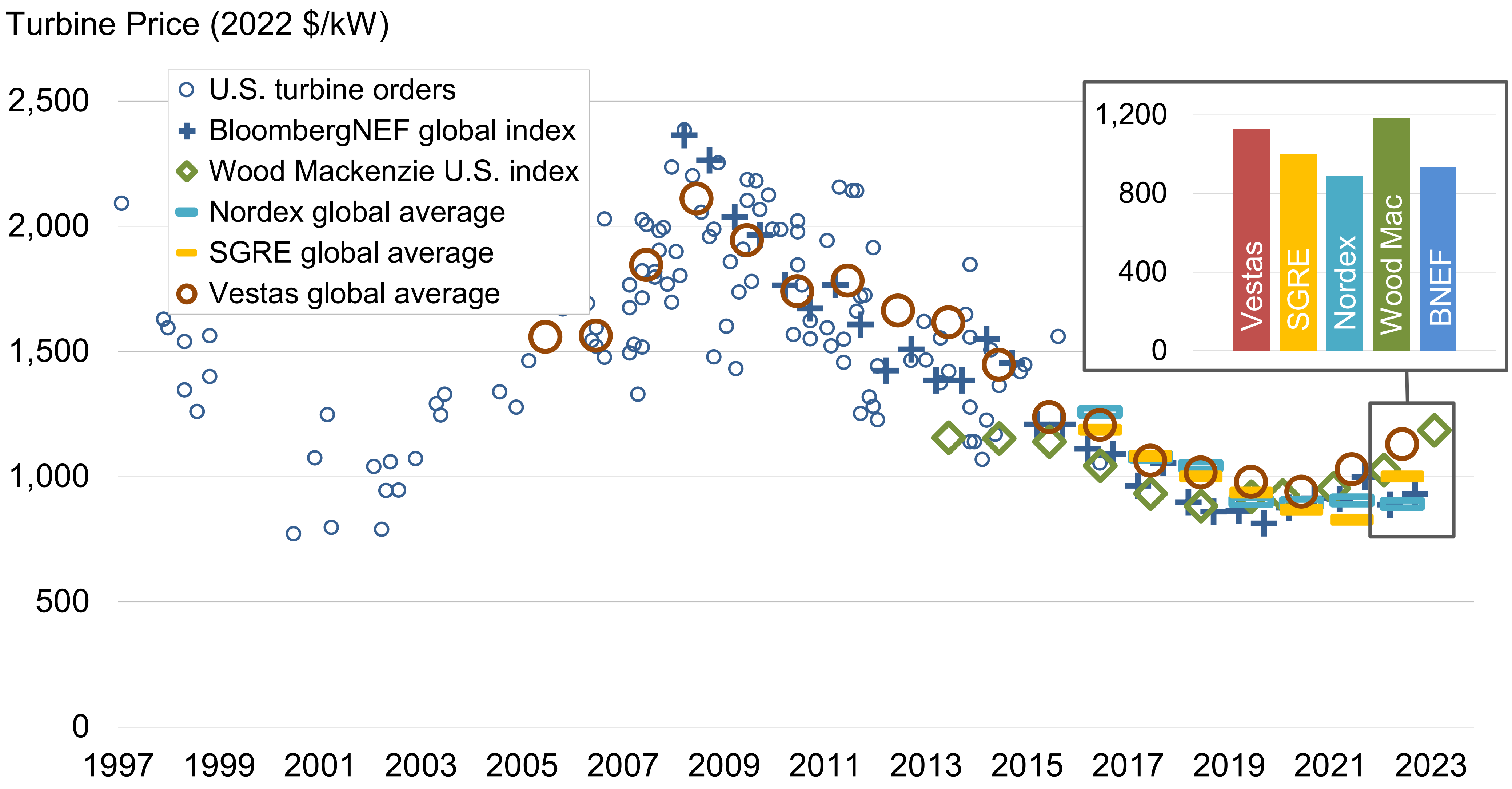
Performance decline after year 10 may, in part, reflect operational choices impacted by the federal PTC

Source: EIA, FERC, Berkeley Lab

For more analysis on wind project performance with plant age, see: https://emp.lbl.gov/publications/how-does-wind-project-performance

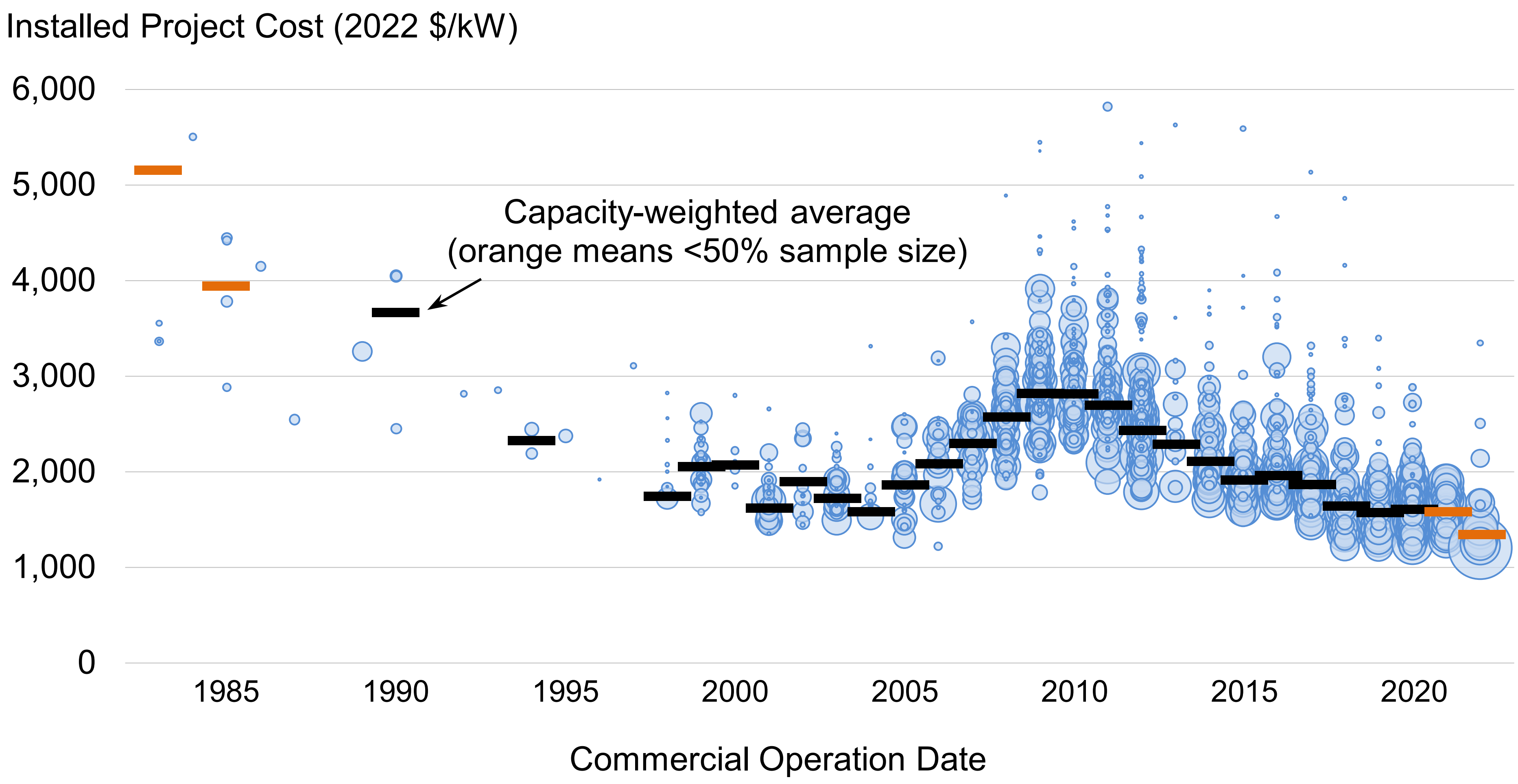
Cost Trends

Wind turbine prices increased in 2022, reaching roughly $1,000/kW



Sources: Berkeley Lab, annual financial reports, forecast providers

Surprisingly, average installed project costs among our small sample of 2022 projects did not follow turbine prices higher



Note: Size of "bubble" reflects project capacity

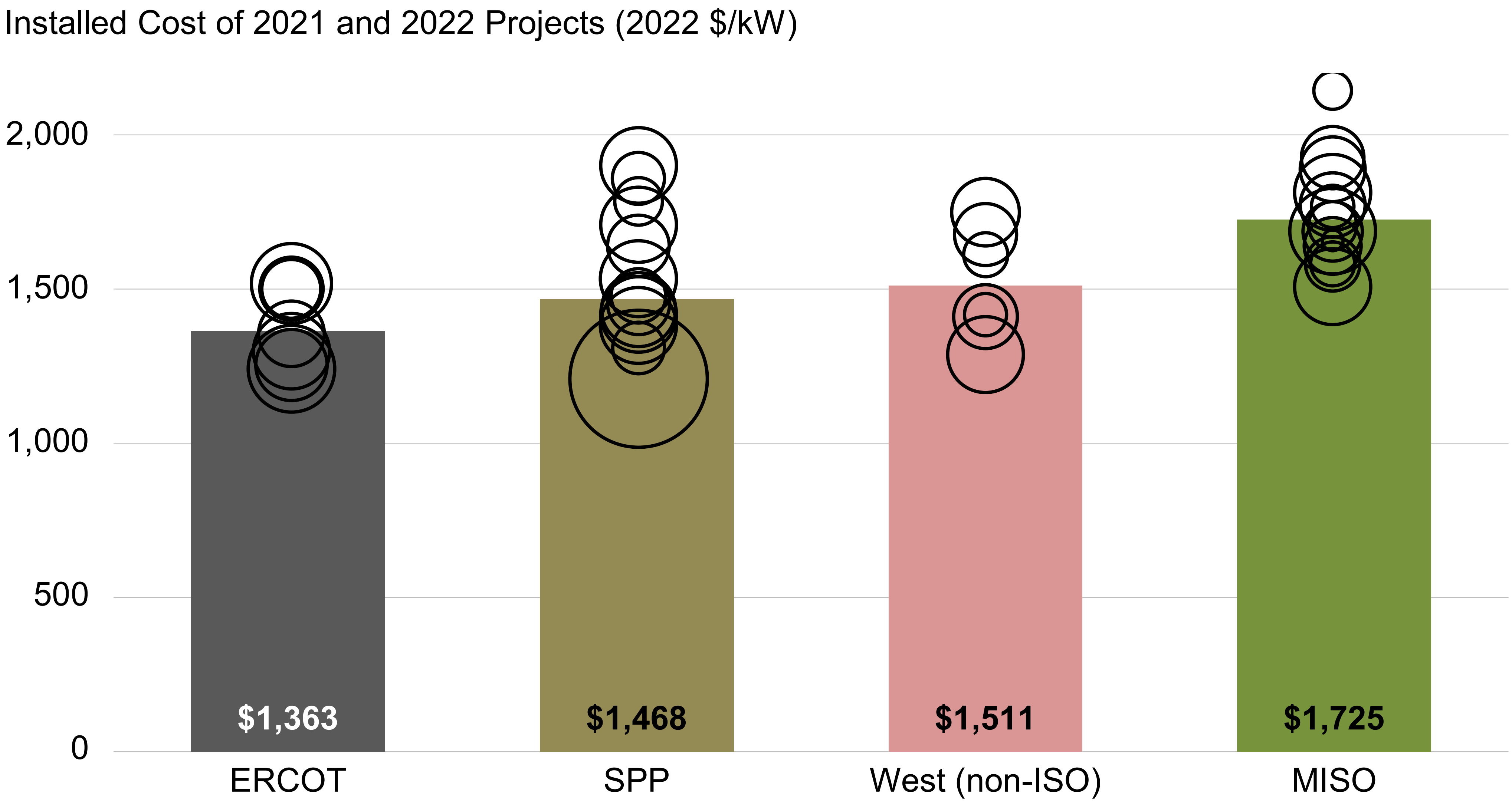
Sources: Berkeley Lab, EIA (some data points suppressed to protect confidentiality)

<u>Low costs a result of:</u>

- concentration of deployment in lowest-cost ERCOT and SPP regions
- impact of one very-large project completed in 2022
- relatively small sample of 2022 CapEx data

Interactive data visualization: https://emp.lbl.gov/wind-energy-capital-expenditures-capex

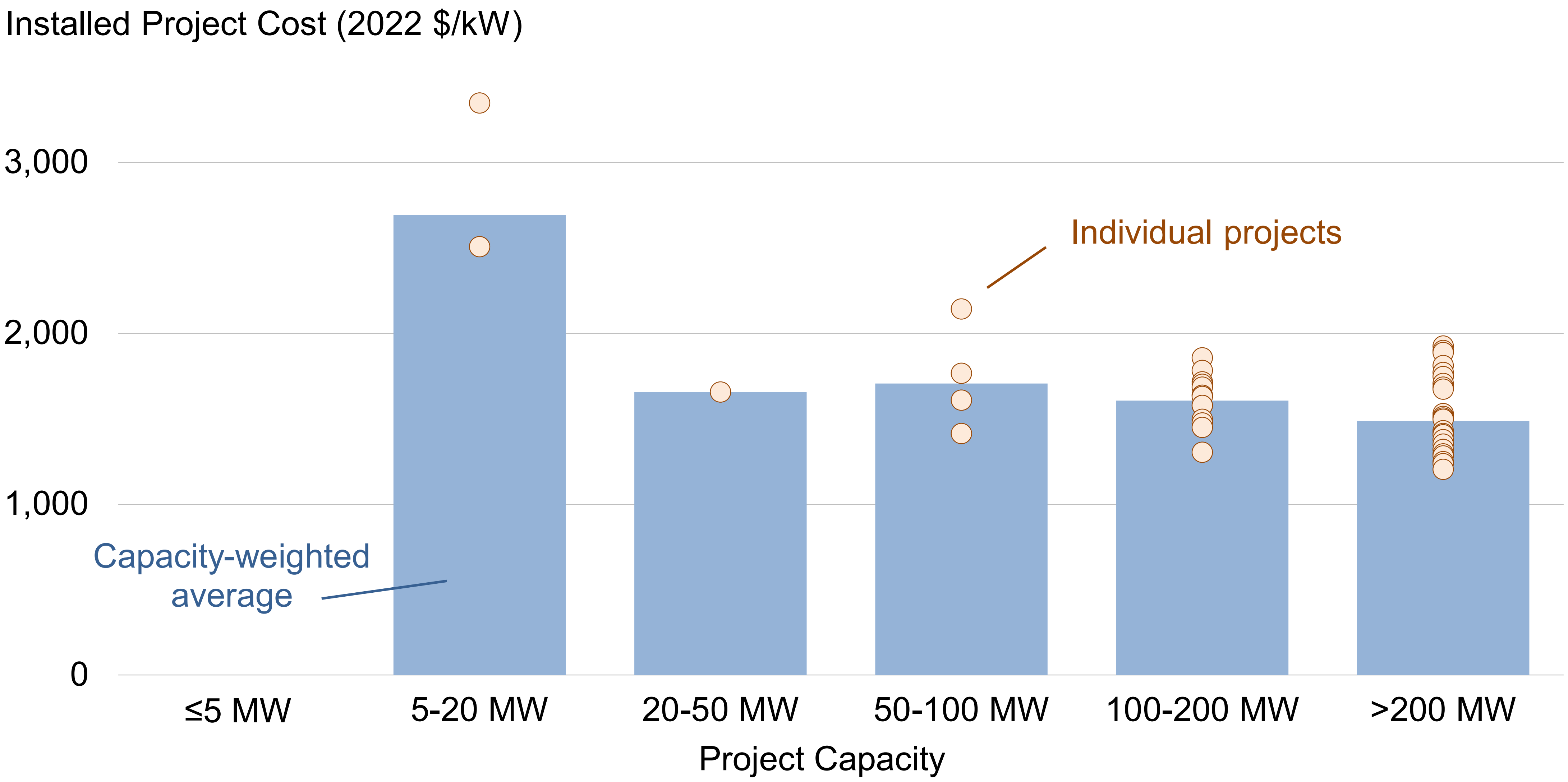
Considering projects installed in 2021 and 2022, ERCOT and SPP are the two lowest-cost regions



Note: Size of "bubble" reflects project capacity
Source: Berkeley Lab

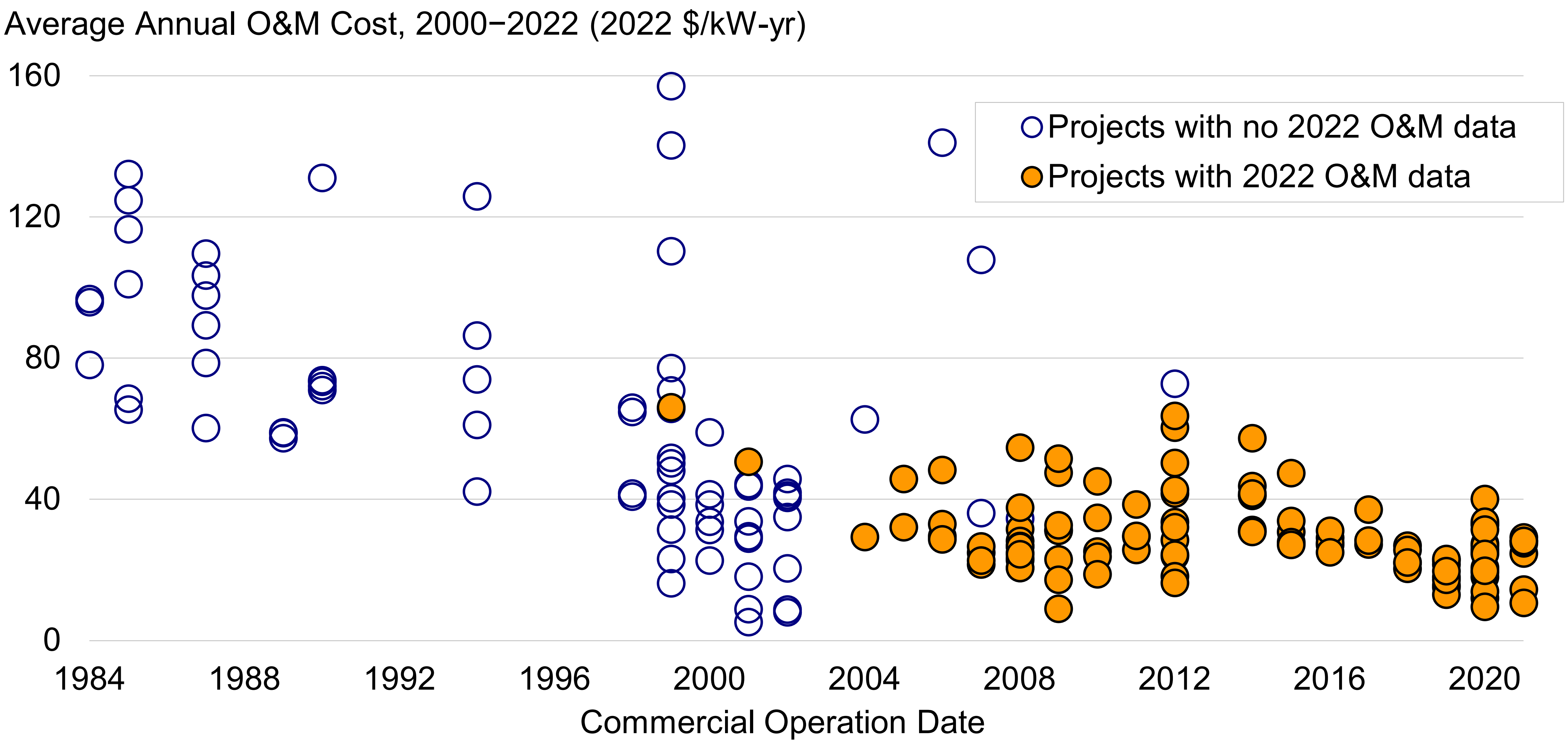
Interactive data visualization: https://emp.lbl.gov/wind-energy-capital-expenditures-capex

Installed costs (per megawatt) generally declined with project size considering projects installed in 2021 and 2022



Source: Berkeley Lab

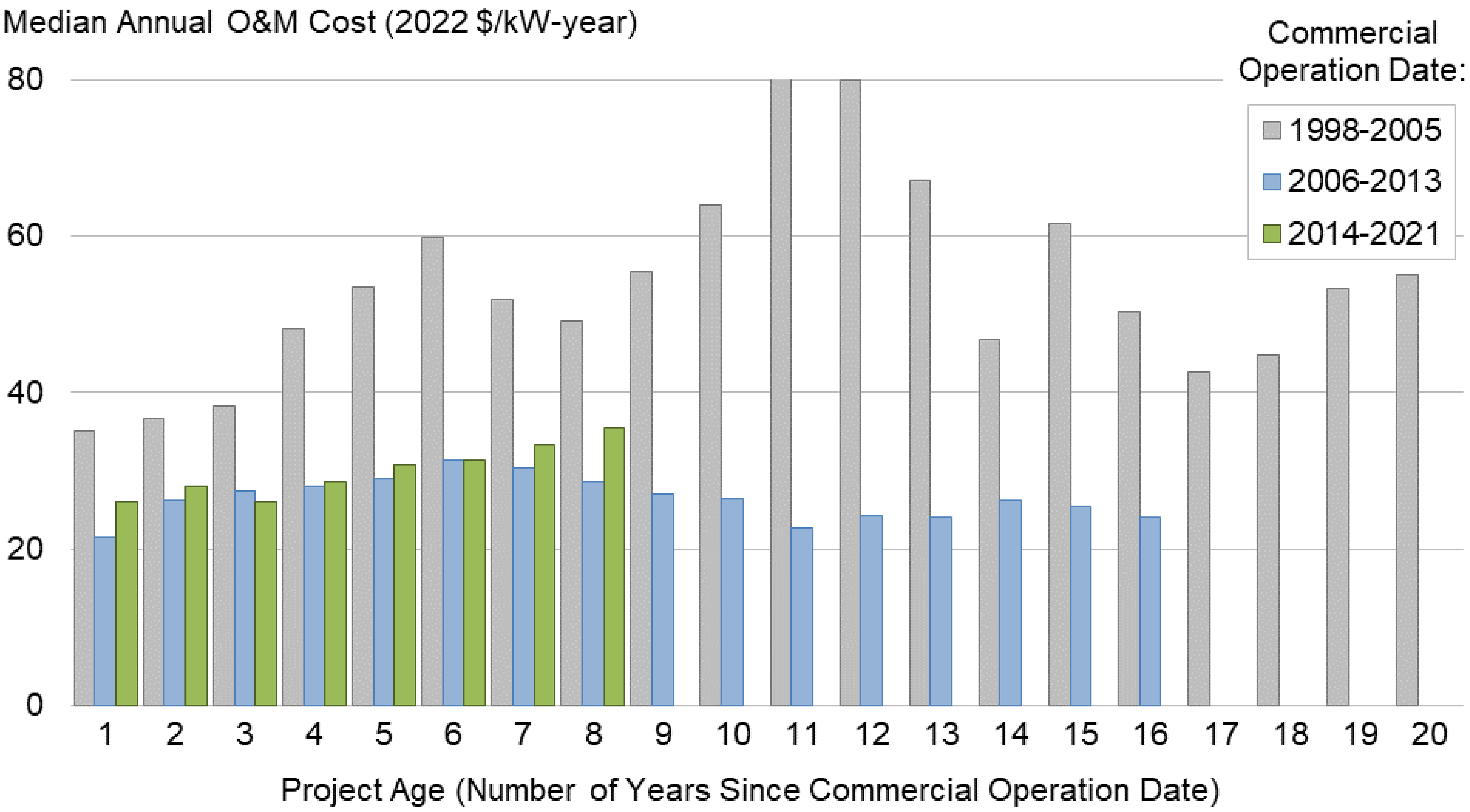
Operations and maintenance (O&M) costs vary by commercial operations date and project age



Source: Berkeley Lab; some data points suppressed to protect confidentiality

Note: Sample is limited; few projects in sample have complete records of O&M costs from 2000-22; O&M costs reported here <u>do not</u> include all operating costs.

O&M costs are lower for more-recently built projects, but cost trends as projects age do not follow consistent patterns



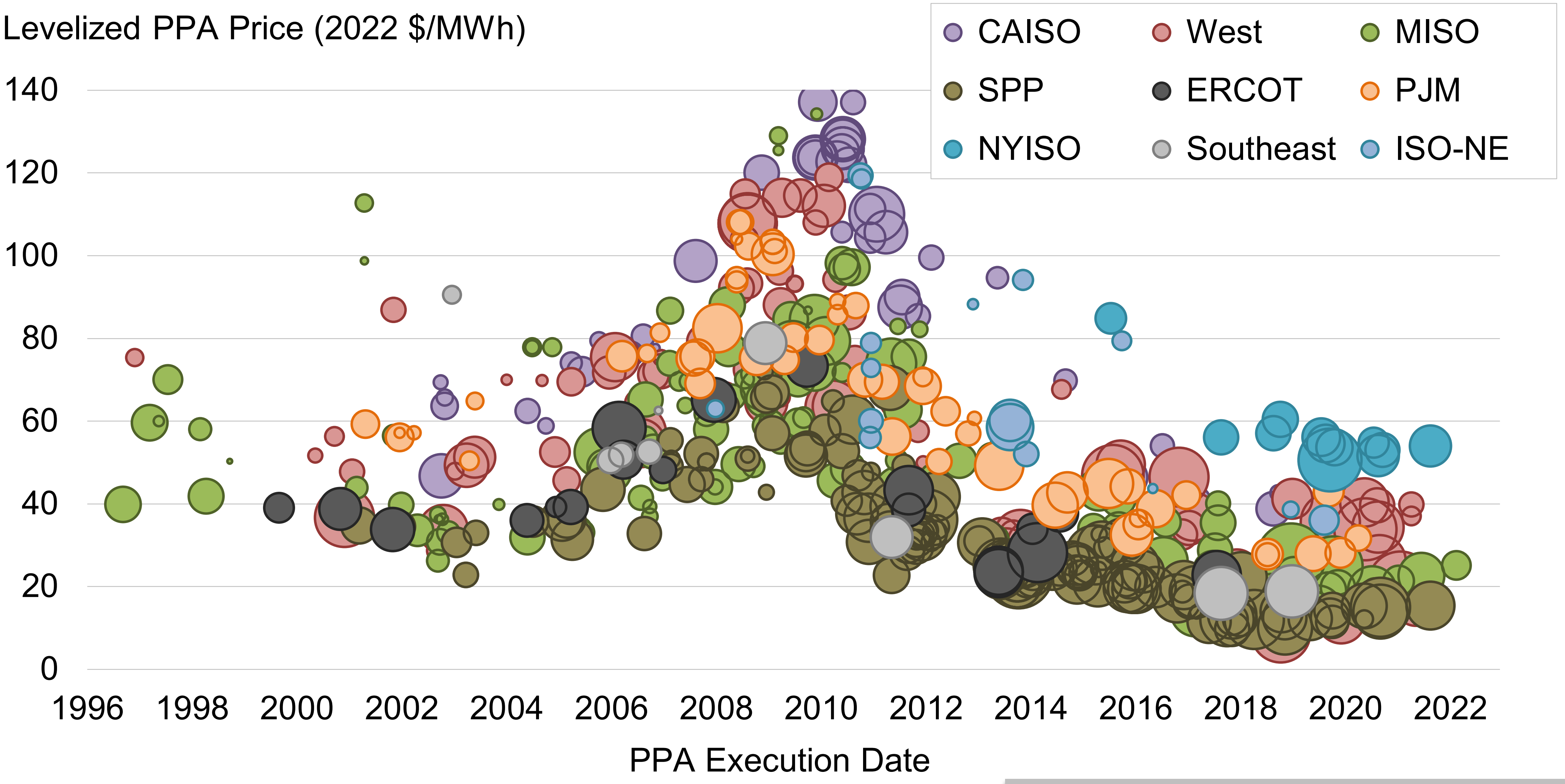
O&M reported here does not include all operating costs: all-in operating costs for the most recent wind projects average >$40/kW-year

Source: Berkeley Lab; medians shown only for groups of two or more projects, and only projects >5 MW are included

Note: Sample size is limited, especially in years 15-20

Power Sales Price and Levelized Cost Trends

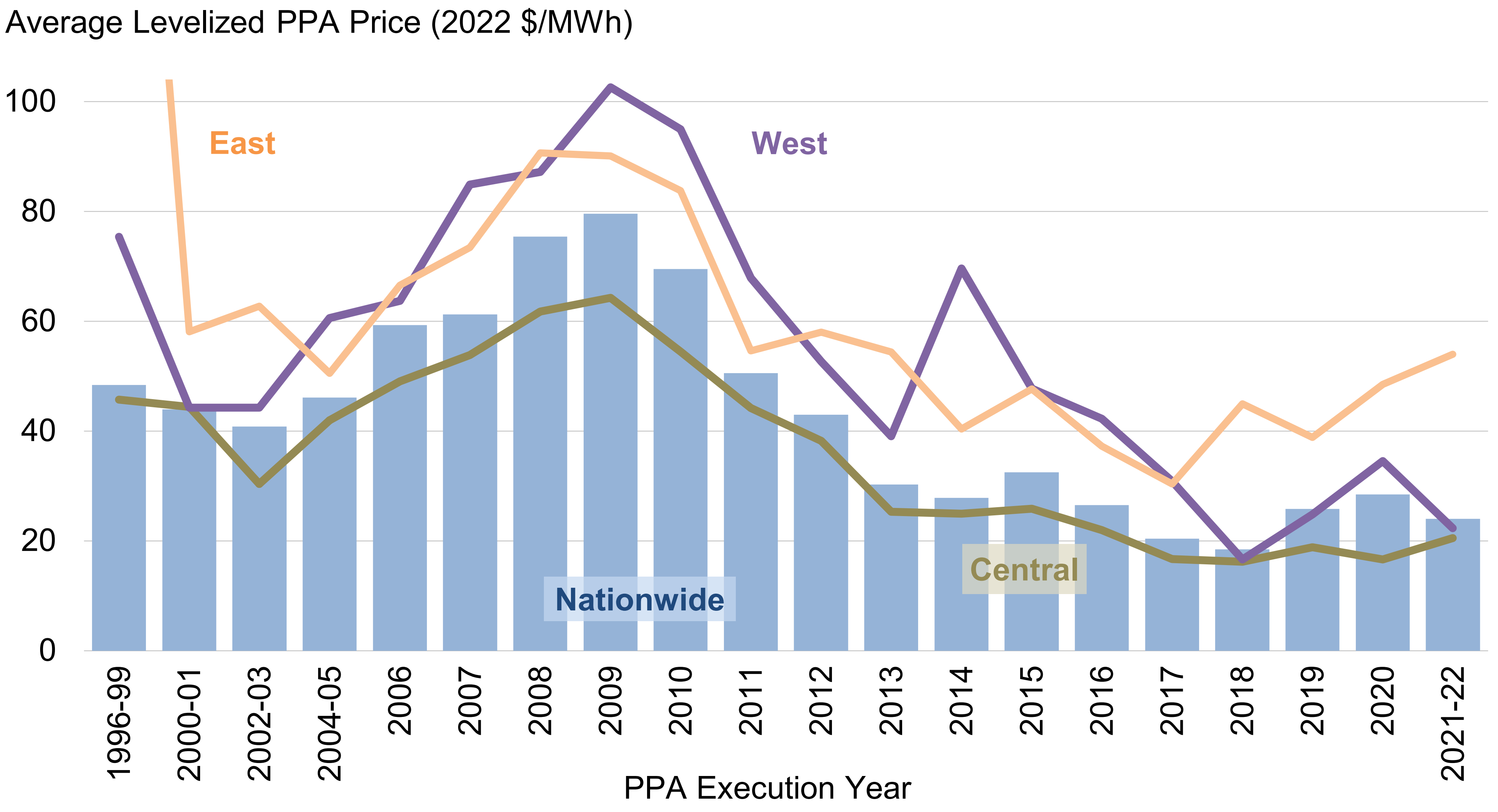
Wind power purchase agreement (PPA) prices have been drifting higher since 2018; recent range of below $20/MWh to over $40/MWh



Note: Size of bubble reflects contract capacity
Source: Berkeley Lab, FERC

Interactive data visualization: https://emp.lbl.gov/wind-power-purchase-agreement-ppa-prices

Average PPA prices have steeply declined since 2009 but risen in more recent years; prices around $20/MWh in central region

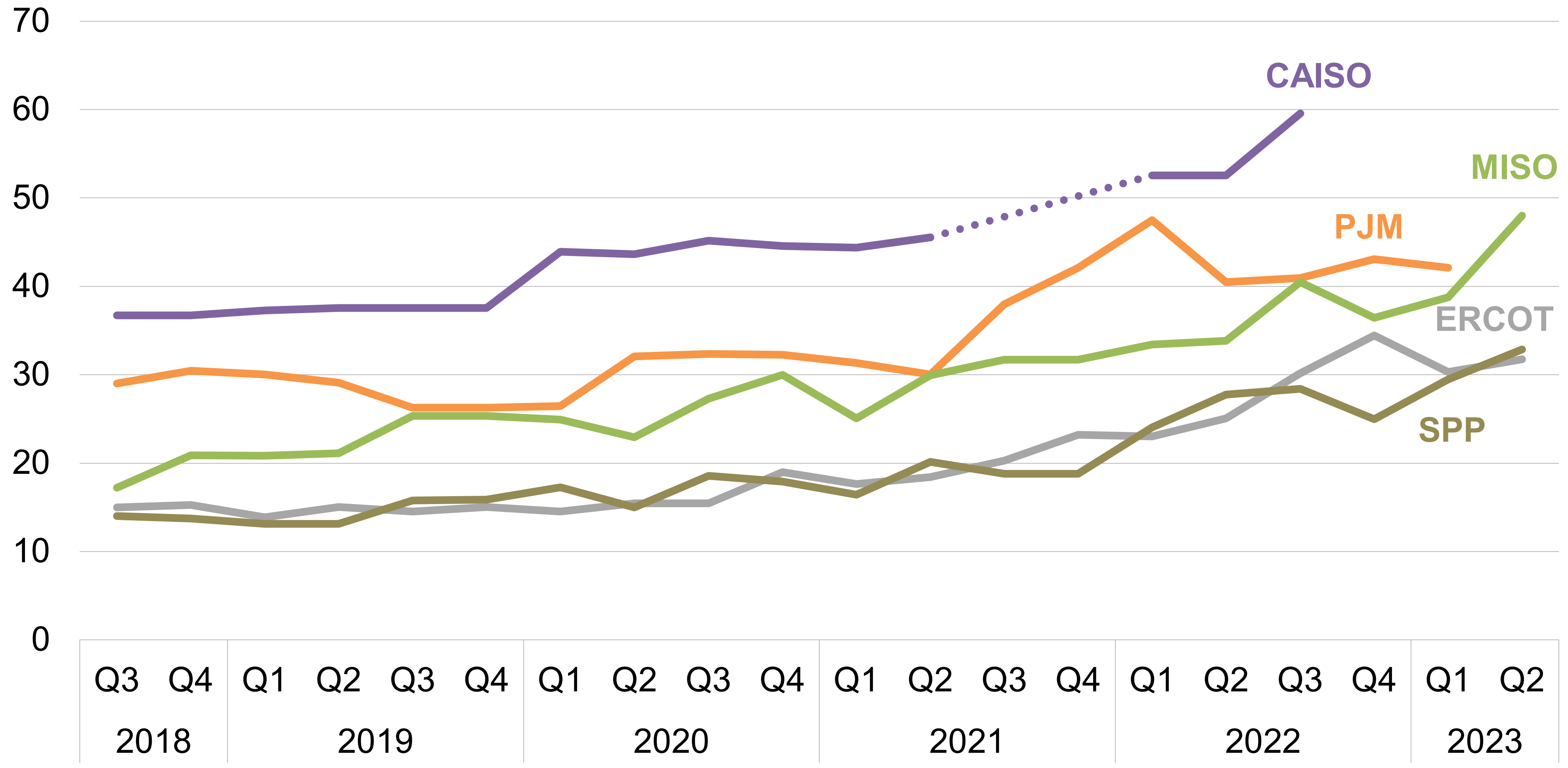


Source: Berkeley Lab, FERC

Note: West = CAISO, West (non-ISO); Central = MISO, SPP, ERCOT; East = PJM, NYISO, ISO-NE, Southeast (non-ISO)

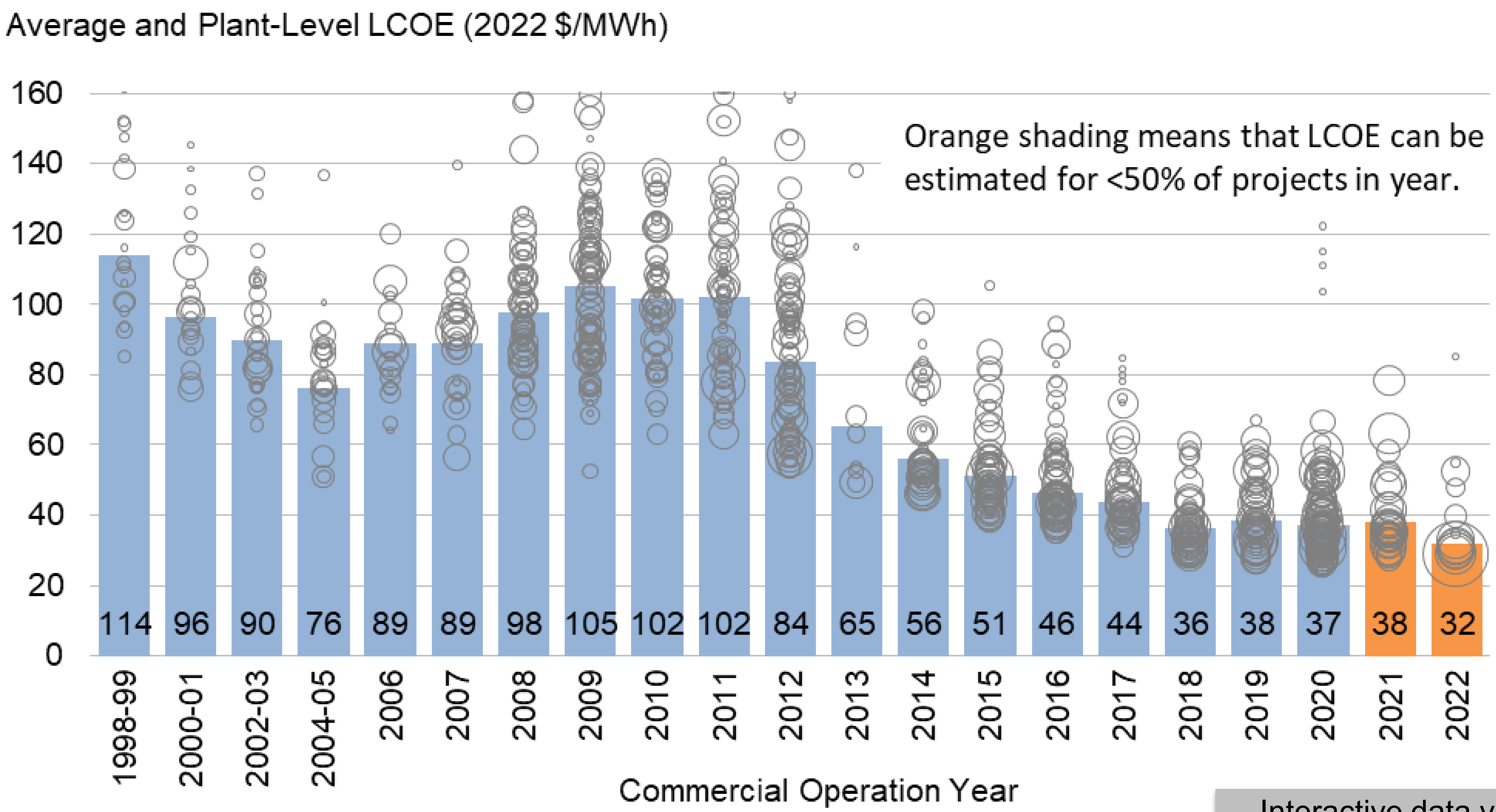
LevelTen Energy price indices confirm rising PPA prices, and regional variations in wind energy prices

Level10 PPA Price Index (2022 $/MWh, 25th percentile of offers)



Source: LevelTen Energy
Note: See full report for approach to converting nominal dollar LevelTen data to levelized real 2022$ as reported in figure above.

Levelized cost of wind energy (LCOE): nationwide average of $32/MWh for limited sample of projects installed in 2022

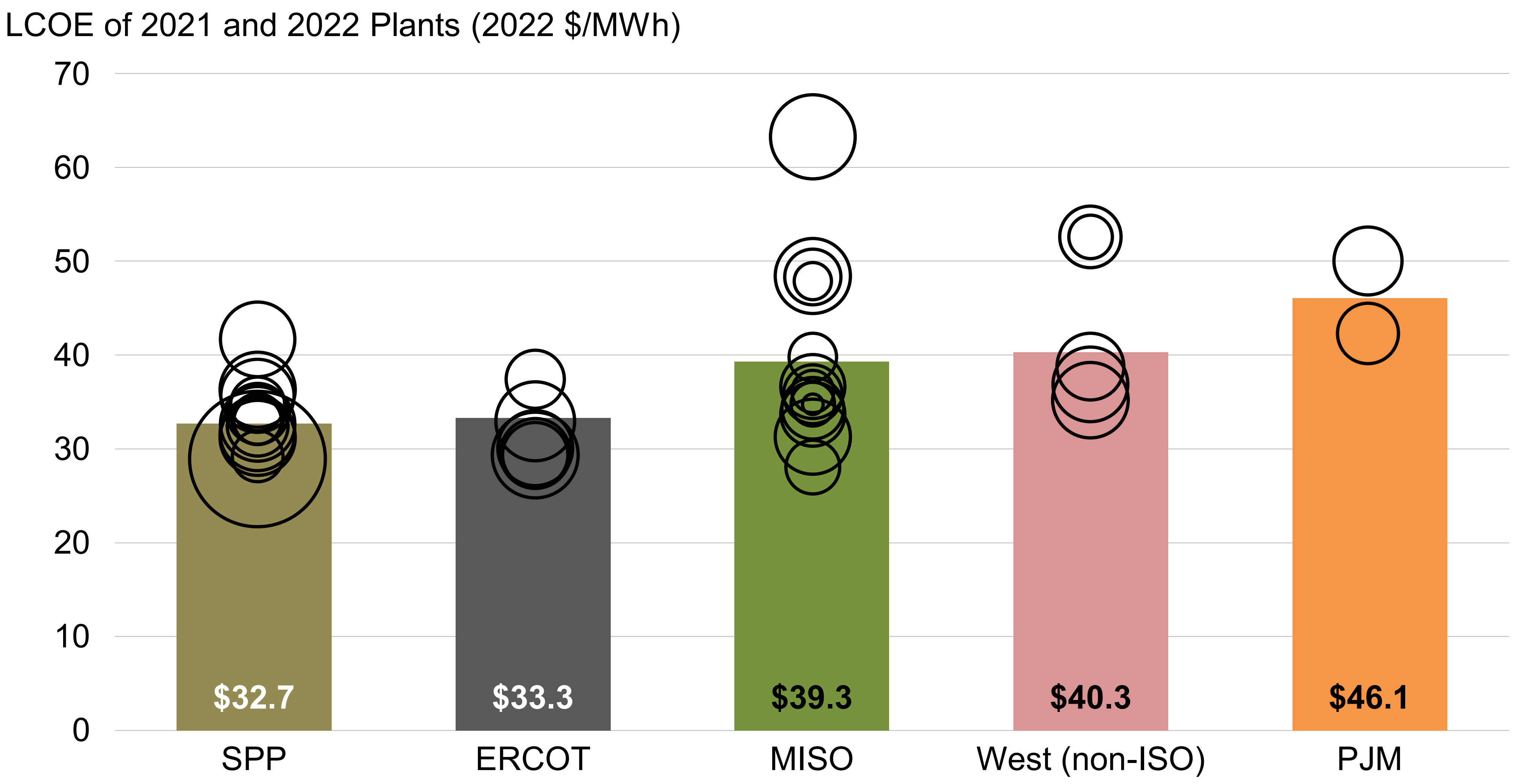


Source: Berkeley Lab

Note: Yearly estimates reflect variations in installed cost, capacity factors, operational costs, cost of financing, and project life; includes accelerated depreciation but excludes PTC. See full report for details.

Interactive data visualization: https://emp.lbl.gov/levelized-cost-wind-energy

Levelized costs vary by region, with the lowest costs in SPP and ERCOT for recently built projects

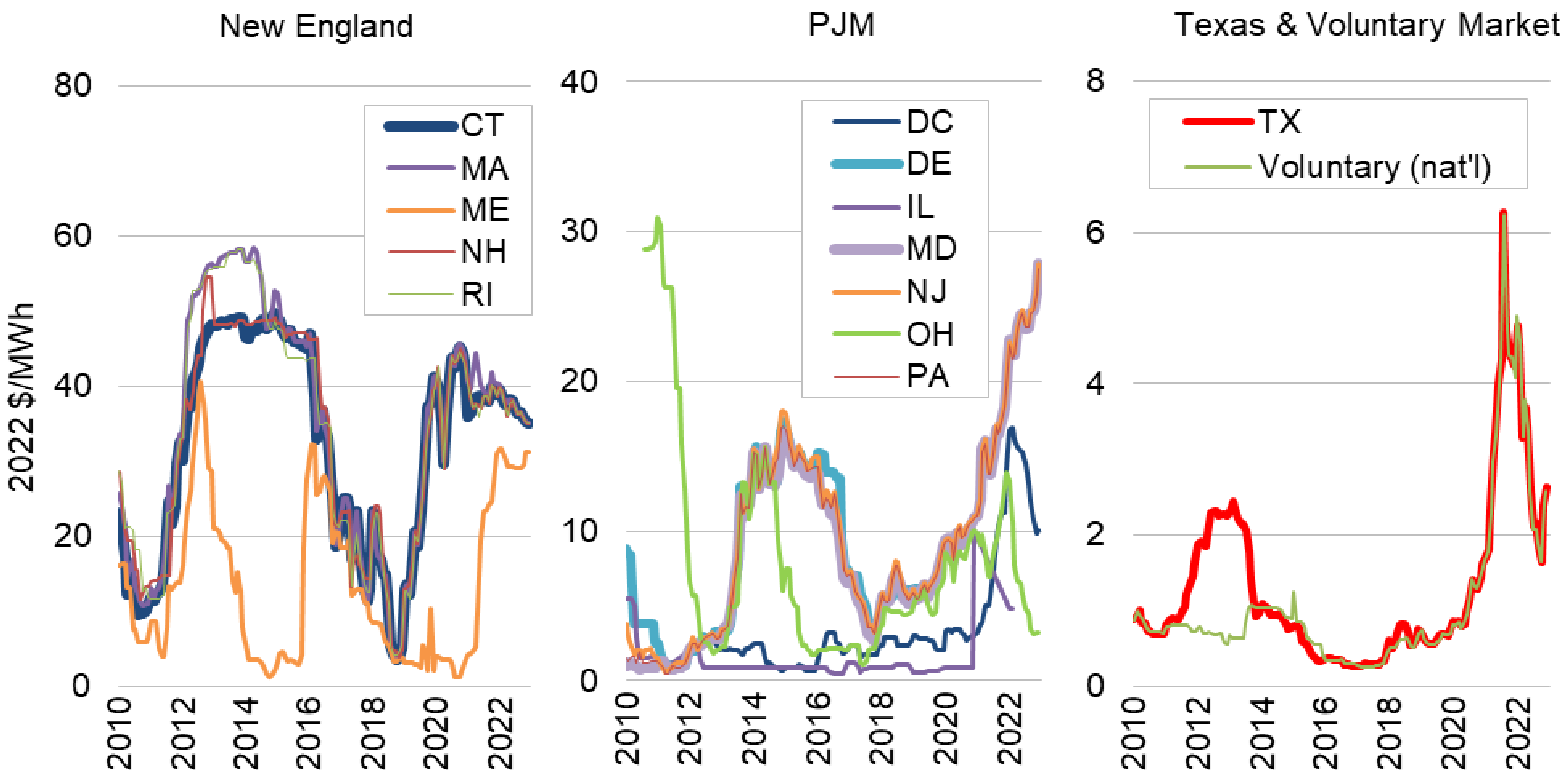


Note: Size of bubble reflects project capacity

Source: Berkeley Lab

Interactive data visualization: https://emp.lbl.gov/levelized-cost-wind-energy

Renewable Energy Certificate (REC) prices continue to vary substantially across markets and time

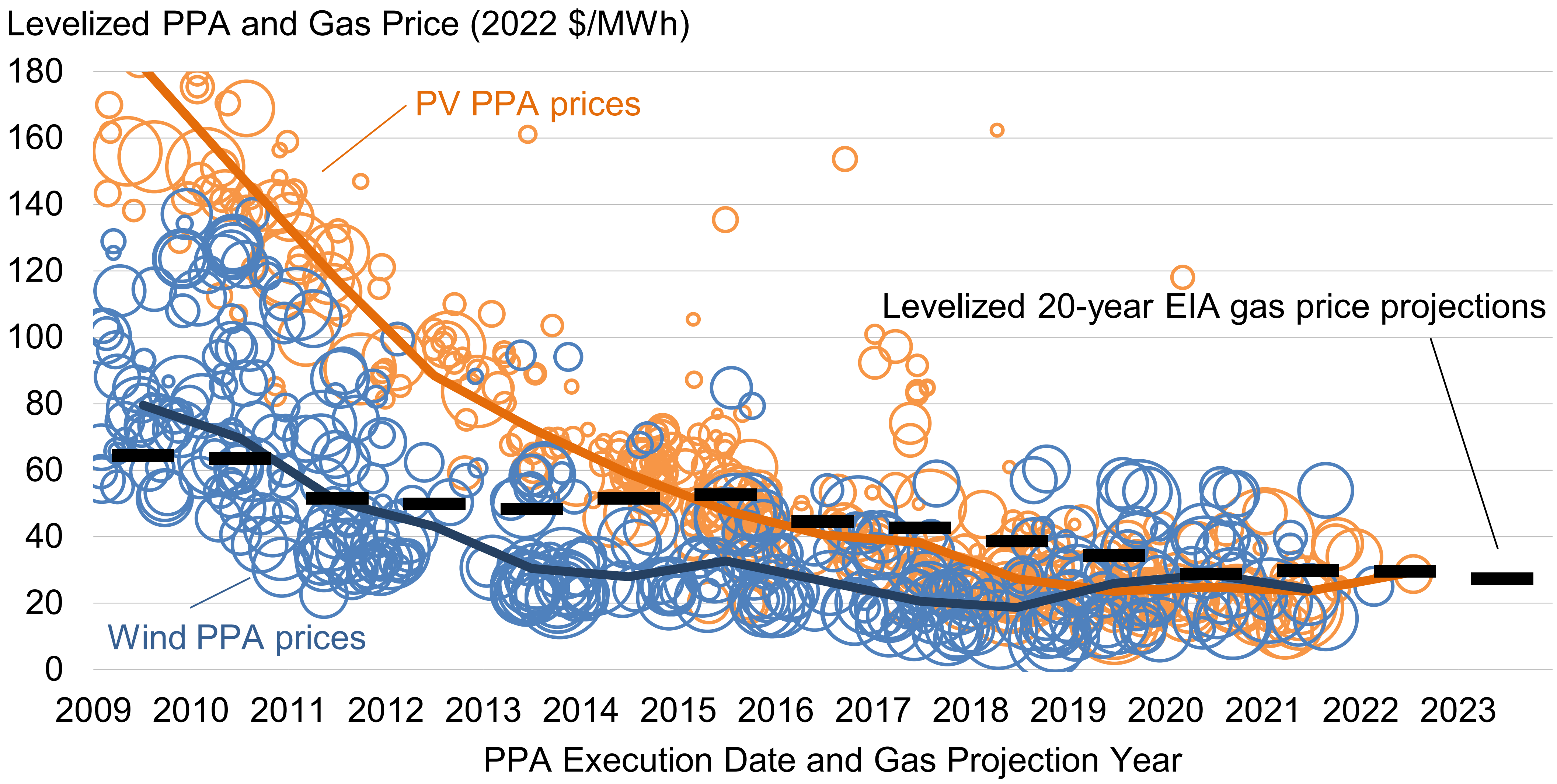


Source: Marex Spectron

REC prices vary by: market type (compliance vs. voluntary); geographic region; specific design of state RPS policies.

Cost and Value Comparisons

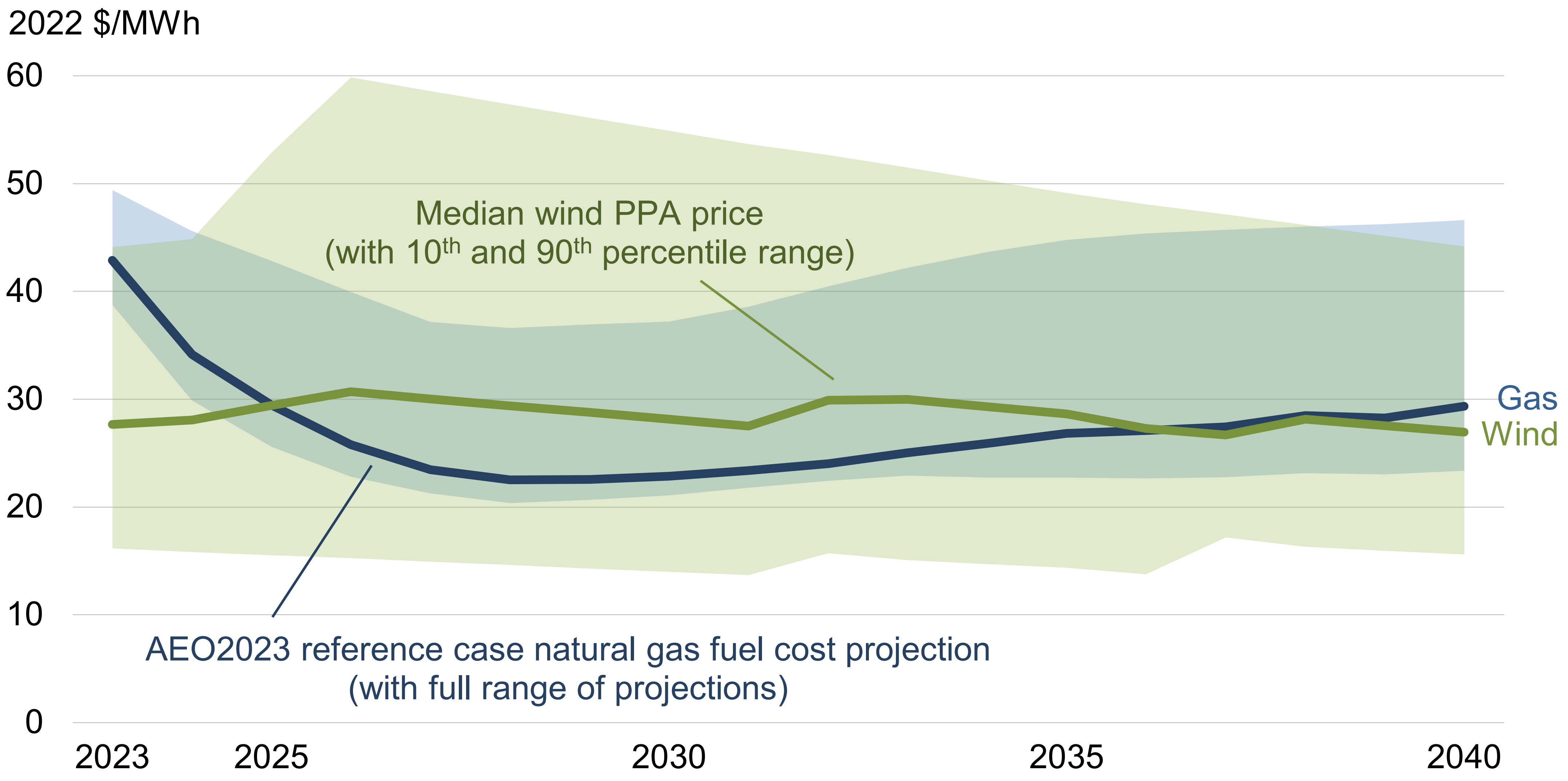
Despite relatively low wind PPA prices, wind faces competition from solar and natural gas



Source: Berkeley Lab, FERC, EIA

Note: Smallest bubble sizes reflect smallest-volume PPAs (<5 MW), whereas largest reflect largest-volume PPAs (400 MW).

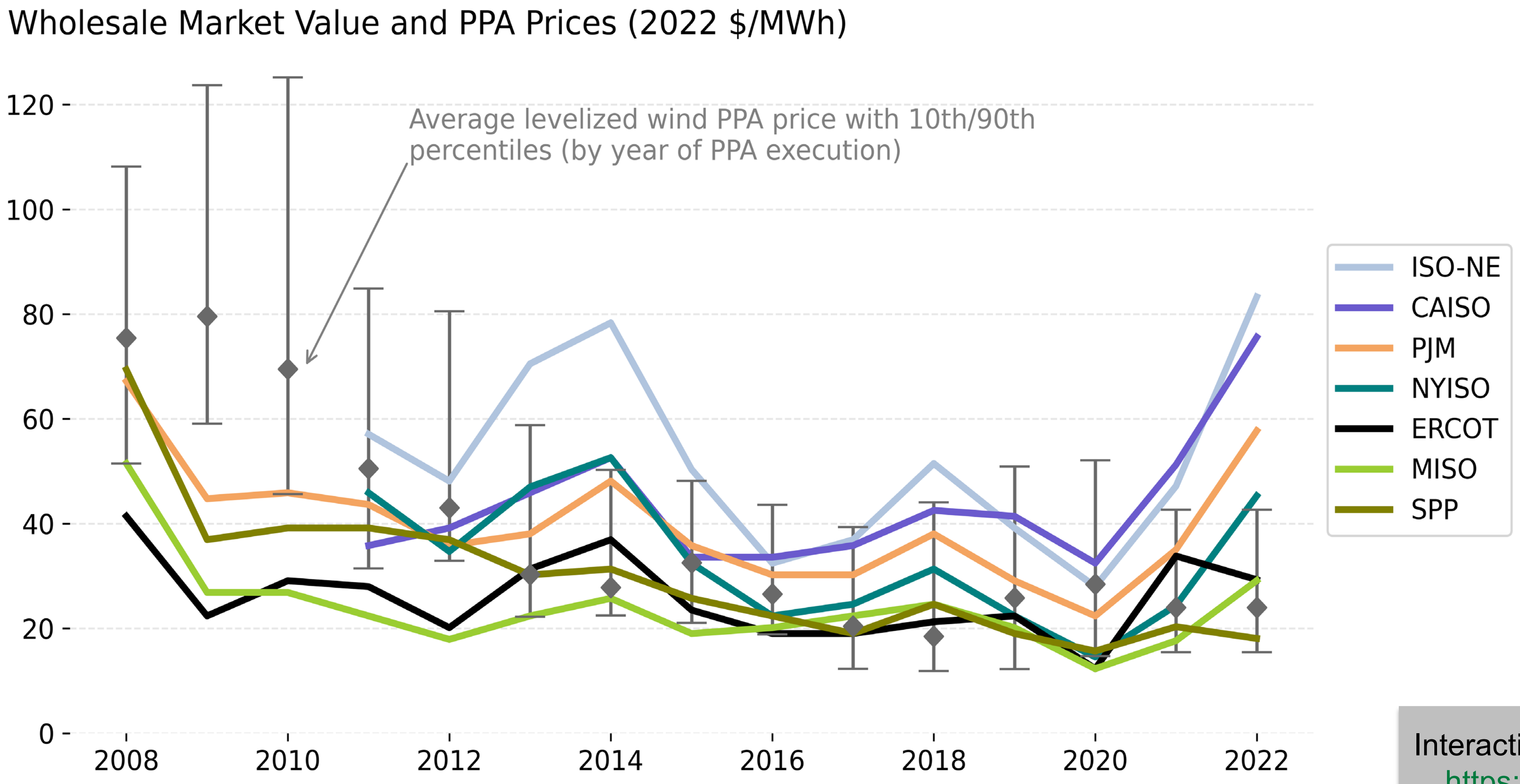
Recent wind prices are comparable to the expected future cost of burning fuel in natural gas plants



Source: Berkeley Lab, FERC, EIA

Notes: Price comparisons shown are far from perfect—see full report for details

The grid-system market value of wind surged in 2022 across many regions and was often higher than recent wind PPA prices

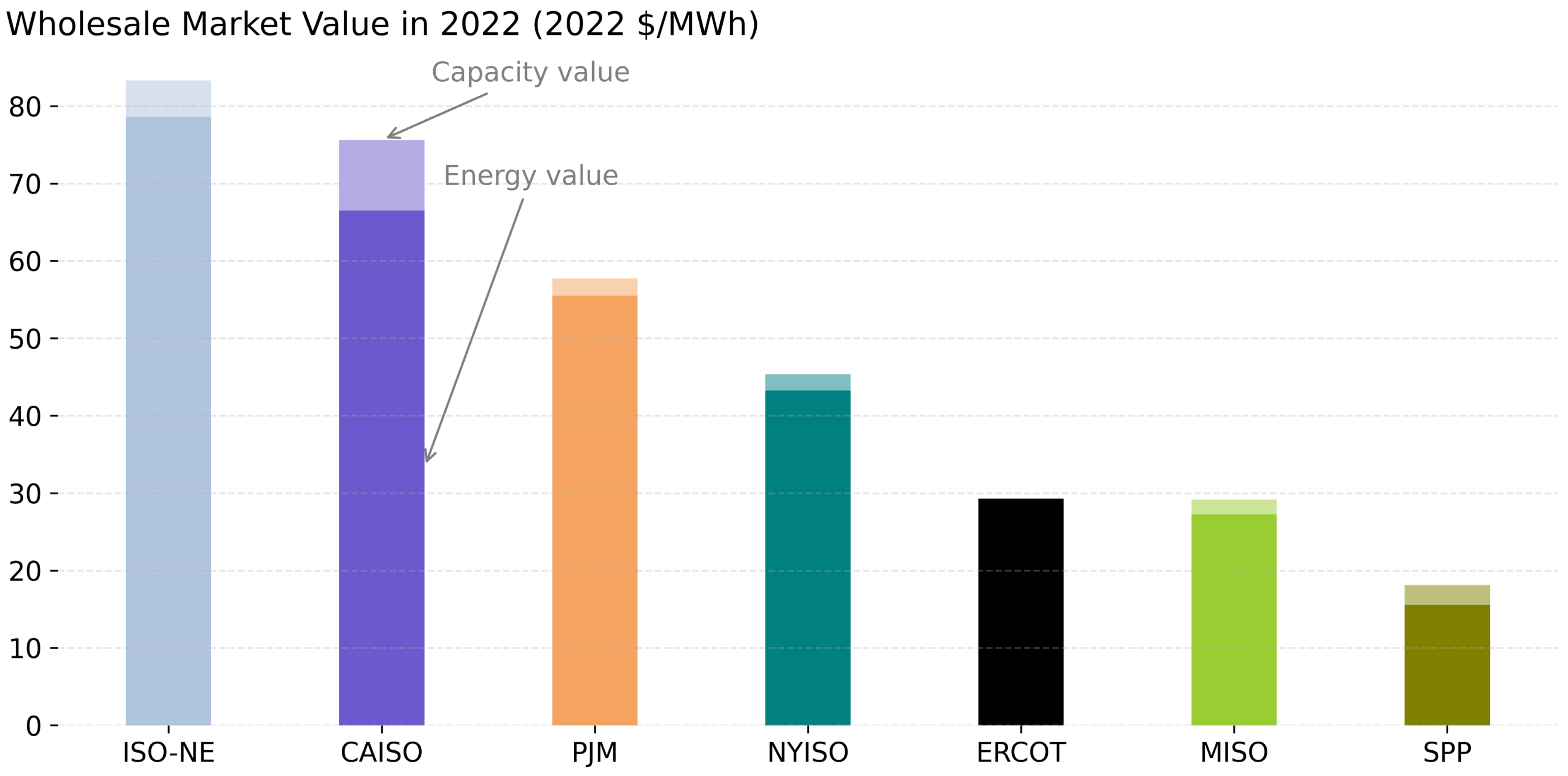


Sources: Berkeley Lab, ABB, ISOs

Wholesale market value considers hourly local wholesale energy price and hourly wind output, along with capacity value where available

Interactive data visualization: https://emp.lbl.gov/wind-energy-market-value

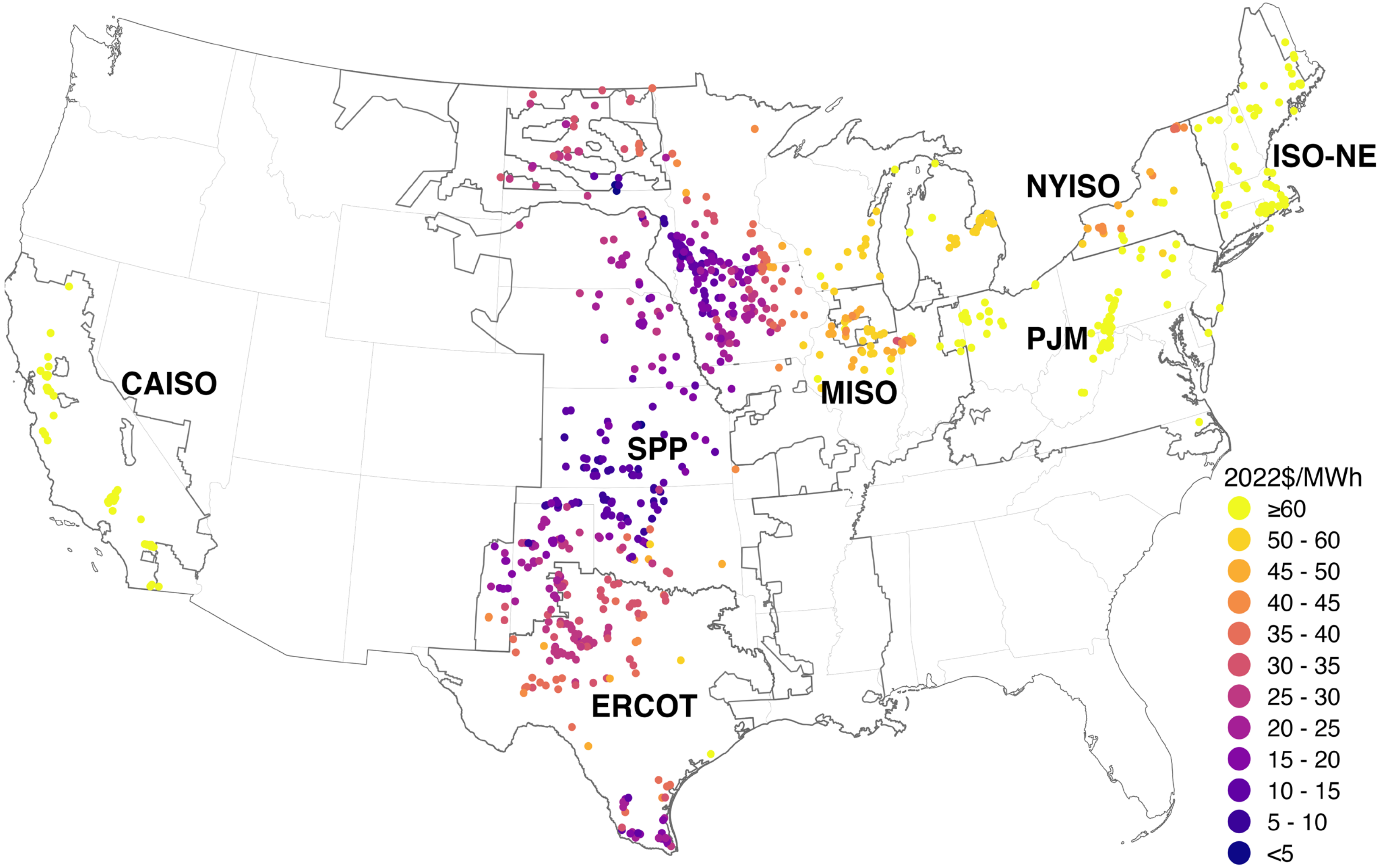
The wholesale market value of wind energy in 2022 varied by region: lowest in SPP, MISO, and ERCOT; highest in ISO-NE, CAISO, and PJM



Sources: Berkeley Lab, ABB, ISOs

Interactive data visualization: https://emp.lbl.gov/wind-energy-market-value

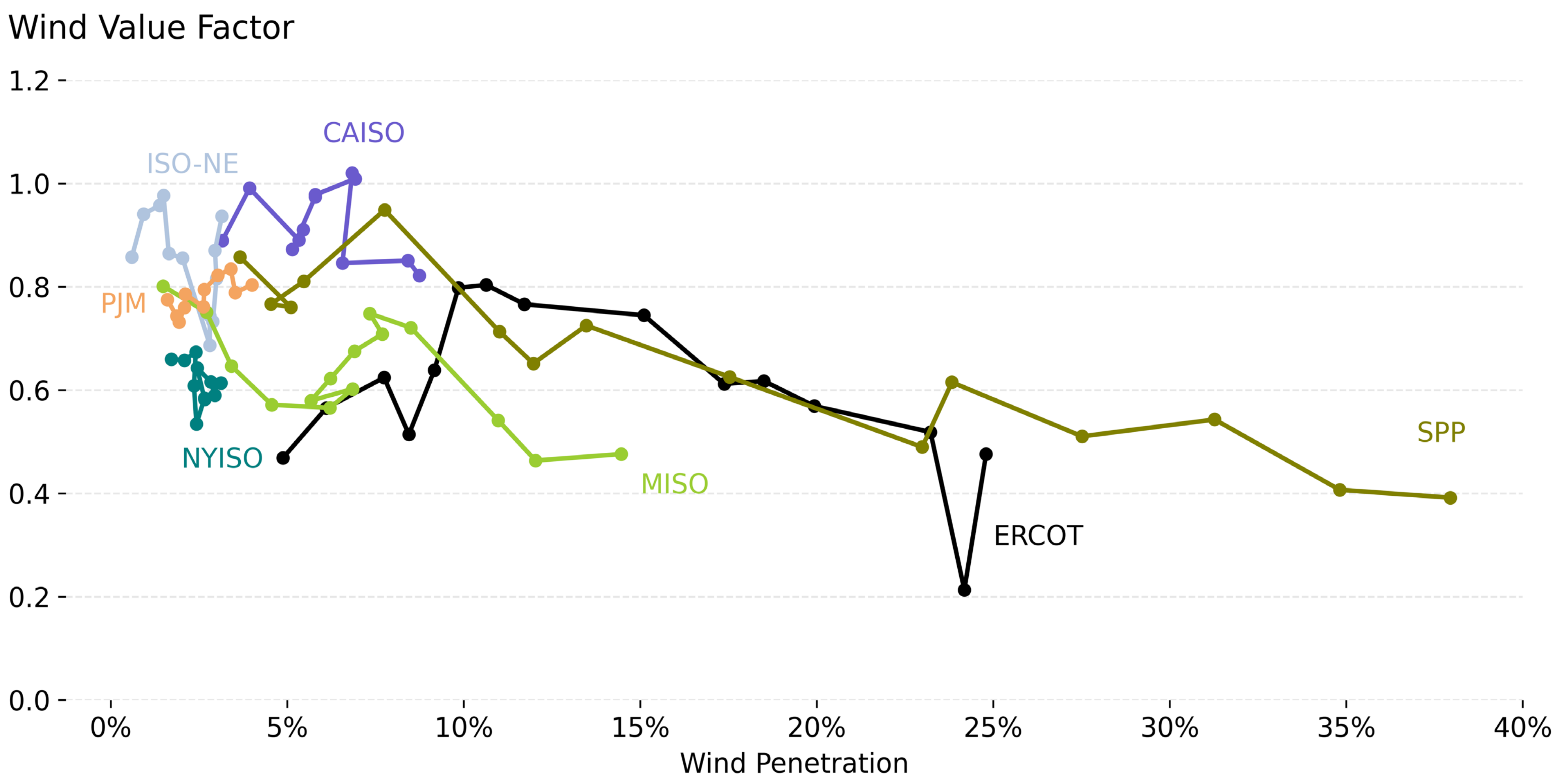
The grid-system market value of wind varies substantially by project location



Sources: Berkeley Lab, ABB, ISOs

Interactive data visualization: https://emp.lbl.gov/wind-energy-market-value

Average "value factor" of wind (value relative to flat block) is highly variable across regions, tends to decline with penetration

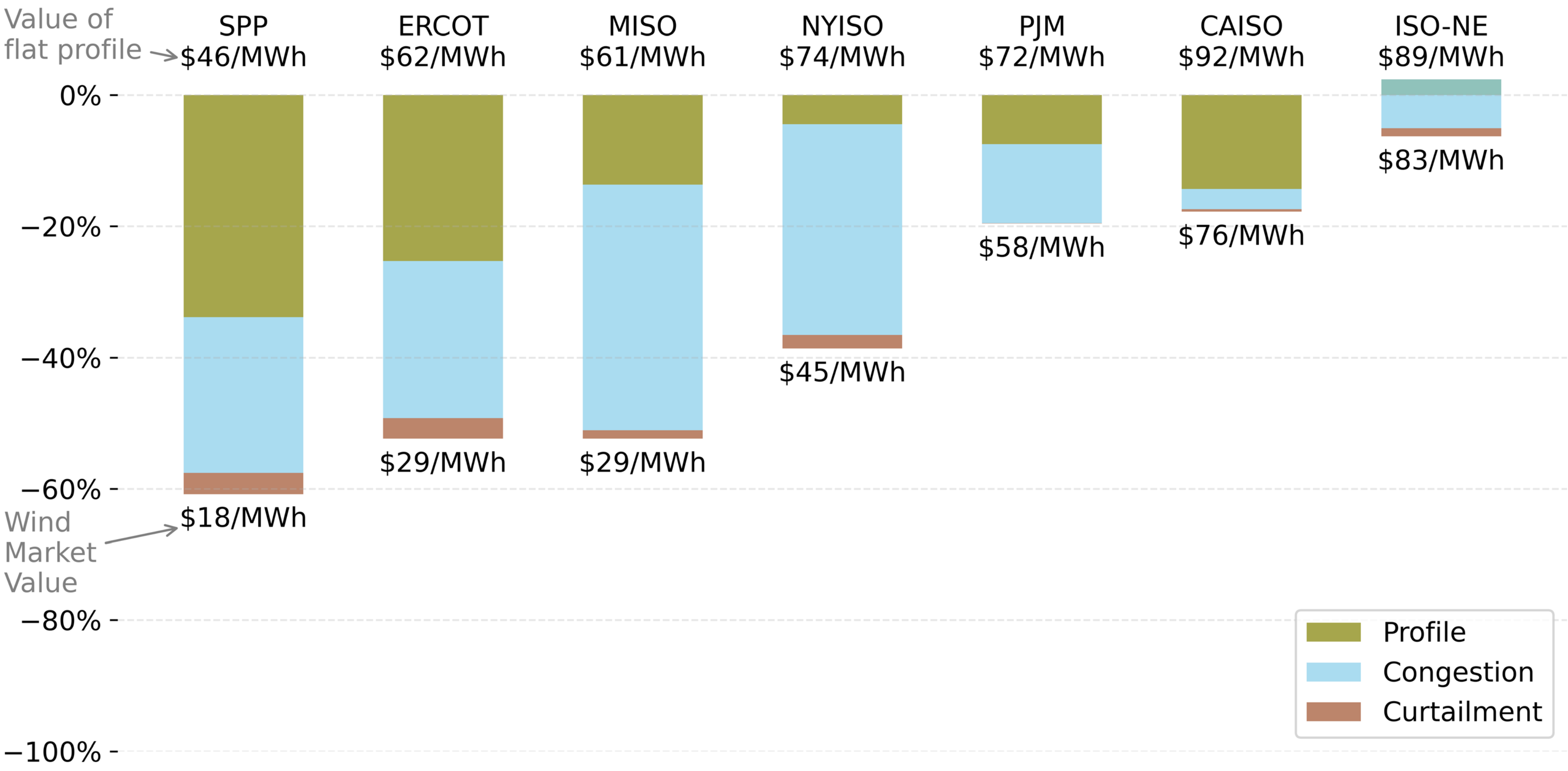


Sources: Berkeley Lab, ABB, ISOs

Value factor = wholesale market value of wind relative to generalized flat block of power in region; generalized flat block is 24x7 average price across all pricing nodes in region

Grid-system market value of wind tends to decline with penetration, impacted by output profile, transmission congestion, and curtailment

Average market value de-rate of wind in 2022 relative to a flat block varied by region: dominated by wind's output profile in some regions and congestion in others

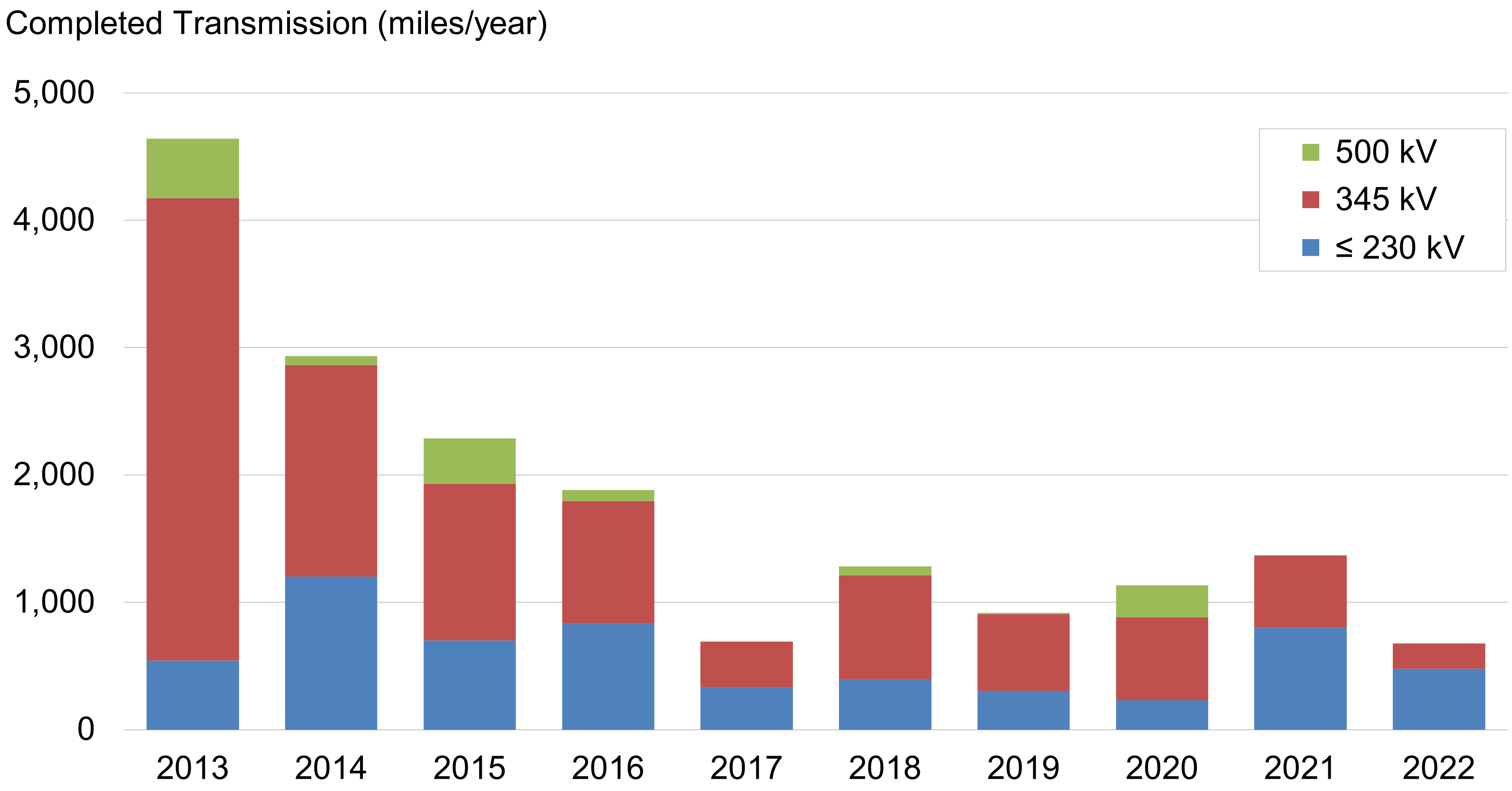


Note: In ISO-NE, the temporal profile of wind provides a slight premium value over a flat output profile (+2%). The color shows as teal because the negative congestion penalty (-7%) is layered on top of the positive profile premium.

Sources: Berkeley Lab, ABB, ISOs

As a location-dependent resource, wind power often requires or benefits from new transmission

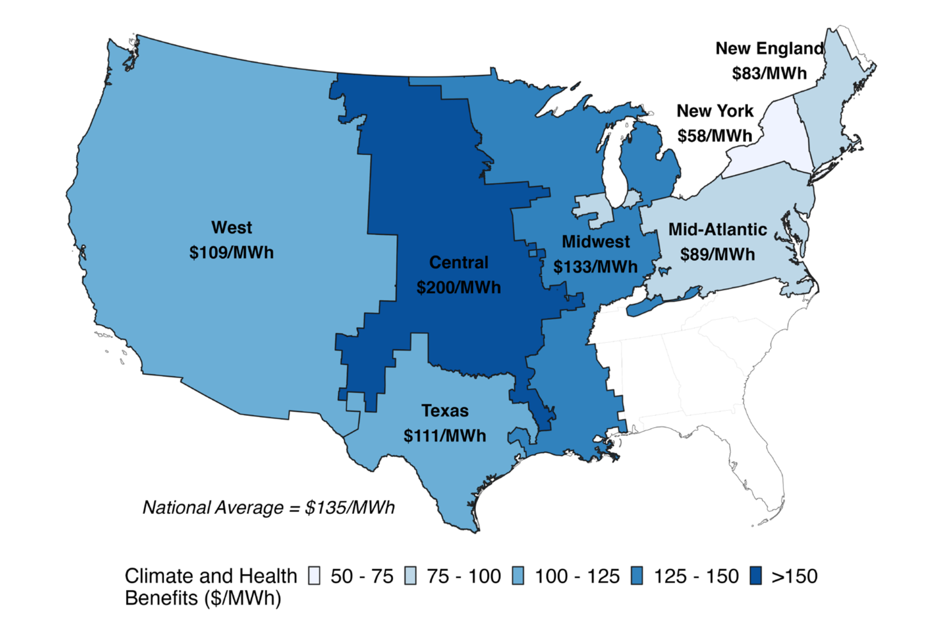
New transmission build has been relatively modest in recent years



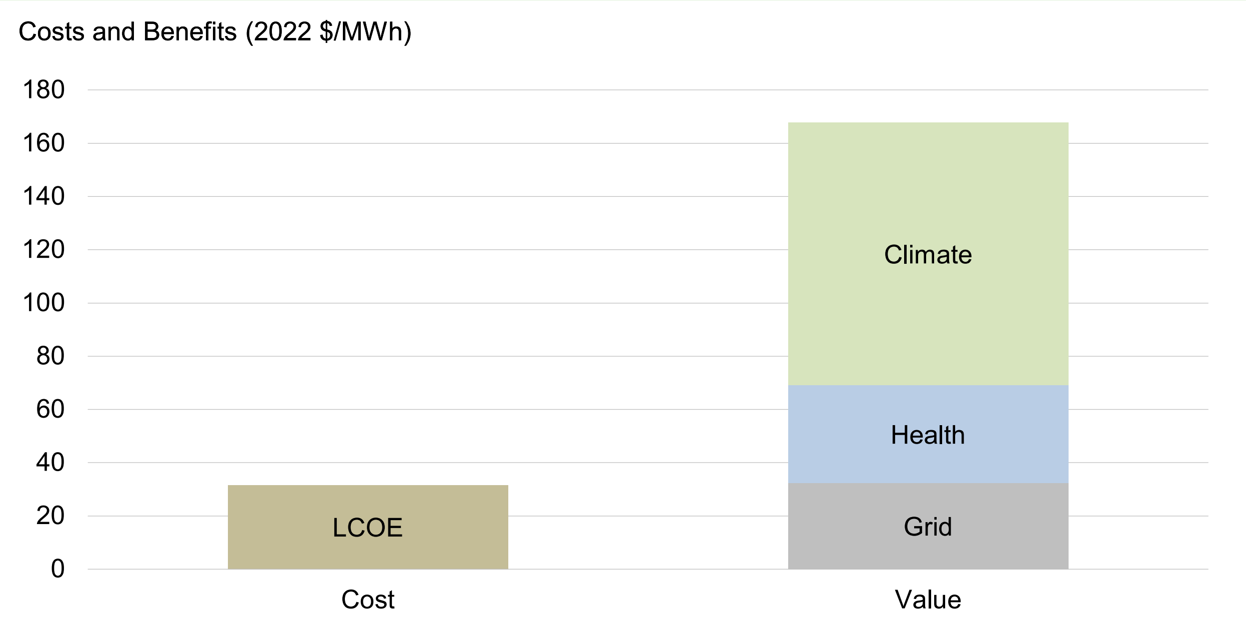
Source: FERC

The health and climate benefits of wind are larger than its grid-system value; the combination of all three far exceeds levelized cost of wind

Health and Climate Benefits of Wind in 2022 Vary Regionally, Average $135/MWh Nationally



Grid, Health, and Climate Benefits of Wind Plants in 2022 Far Exceed Recent Wind Project LCOE



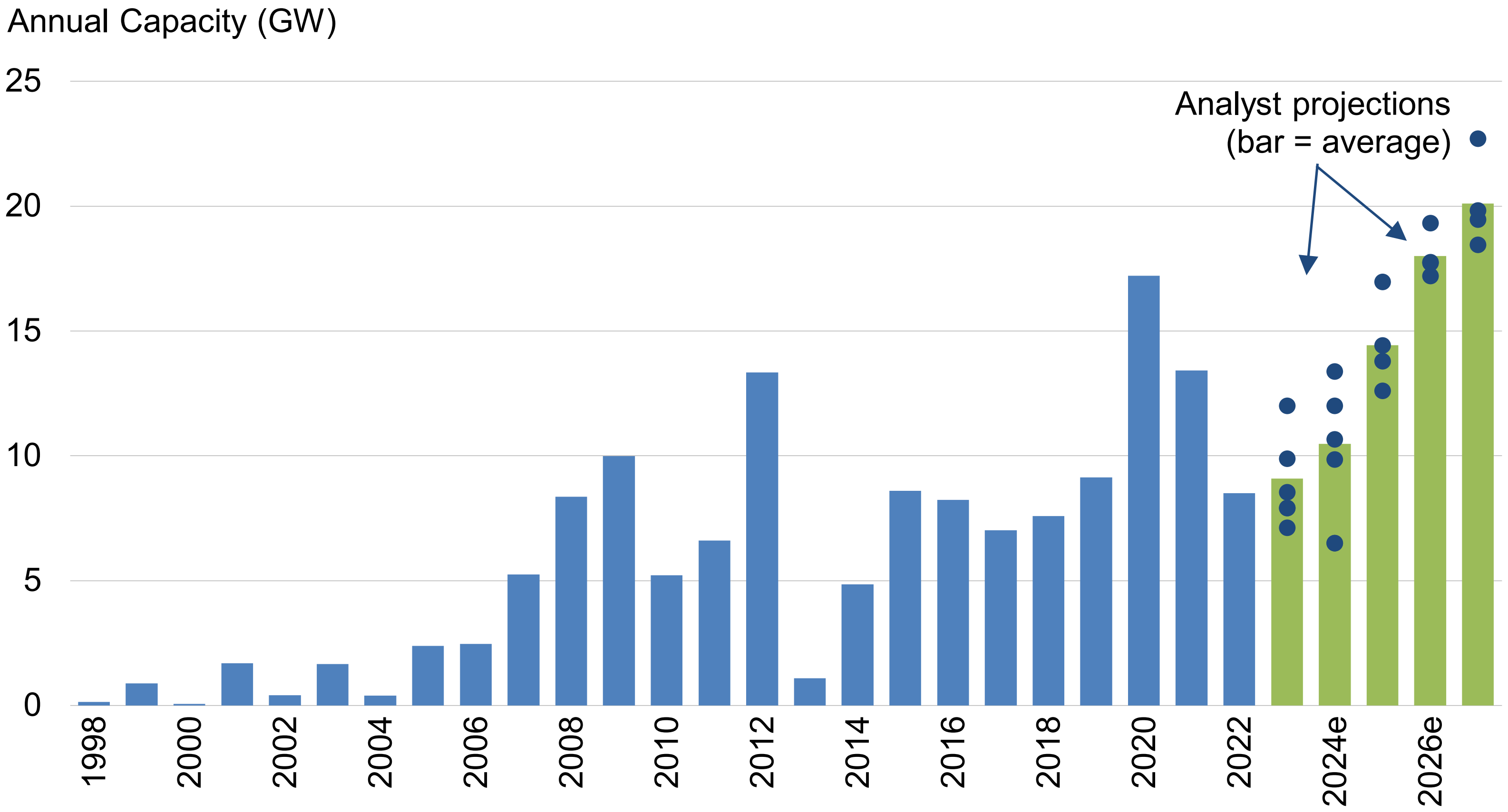
Note: Estimates not provided for Southeast due to small number of wind plants in that region.

Sources: Berkeley Lab, EIA Form 930

Future Outlook

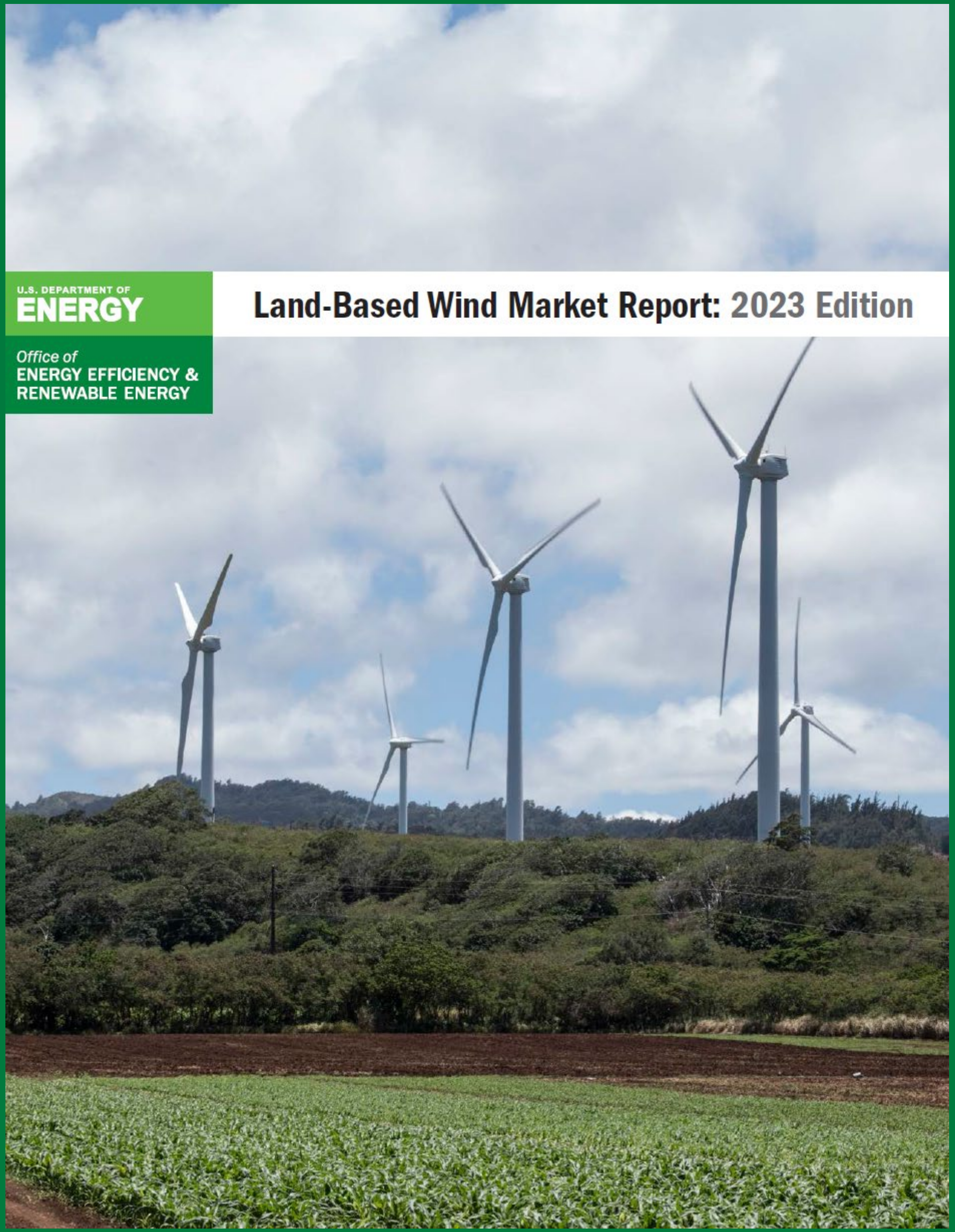
Analysts project growing wind deployment, spurred by incentives in the Inflation Reduction Act (IRA)

- IRA extends PTC at full value for at least ten years for projects that meet wage & apprenticeship requirements
- Two 10% bonuses on top of PTC, for meeting domestic content requirements or for location in energy community
- Additional tax credits for domestic clean energy manufacturing, including for nacelles, blades & towers



Sources: *ACP, independent analyst projections*

- Has resulted in both higher expectations for future capacity growth and a growing number of announcements for new, expanded, and re-opened manufacturing facilities
- Limited transmission, interconnection costs and timeframes, siting and permitting challenges, inflation and interest rates, and competition from solar may dampen growth



The underlying report, an accessible data file, and multiple visualizations can be found at:

- windreport.lbl.gov

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