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Land-Based Wind Energy Technology Data Update

Figure File: 2025 Edition

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Land-Based Wind Energy Technology Data Update: 2025 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* and *Industry Trends* sections often include data on both land-based and offshore wind; other sections focus solely on land-based
- Focus on historical data, with some emphasis on the previous year – 2024

Funding:

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

Products and Availability:

- This figure file is complemented with a data file and visualizations
- All products available at: windreport.lbl.gov

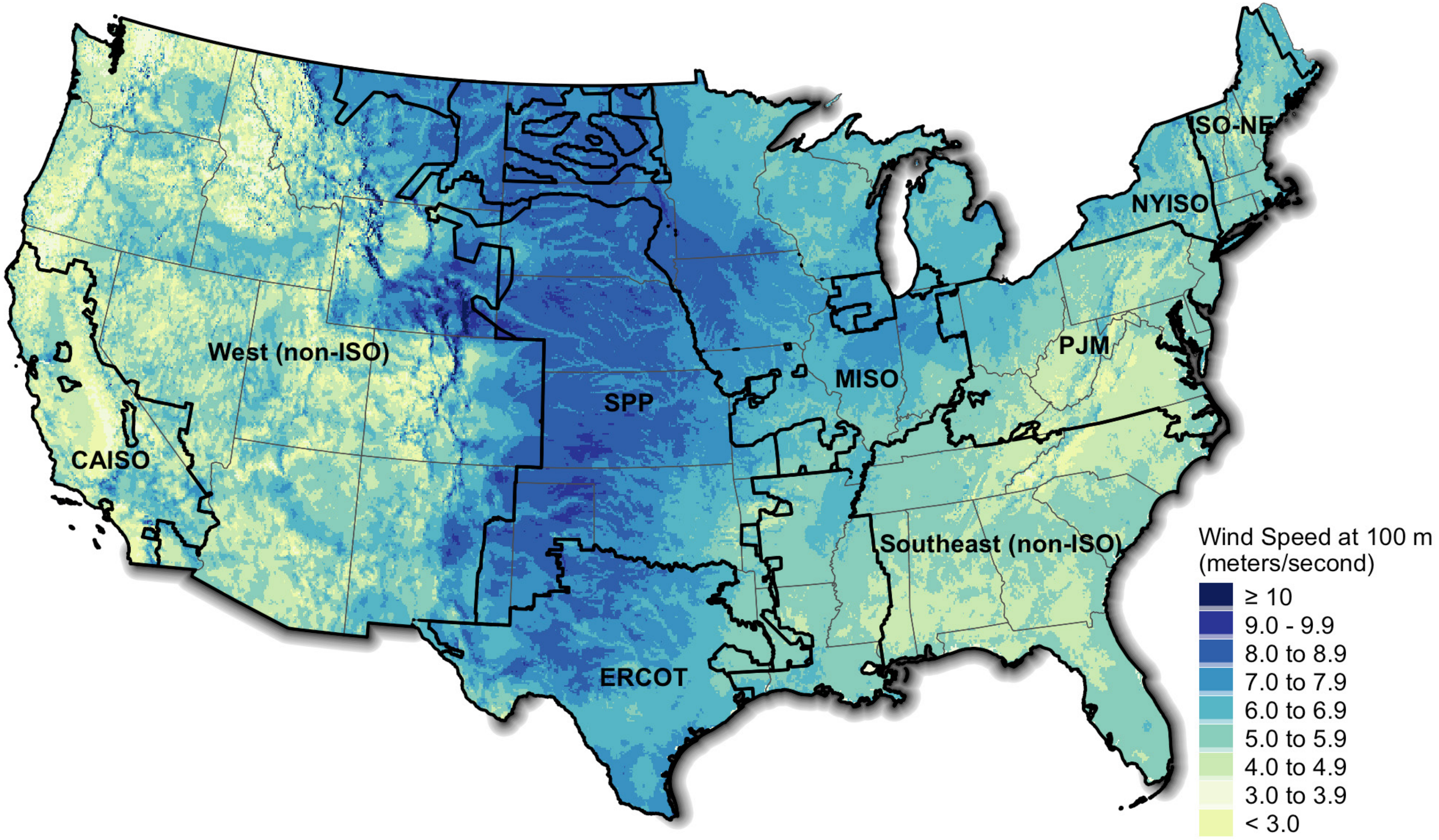
Contents of Figure File

- Installation data
- Industry data
- Technology data
- Performance data
- Cost data
- Power sales price and levelized cost data
- Cost and value data

What’s New this Year in the Online Data Set?

- Additional detail on wind equipment imports
- Larger sample of wind energy capital costs for recent projects
- Reporting of capital expenditure for partial repowering
- Augmented power purchase agreement price indices with Trio

Regional boundaries used in the figures that follow include the seven independent system operators (ISO) and two non-ISO regions

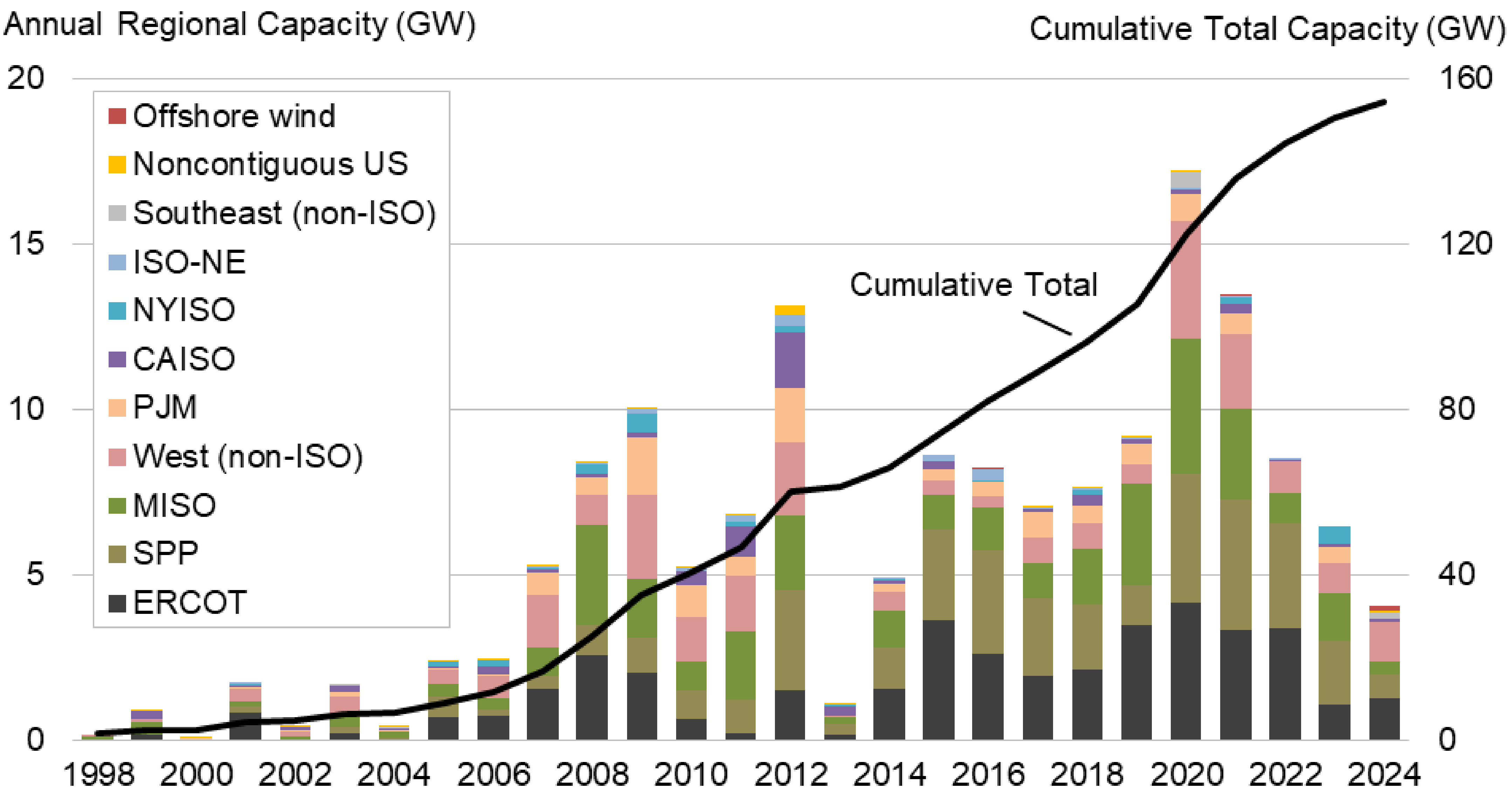


Sources: AWS Truepower, NREL

Regions: Southwest Power Pool (SPP), Electric Reliability Council of Texas (ERCOT), Midcontinent Independent System Operator (MISO), California Independent System Operator (CAISO), ISO New England (ISO-NE), PJM Interconnection (PJM), and New York Independent System Operator (NYISO), and the non-ISO West and Southeast.

Installation Data

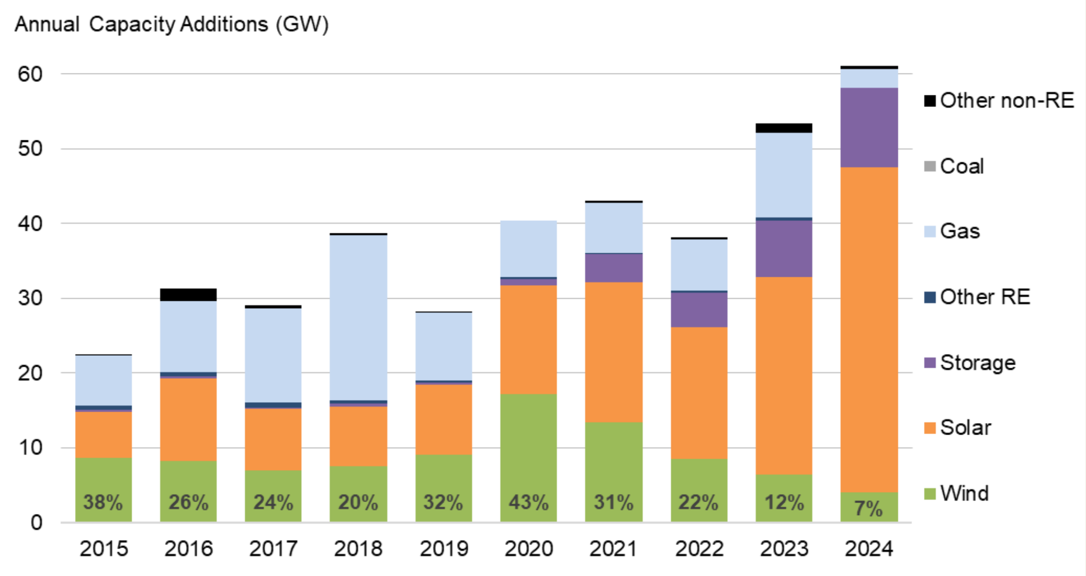
Annual and cumulative growth in U.S. wind power capacity: 4 GW added in 2024, cumulative total of 154 GW



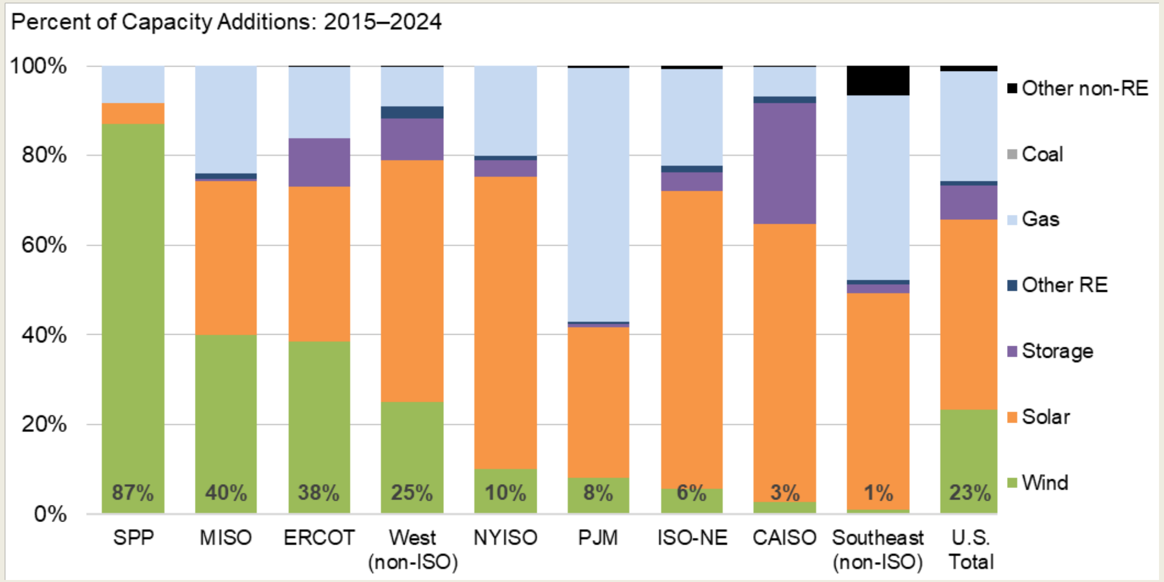
Source: ACP

Relative contribution of resource types in annual capacity additions

Relative contribution of resource types in annual capacity additions



Resource capacity additions by region: 2015-2024



Sources: EIA, ACP

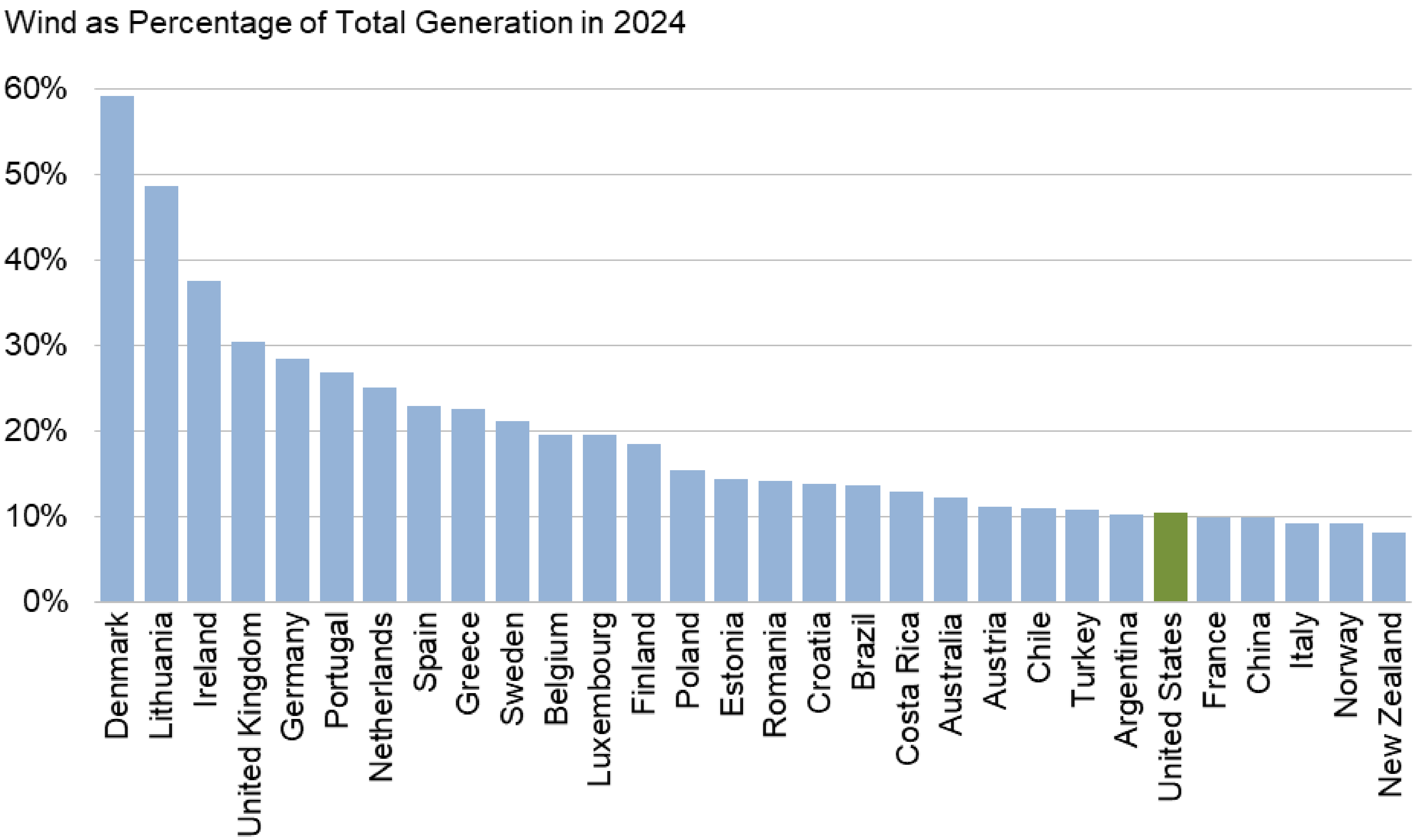
International rankings of total wind power capacity

Annual Capacity (2024, GW)	
China	79.8
United States	**4.0**
Germany	4.0
India	3.4
Brazil	3.3
United Kingdom	1.9
France	1.7
Finland	1.4
Canada	1.4
Turkey	1.3
Rest of World	14.6
TOTAL	**117**

Cumulative Capacity (end of 2024, GW)	
China	521
United States	**154**
Germany	73
India	48
Brazil	34
United Kingdom	32
Spain	31
France	25
Canada	18
Sweden	17
Rest of World	183
TOTAL	**1,136**

Sources: GWEC, ACP

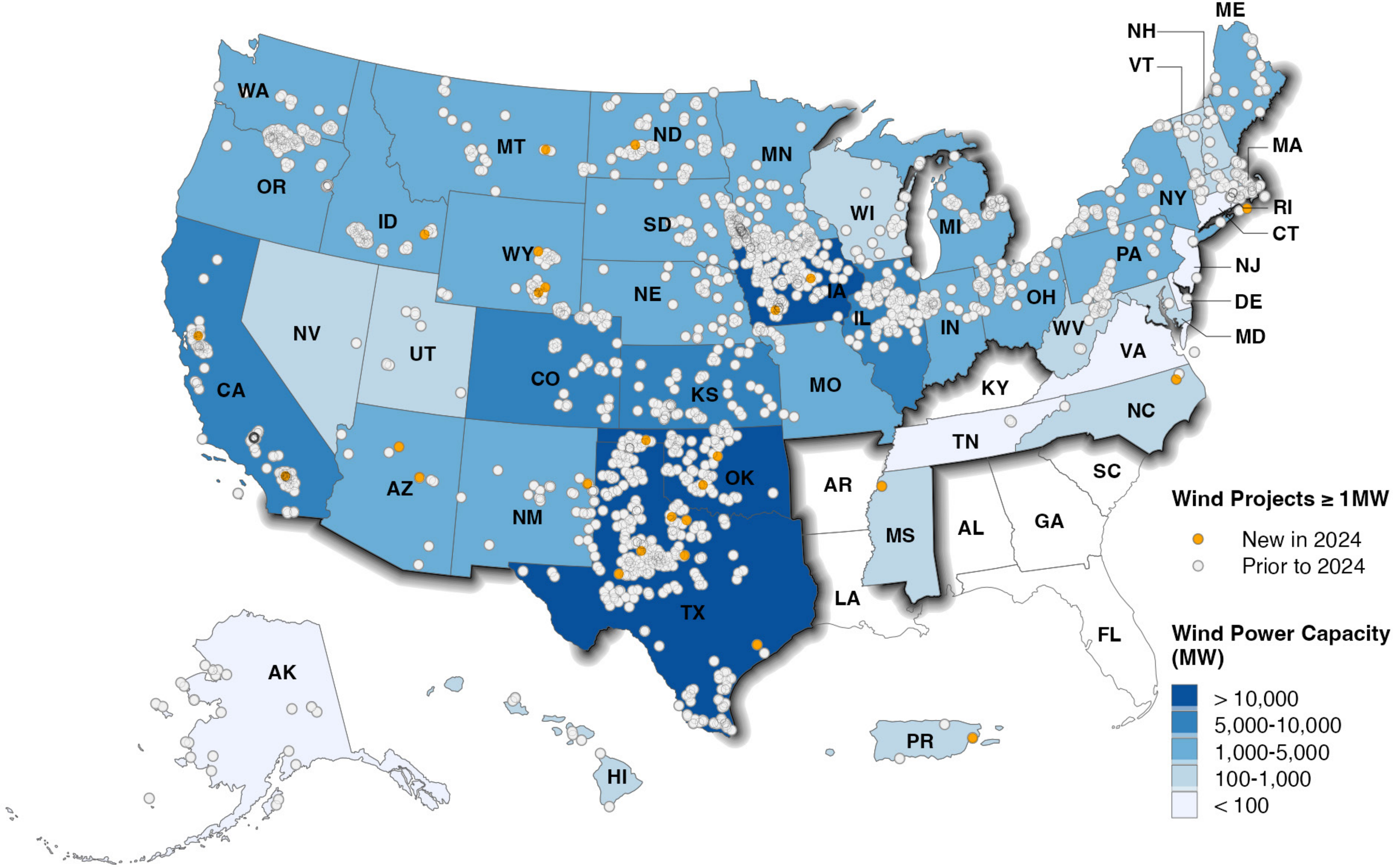
Wind energy generation percentage in subset of global wind markets: U.S. wind generation share of 10.3% in 2024



Source: IEA

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

U.S. wind power installations by state



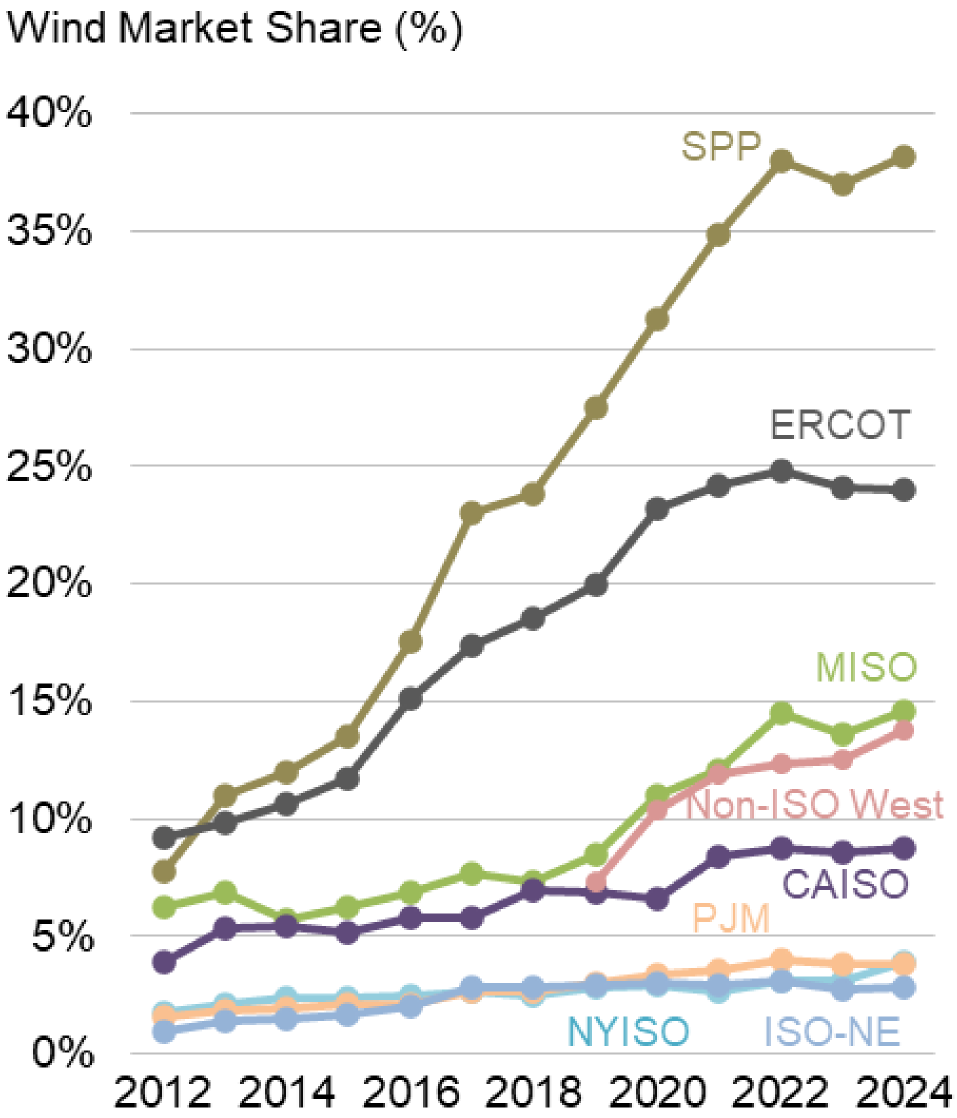
Source: ACP, Berkeley Lab

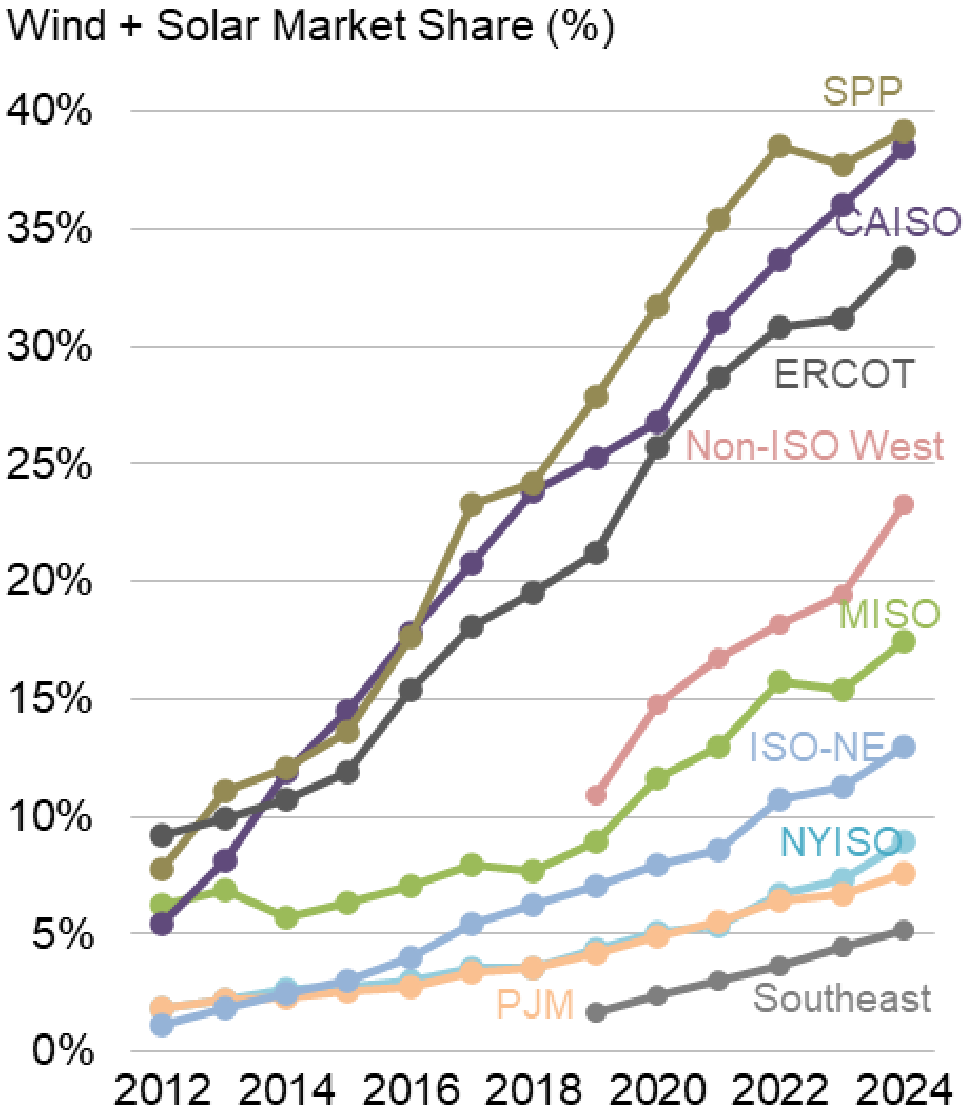
U.S. wind power installations by state

Installed Capacity (MW)				2024 Wind Generation as a Percentage of:			
Annual (2024)		Cumulative (end of 2024)		In-State Generation		In-State Sales	
Texas	1,271	Texas	42,747	Iowa	63.0%	South Dakota	89.9%
Oklahoma	552	Oklahoma	13,135	South Dakota	59.1%	Iowa	80.7%
Wyoming	454	Iowa	13,009	Kansas	51.7%	Kansas	73.0%
Arizona	379	Kansas	9,097	Oklahoma	40.6%	Wyoming	54.3%
North Dakota	199	Illinois	7,972	New Mexico	37.3%	Oklahoma	53.1%
Iowa	191	California	6,314	North Dakota	34.7%	North Dakota	50.7%
North Carolina	189	Colorado	5,394	Nebraska	32.4%	New Mexico	50.4%
Mississippi	185	Minnesota	4,826	Colorado	29.0%	Montana	37.4%
Idaho	160	North Dakota	4,504	Minnesota	25.4%	Nebraska	35.0%
New York	132	New Mexico	4,327	Wyoming	22.7%	Colorado	31.0%
California	116	Oregon	4,055	Montana	22.1%	Texas	25.2%
Montana	99	Michigan	3,768	Texas	22.0%	Maine	25.2%
New Mexico	80	Wyoming	3,740	Maine	19.2%	Minnesota	22.9%
Puerto Rico	26	Indiana	3,658	Idaho	15.2%	Illinois	18.3%
		South Dakota	3,618	Oregon	15.0%	Oregon	16.3%
		Nebraska	3,519	Illinois	13.0%	Idaho	10.8%
		Washington	3,407	Vermont	12.8%	Michigan	9.9%
		New York	2,881	Indiana	10.3%	Indiana	9.8%
		Missouri	2,438	Missouri	9.9%	Washington	9.3%
		Montana	1,898	Washington	8.2%	Missouri	8.7%
Rest of U.S.	*0*	*Rest of U.S.*	*10,105*	*Rest of U.S.*	*1.8%*	*Rest of U.S.*	*1.6%*
Total	**4,033**	**Total**	**154,411**	**Total**	**10.3%**	**Total**	**11.4%**

Source: ACP, EIA

Wind (and solar) generation as a proportion of load by region: SPP wind share was 38% in 2024, ERCOT was 24%

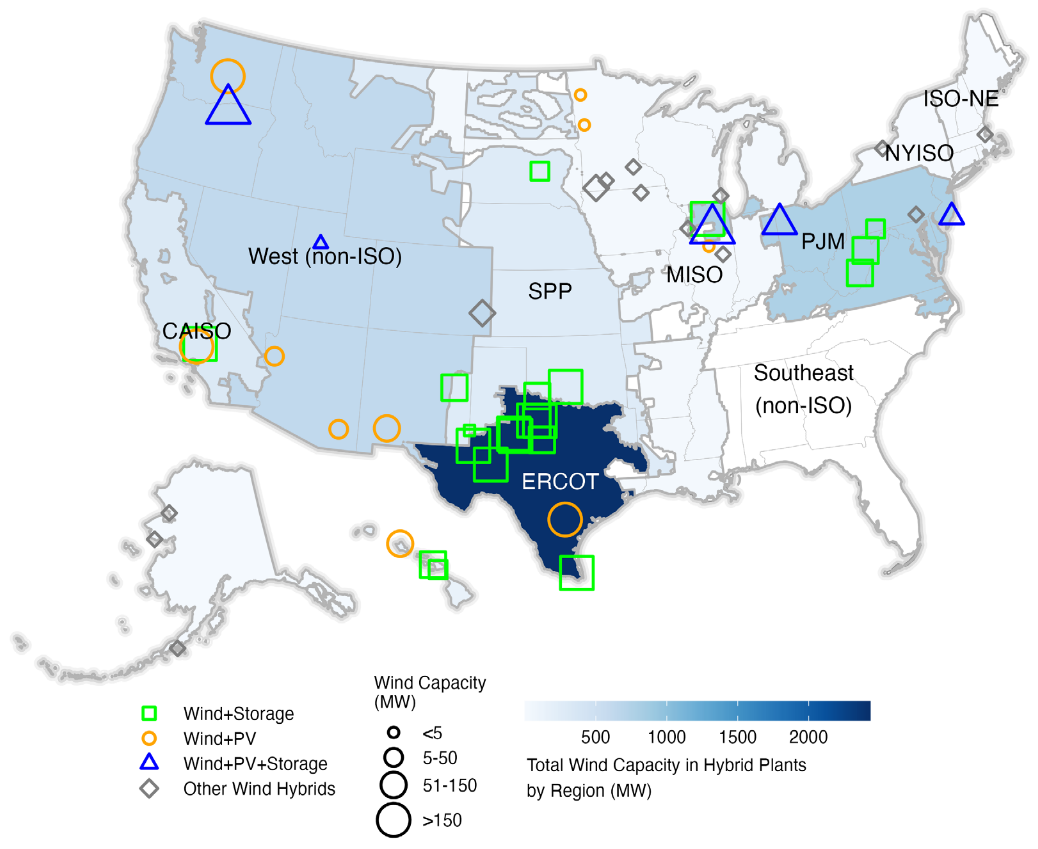




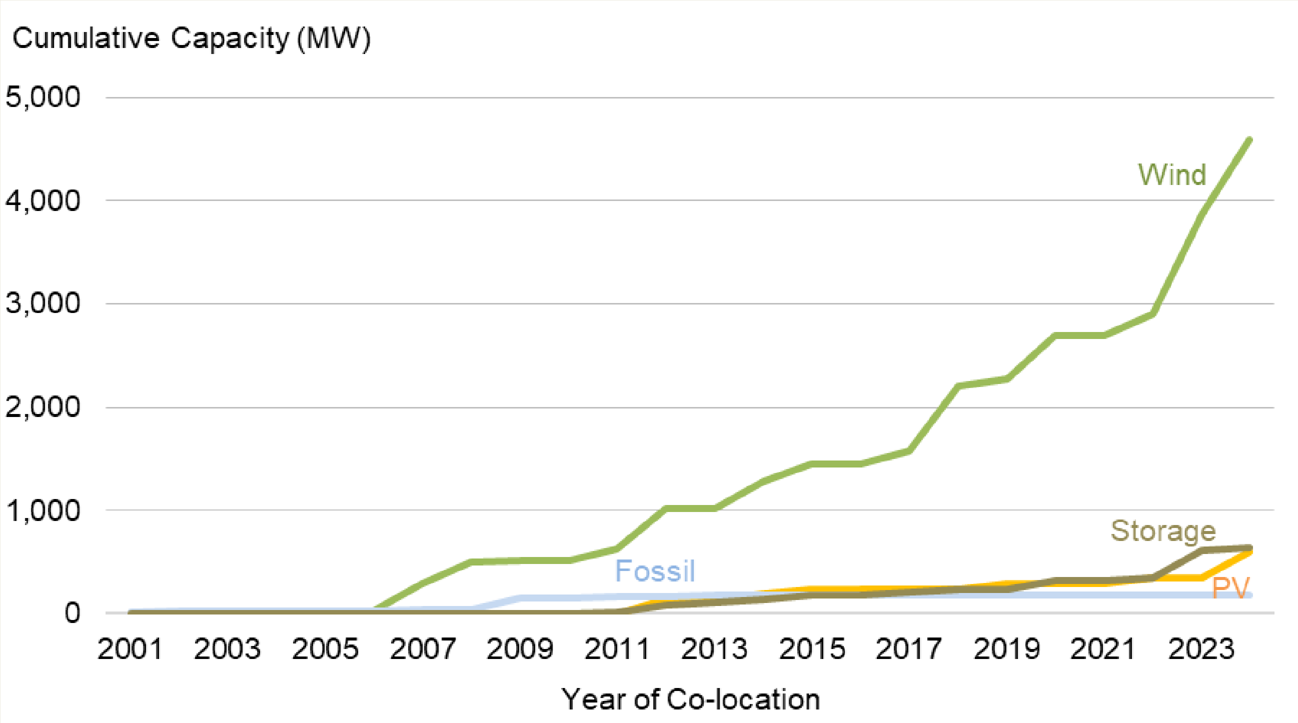
Sources: EIA, Hitachi, MISO, CAISO, SPP, NYISO, PJM, ISO-NE, ERCOT, Berkeley Lab

Online wind hybrid / co-located projects: wind+storage, wind+other generator(s), wind+other generator(s)+storage

Online Wind Hybrid / Co-located Projects



Growth in Wind Hybrid / Co-Located Projects

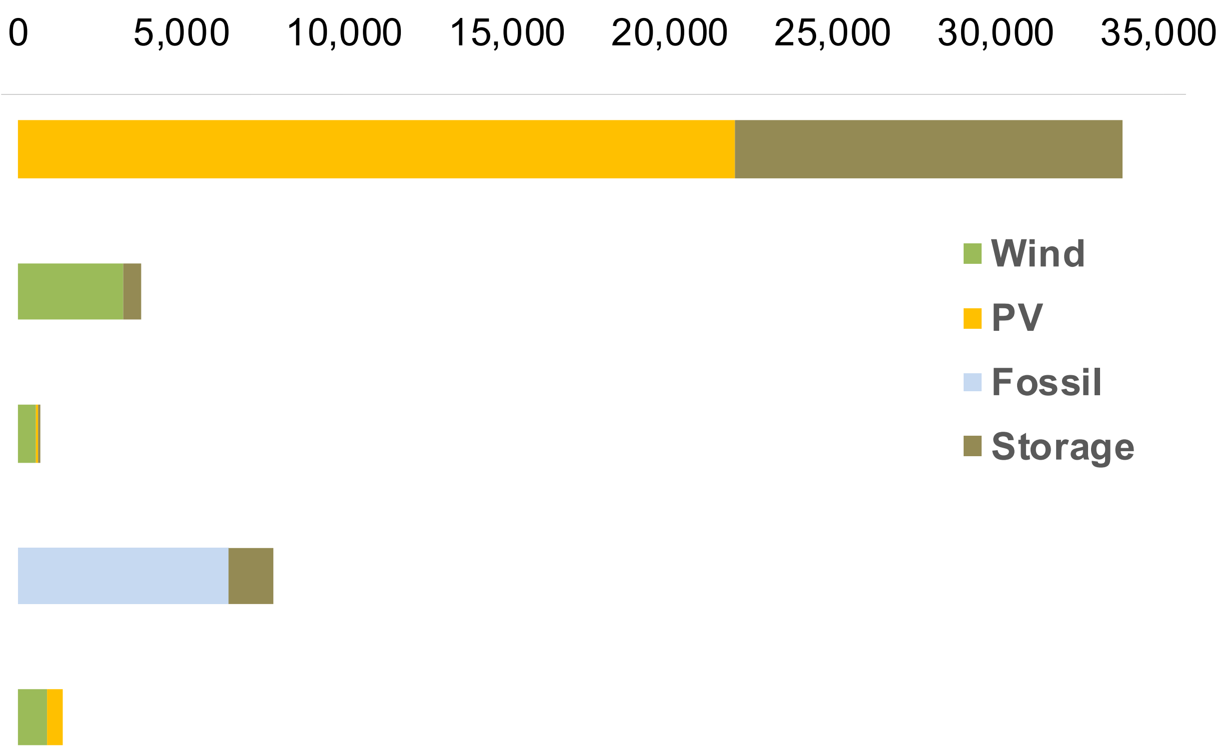


Sources: EIA-860 Early Release, Berkeley Lab

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

Common online hybrid / co-located projects: wind hybrids total 4,600 MW wind, 640 MW storage, 600 MW solar, 185 MW fossil

	# projects	Storage ratio	Duration (hrs)
PV+Storage	359	54%	3.0
Wind+Storage	20	18%	1.2
Wind+PV+Storage	5	11%	2.0
Fossil+Storage	28	22%	2.8
Wind+PV	10	n/a	n/a

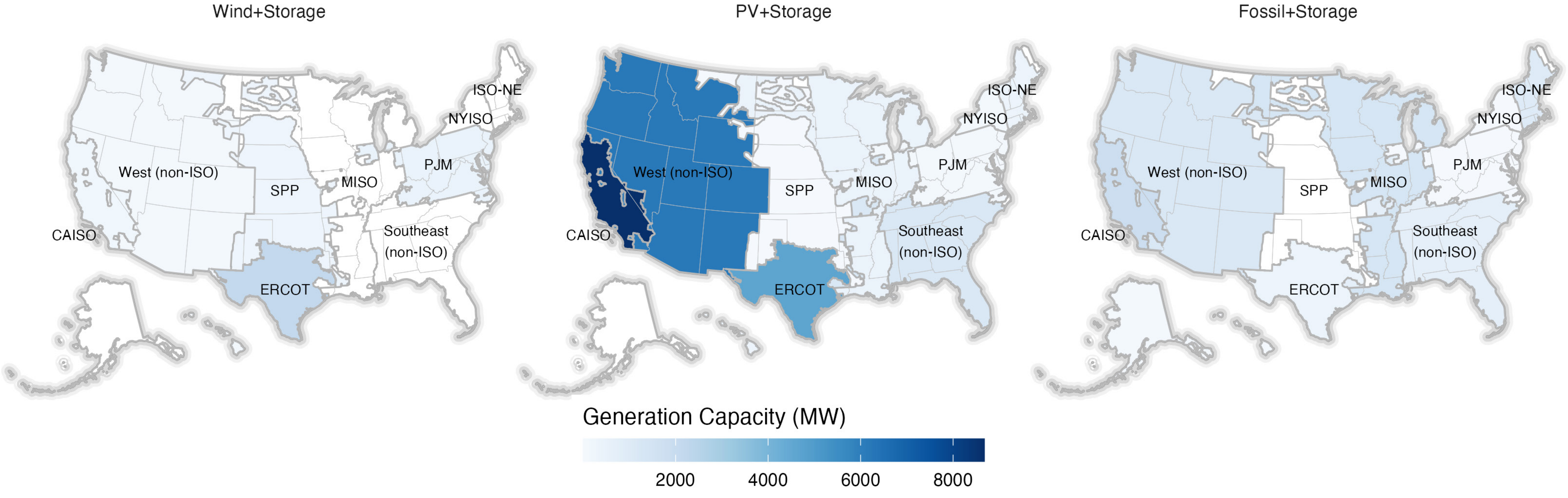


Notes: Not included in the figure are many other hybrid projects with other configurations. Storage ratio defined as total storage capacity divided by total generator capacity for a given project type.

Sources: EIA 860 Early Release, Berkeley Lab

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

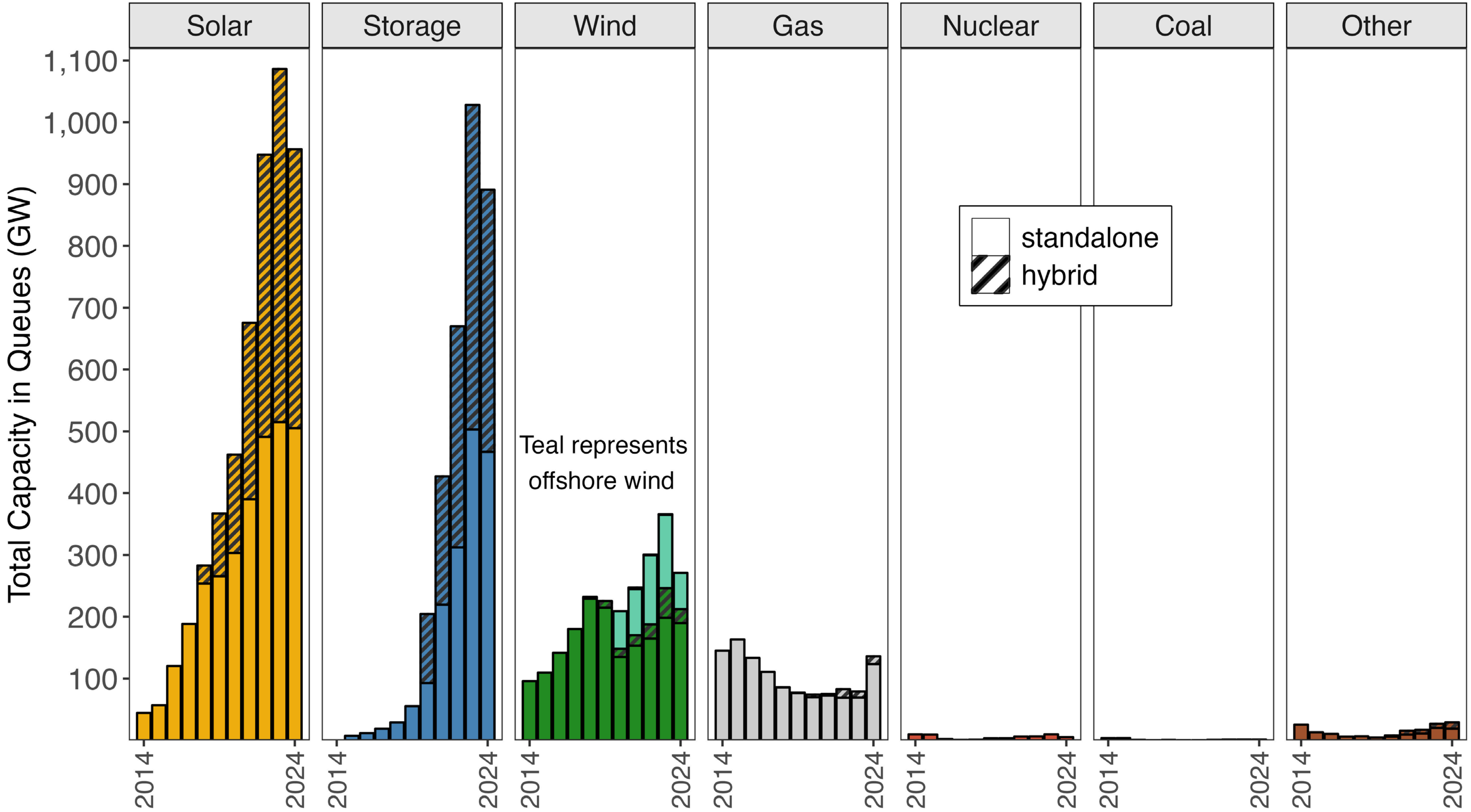
Online generator+storage hybrid / co-located projects: wind+storage, PV+storage, fossil+storage



Sources: EIA 860 Early Release, Berkeley Lab

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

Capacity in selected interconnection queues from 2014 to 2024: 2024 land-based wind = 212 GW, offshore wind = 59 GW

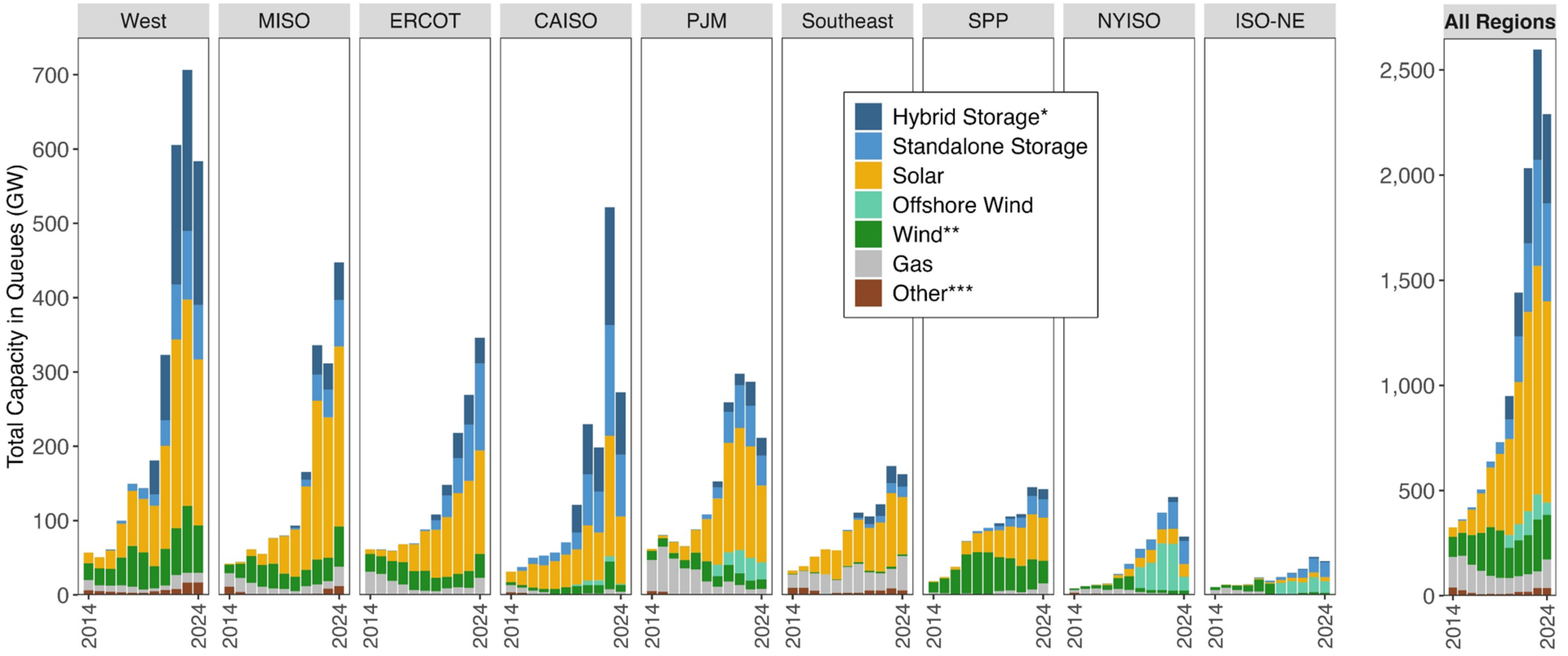


Interactive data visualization: https://emp.lbl.gov/generation-storage-and-hybrid-capacity

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 and interconnection.fyi review of interconnection queues

Capacity in selected interconnection queues from 2014 to 2024, by resource type and region

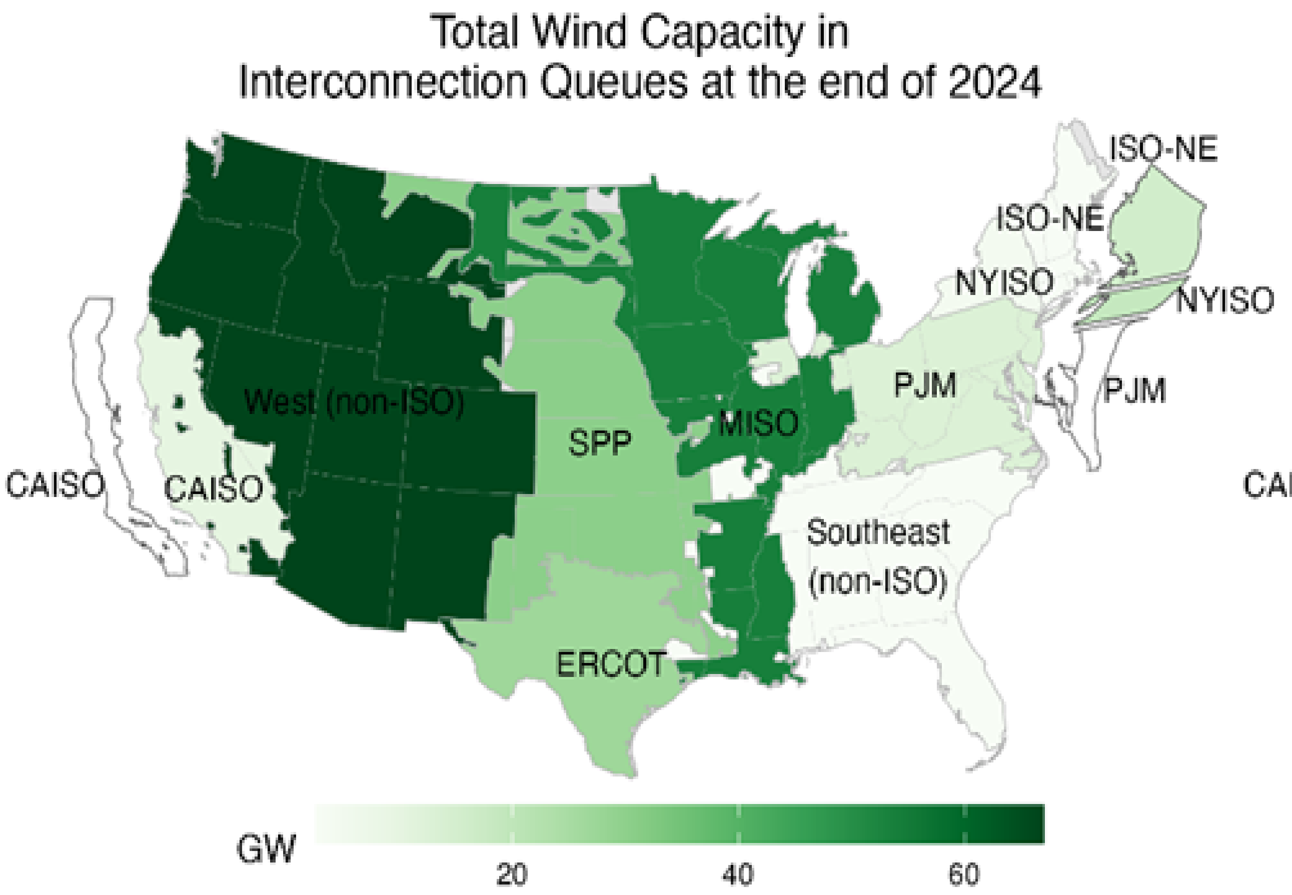


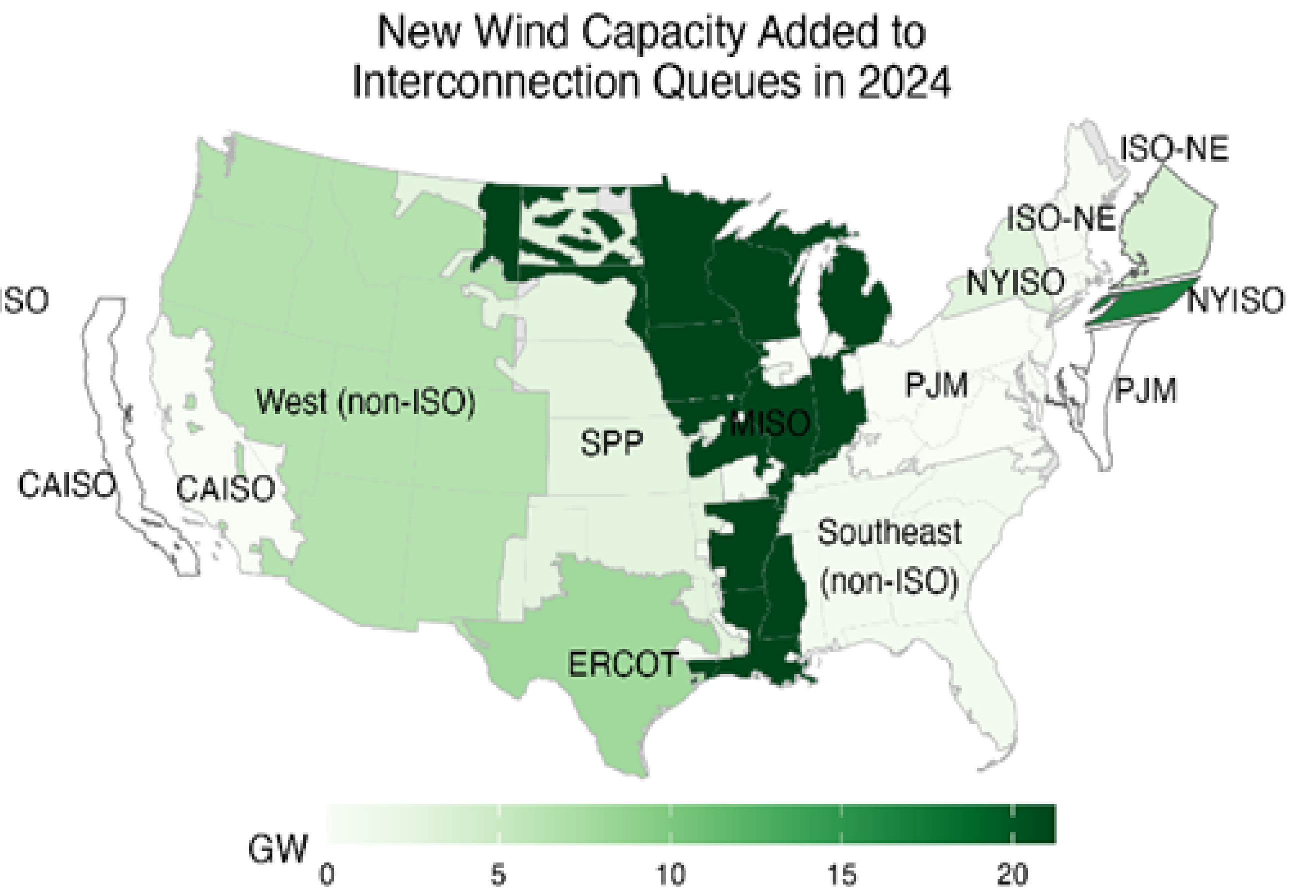
Interactive data visualization: https://emp.lbl.gov/generation-storage-and-hybrid-capacity

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 and interconnection.fyi review of interconnection queues

Wind power capacity in selected interconnection queues at end of 2024, by region



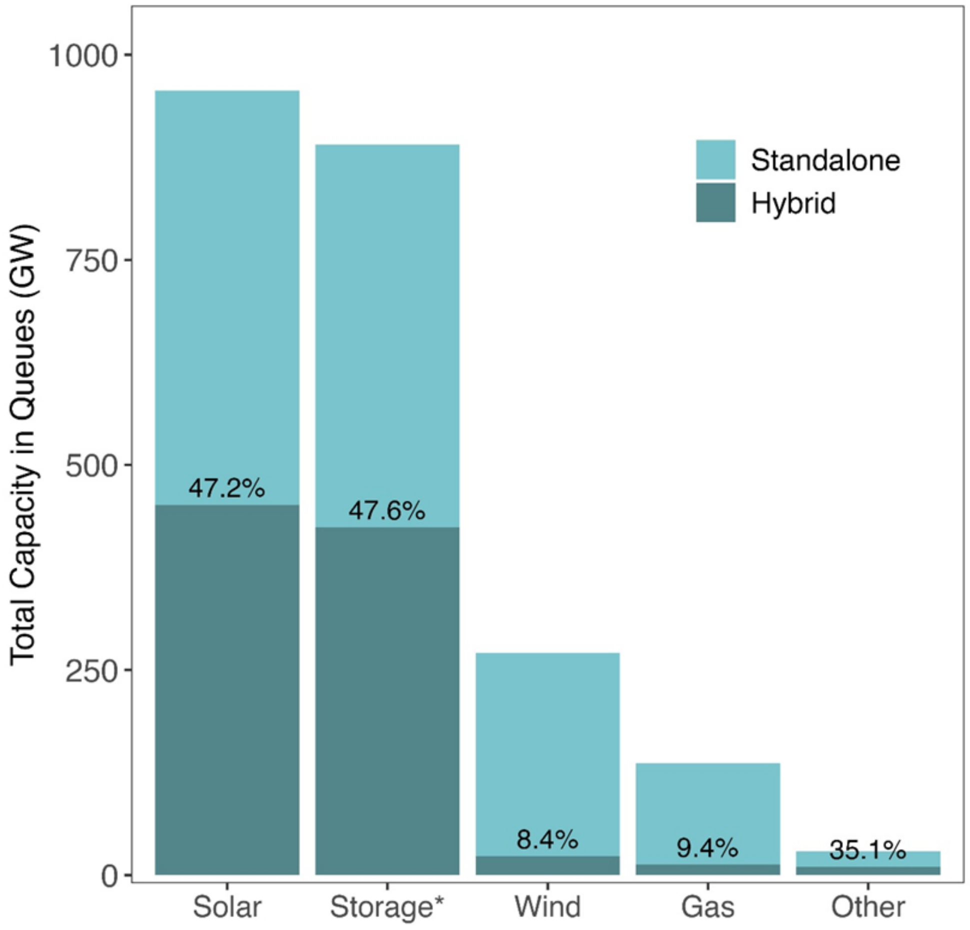


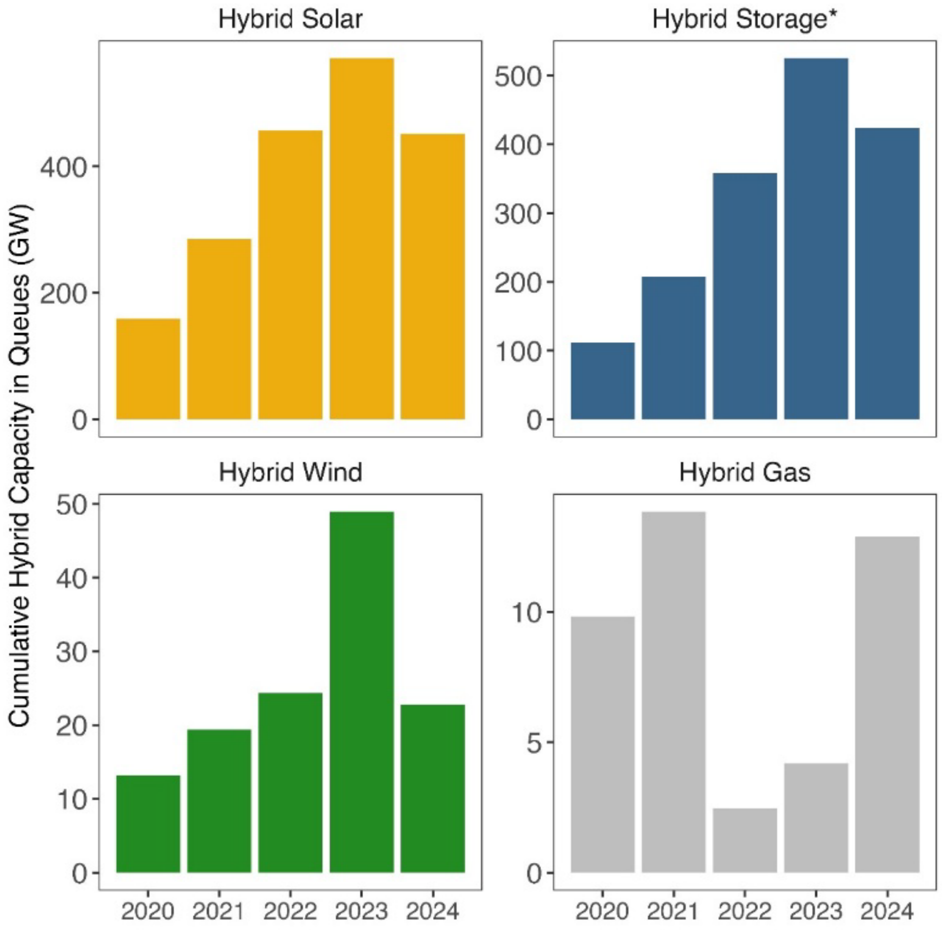
Source: Berkeley Lab and interconnection.fyi review of interconnection queues

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 power plants in selected interconnection queues at end of 2024, including wind and other hybrid configurations



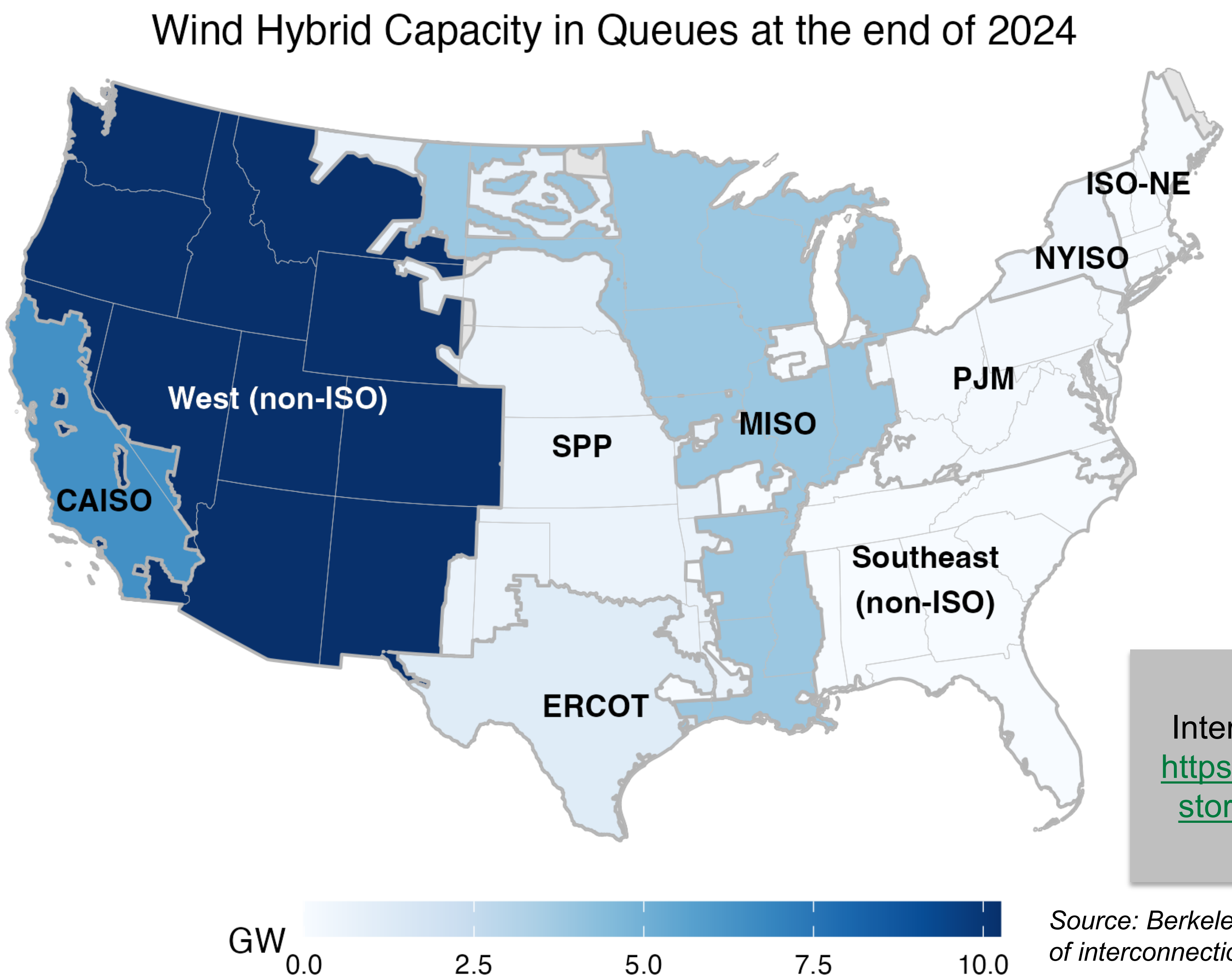


Notes: Notes: (1) Hybrid plants involving multiple generator types (e.g., wind+PV+storage, or just wind+PV) show up in all generator categories, presuming the capacity is known for each generator type. (2) Hybrid storage capacity is estimated using storage:generator ratios from projects that provide separate capacity data.

Source: Berkeley Lab and interconnection.fyi review of interconnection queues

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

Hybrid wind power plants in selected interconnection queues at end of 2024: 22.8 GW, mostly in West and CAISO

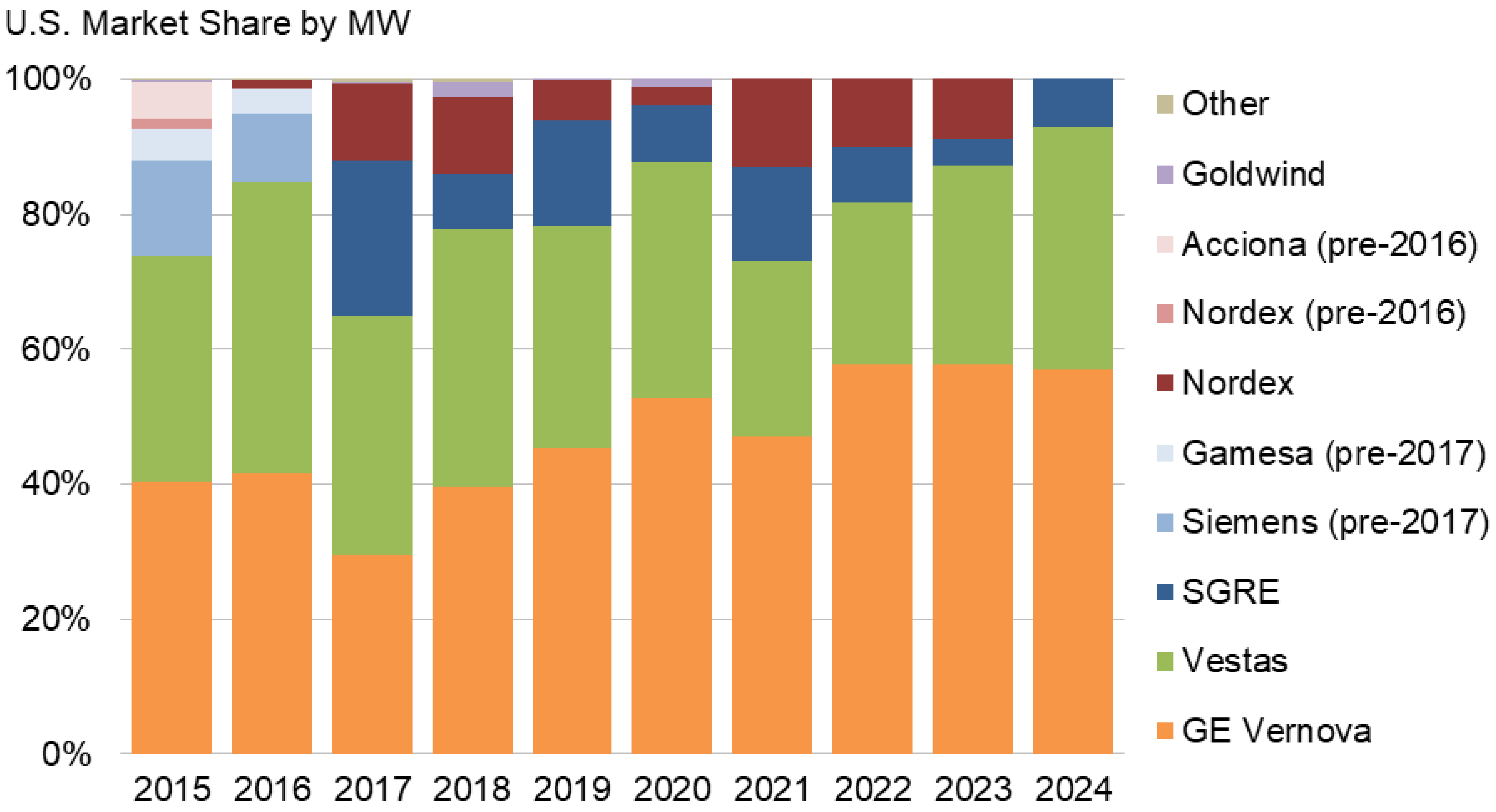


Interactive data visualization: https://emp.lbl.gov/generation-storage-and-hybrid-capacity

Source: Berkeley Lab and interconnection.fyi review of interconnection queues

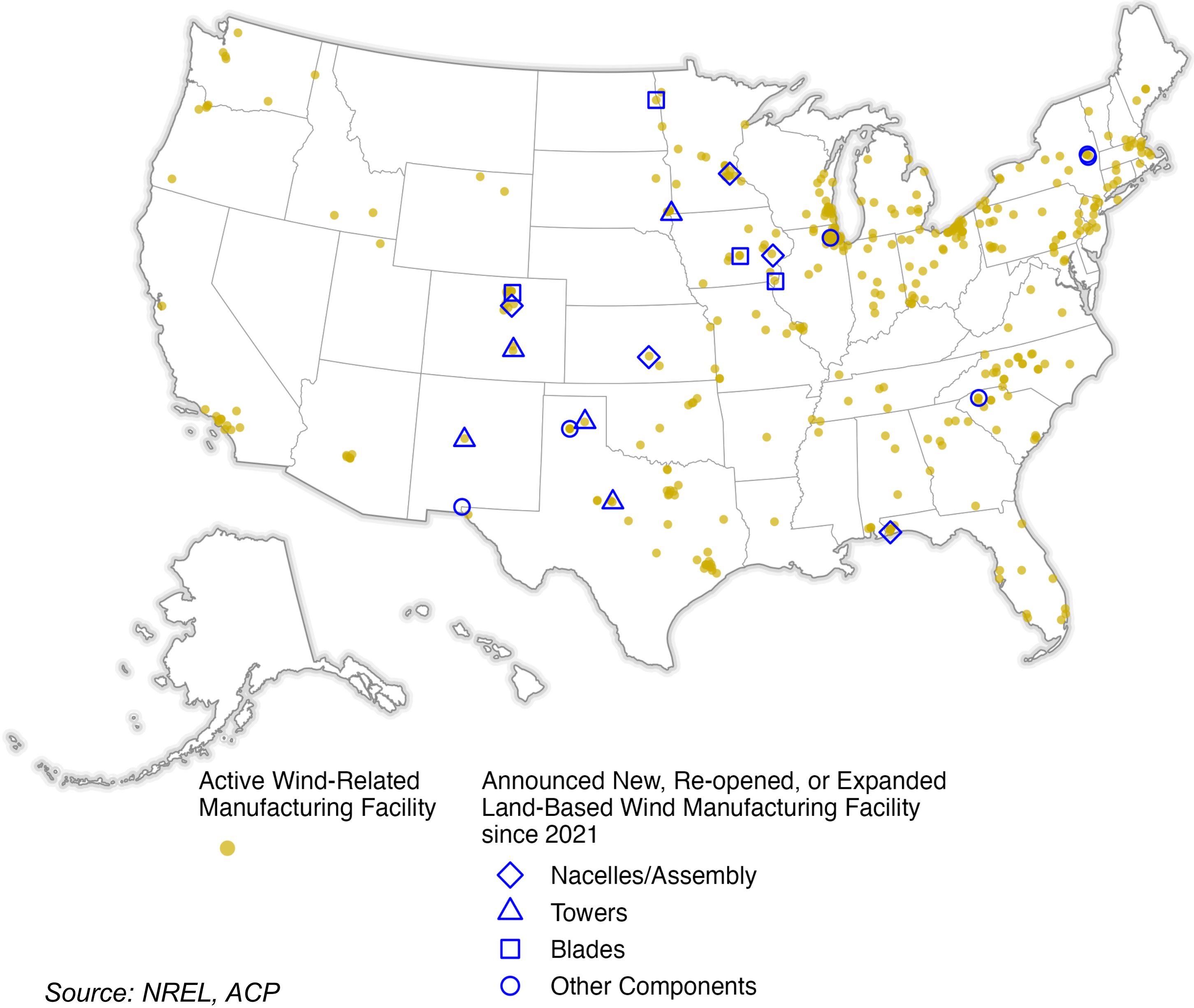
Industry Data

Annual U.S. market share of wind turbine manufacturers by MW, 2015–2024: GE market share = 58% in 2024



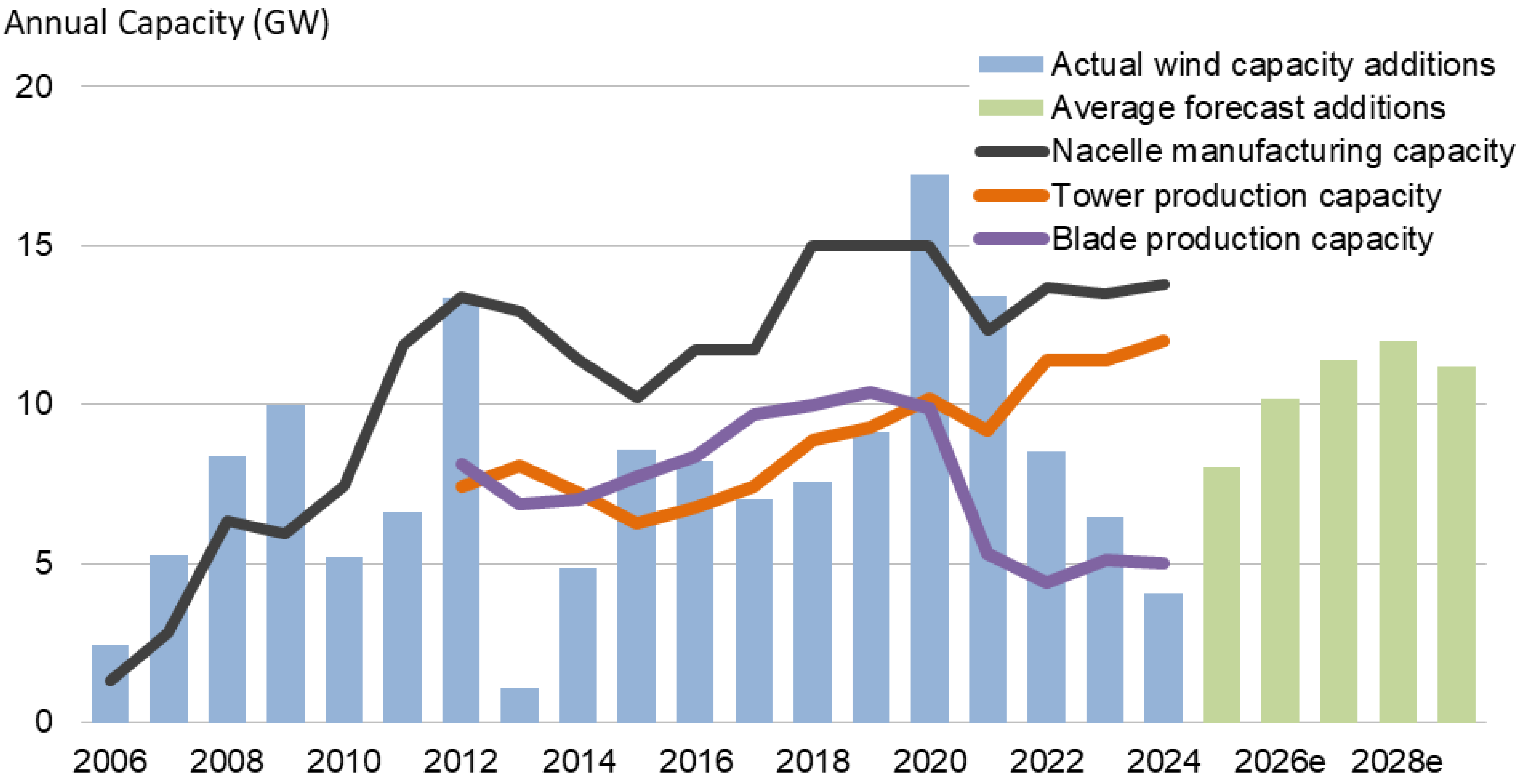
Source: ACP

Location of wind turbine and component manufacturing facilities



Source: NREL, ACP

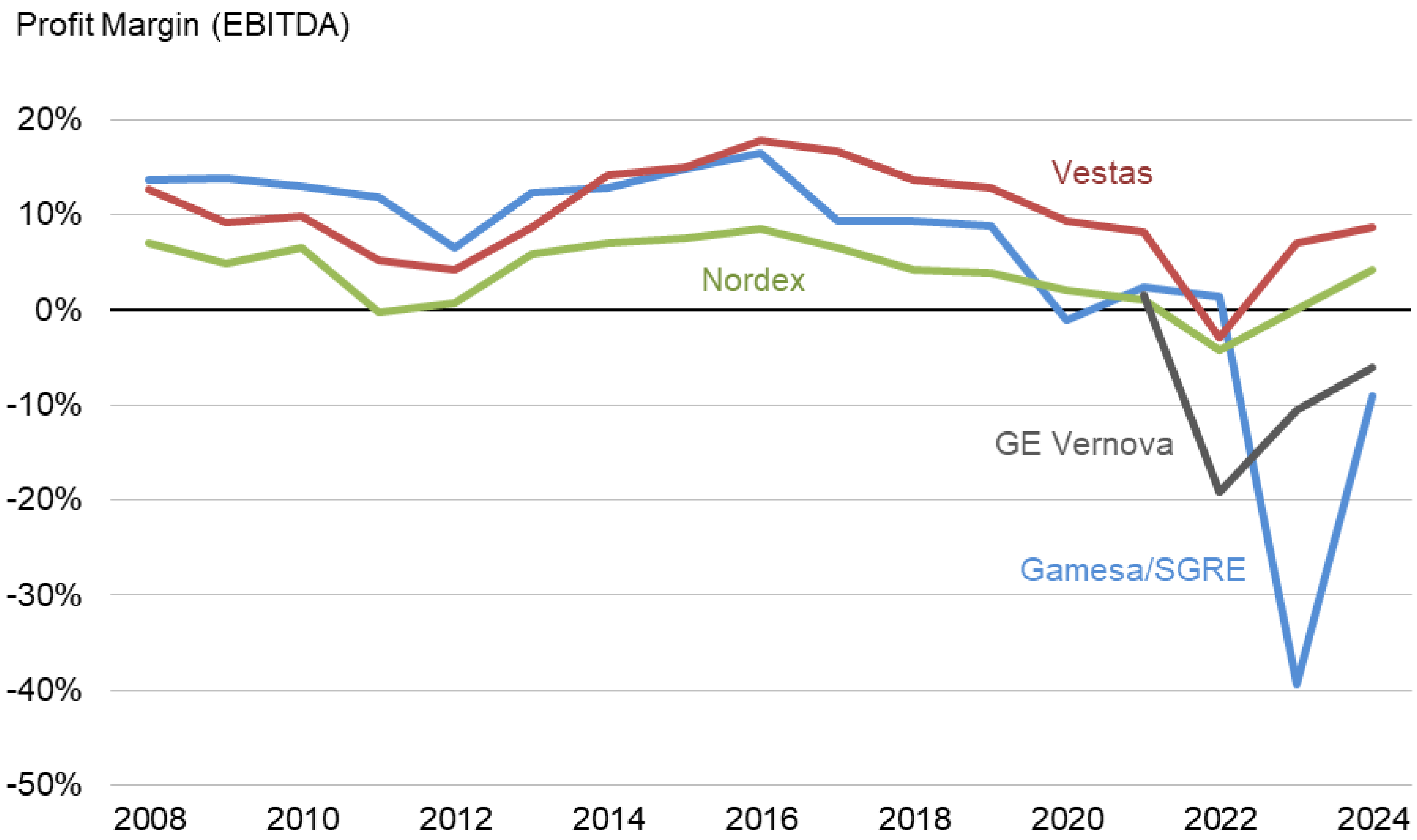
Domestic wind manufacturing capability vs. U.S. wind power capacity installations



Sources: ACP, independent analyst projections, Berkeley Lab

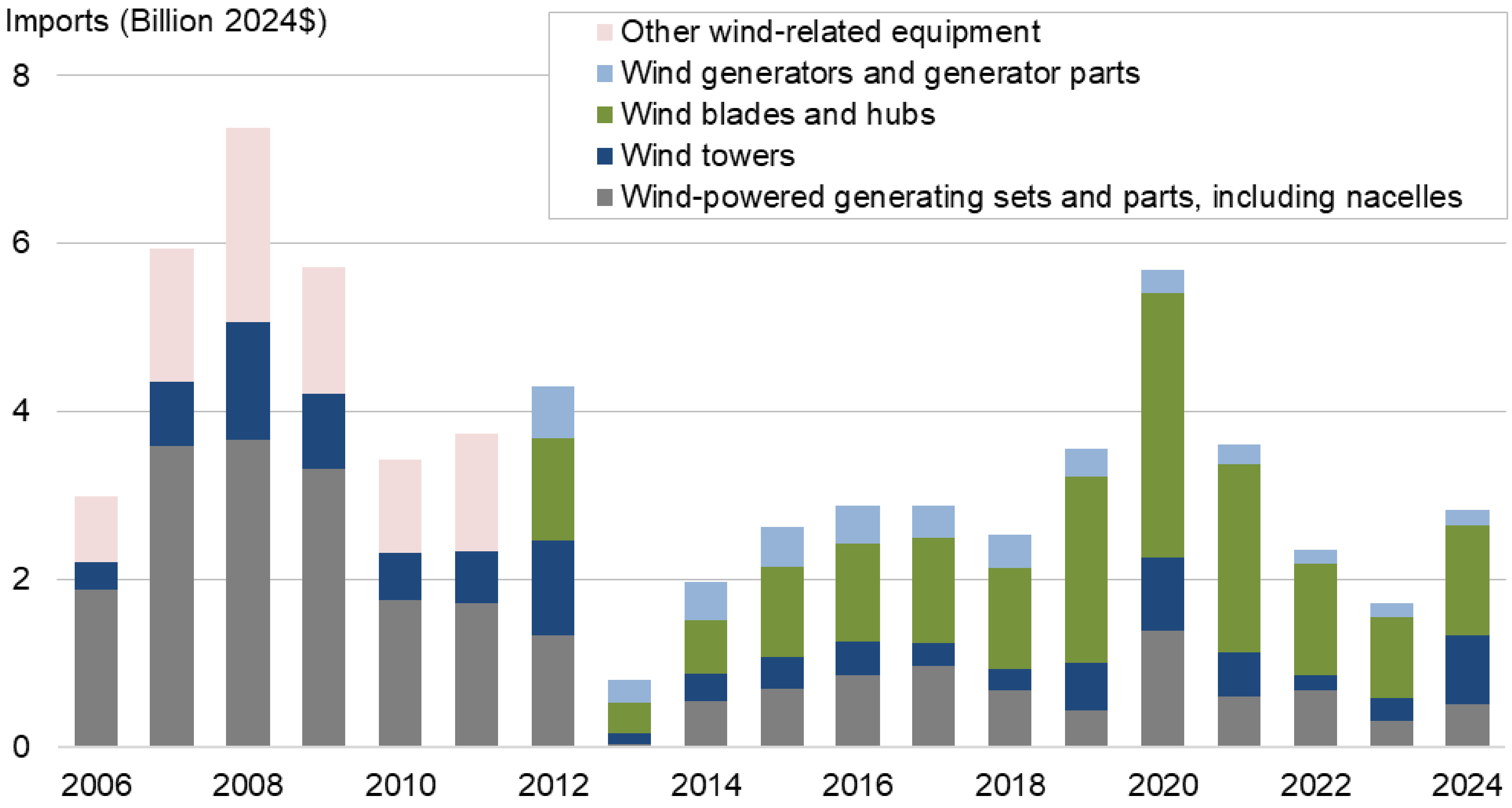
Note: Actual nacelle assembly, tower production, and blades production would be expected to be below maximum production capacity.

Turbine OEM global profitability over time



Sources: OEM annual reports and financial statements

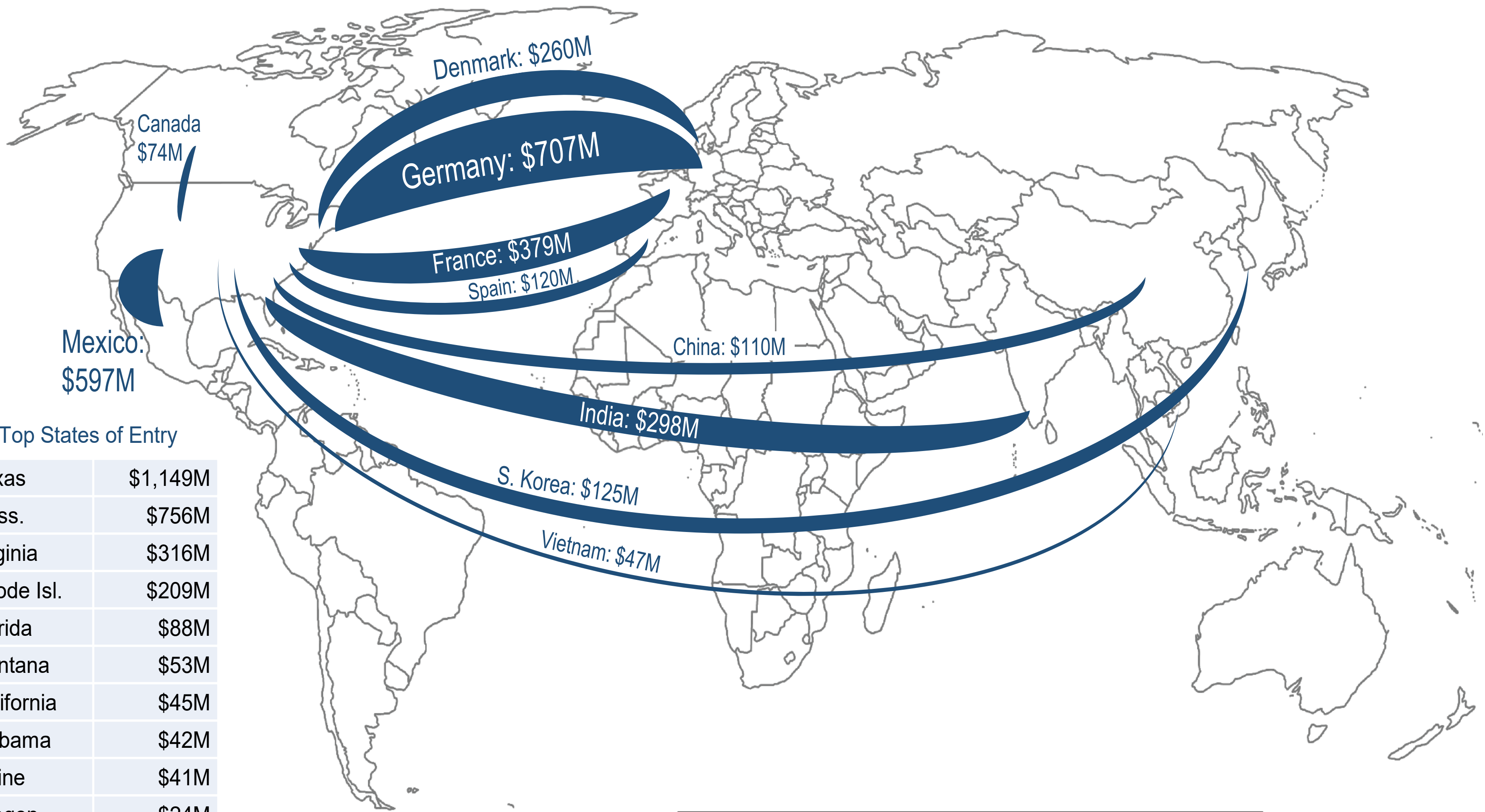
Estimated imports of wind-powered generating sets, nacelles, towers, generators and generator parts, and blades and hubs: $2.8B in 2024



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

Summary map of tracked wind-specific imports into the U.S. in 2024: top-10 countries of origin and states of entry (million 2024$)



Top States of Entry

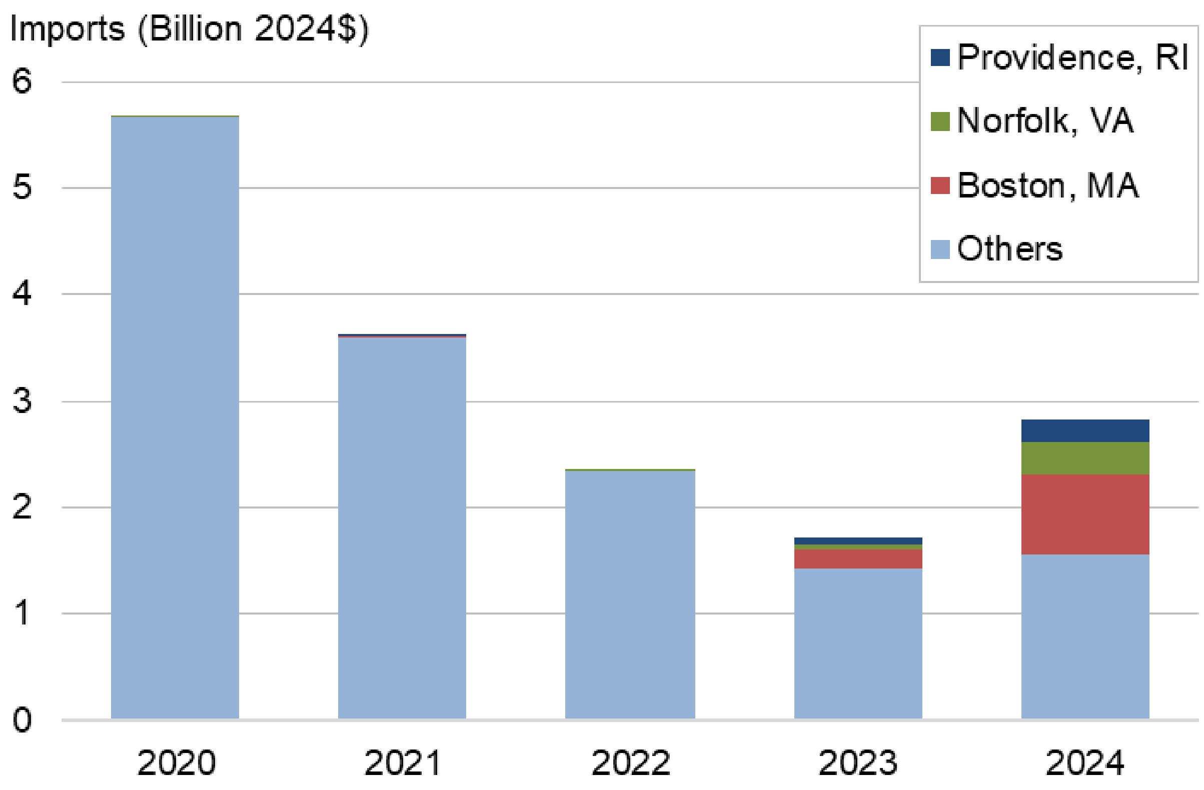
Texas	$1,149M
Mass.	$756M
Virginia	$316M
Rhode Isl.	$209M
Florida	$88M
Montana	$53M
California	$45M
Alabama	$42M
Maine	$41M
Oregon	$24M
Illinois	$23M

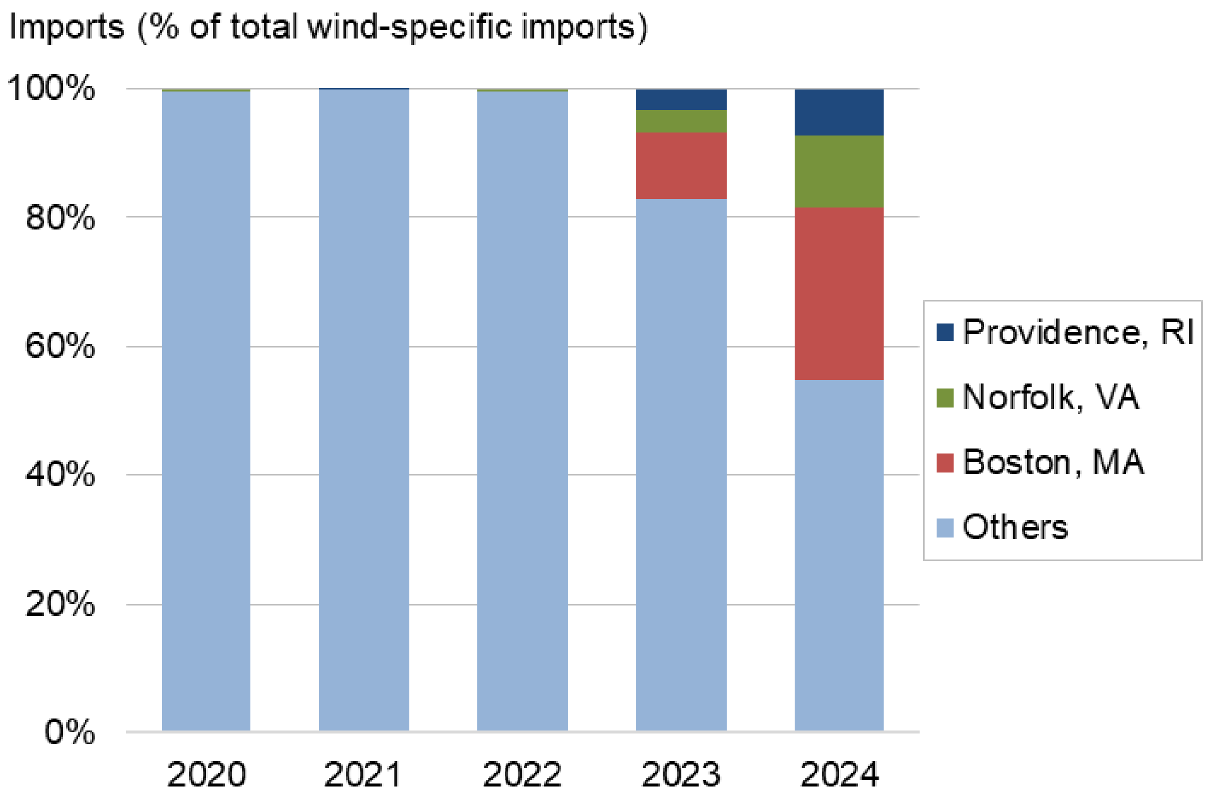
Imports from countries outside the top 10 totaled $112M

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 (that is shown in table). Tracked wind-specific equipment includes: wind-powered generating sets and parts, towers, generators and generator parts, blades and hubs, and nacelles

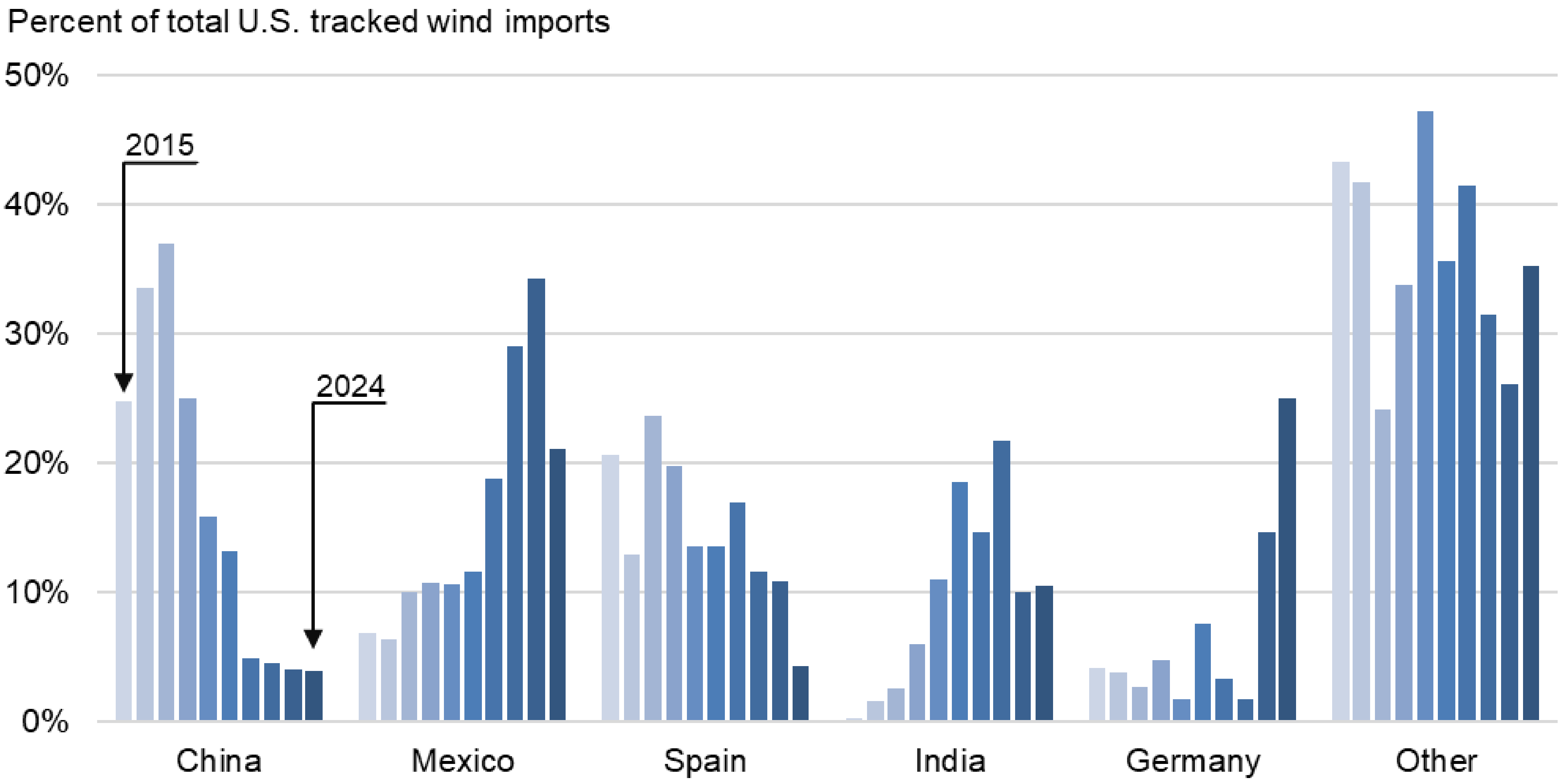
Tracked wind-specific imports over time, some tied to ports serving offshore wind





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

Wind equipment imports over time, by country: percent of total tracked wind-specific imports



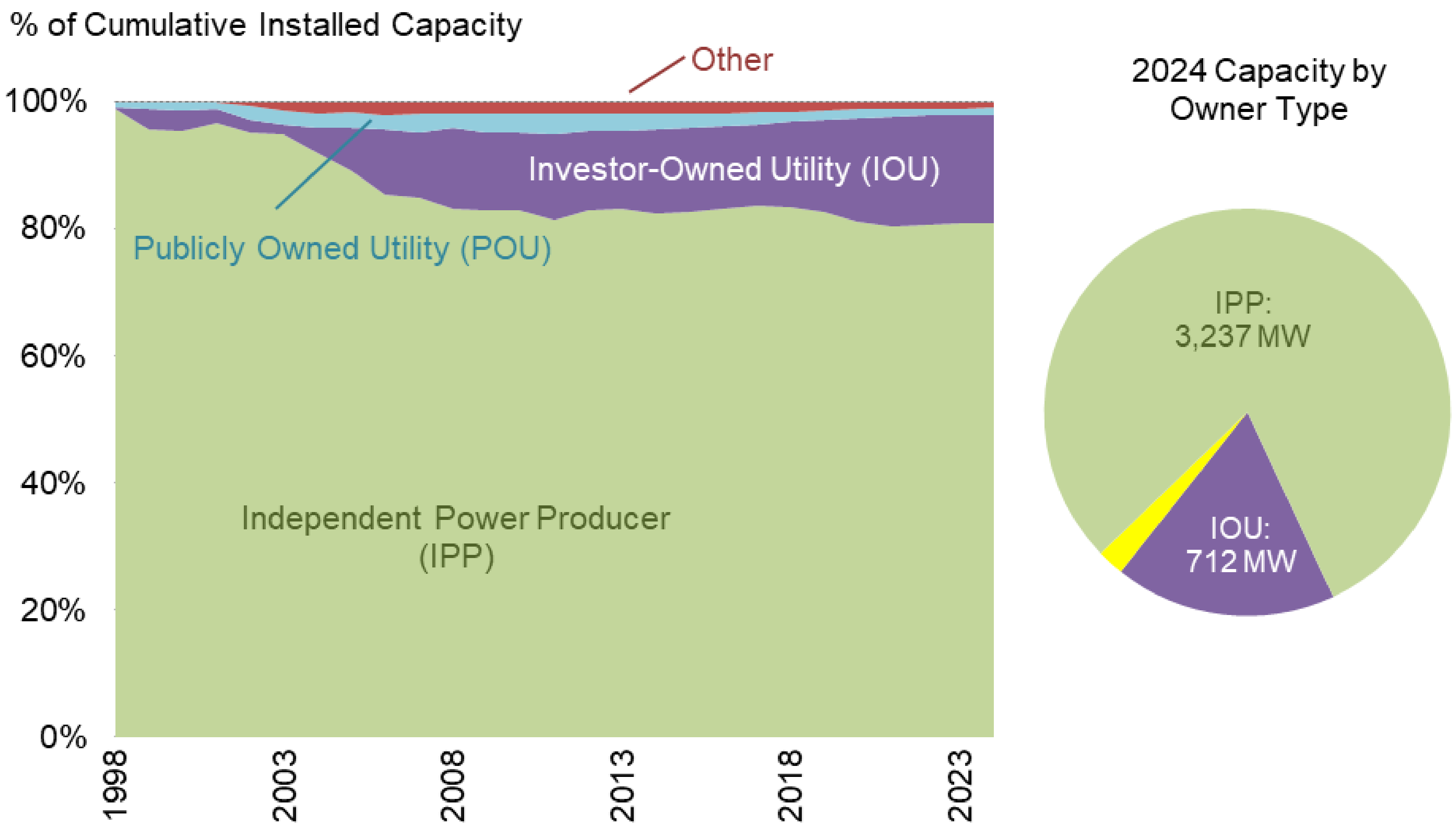
Source: Berkeley Lab analysis of data from USA Trade Online, https://usatrade.census.gov

Notes: Tracked wind-specific equipment includes: wind-powered generating sets and parts, towers, generators and generator parts, blades and hubs, and nacelles

Origins of U.S. imports of selected wind turbine equipment

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

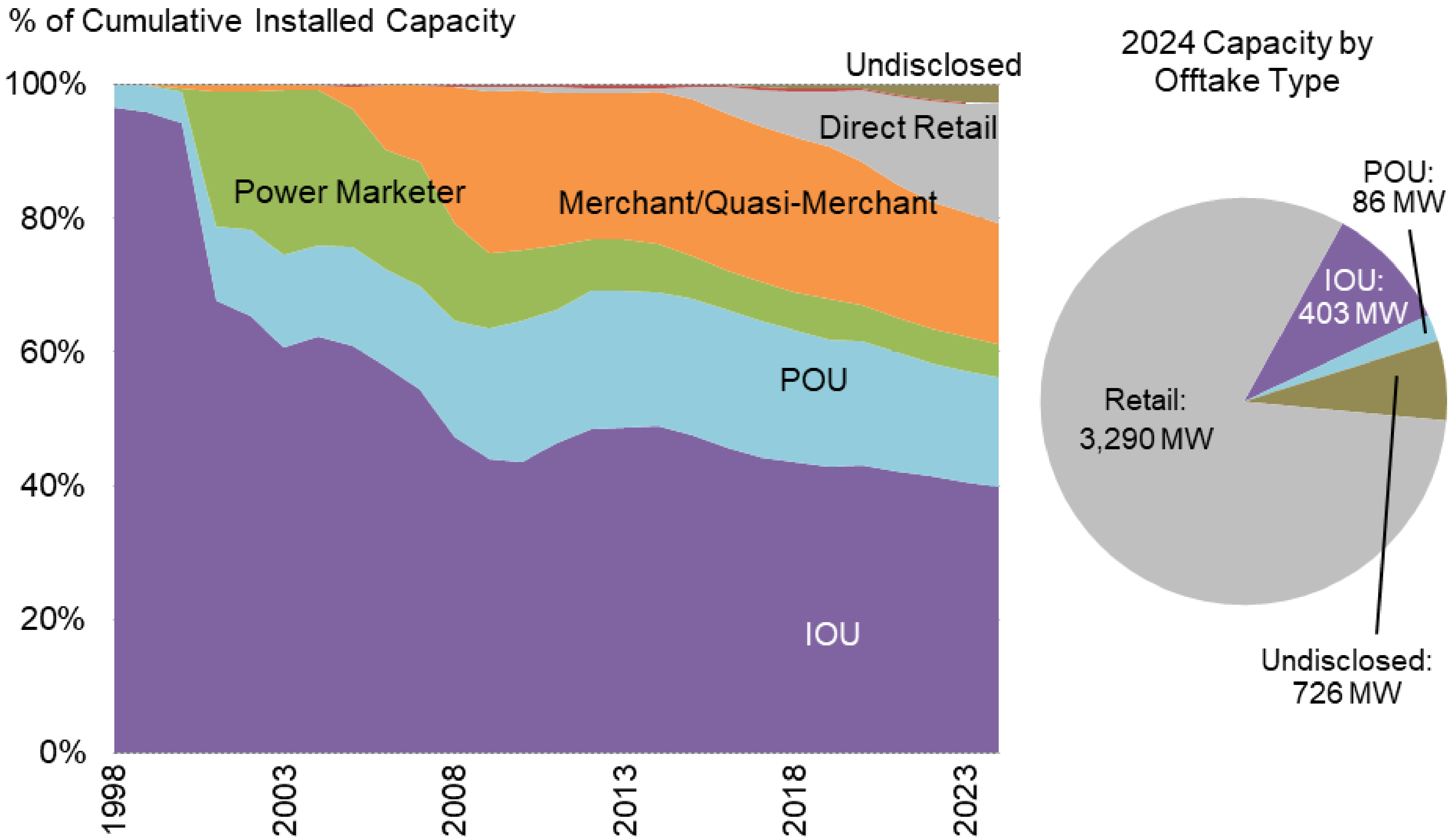
Cumulative and 2024 wind power capacity categorized by owner type



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 2024.

Cumulative and 2024 wind power capacity categorized by power off-take arrangement

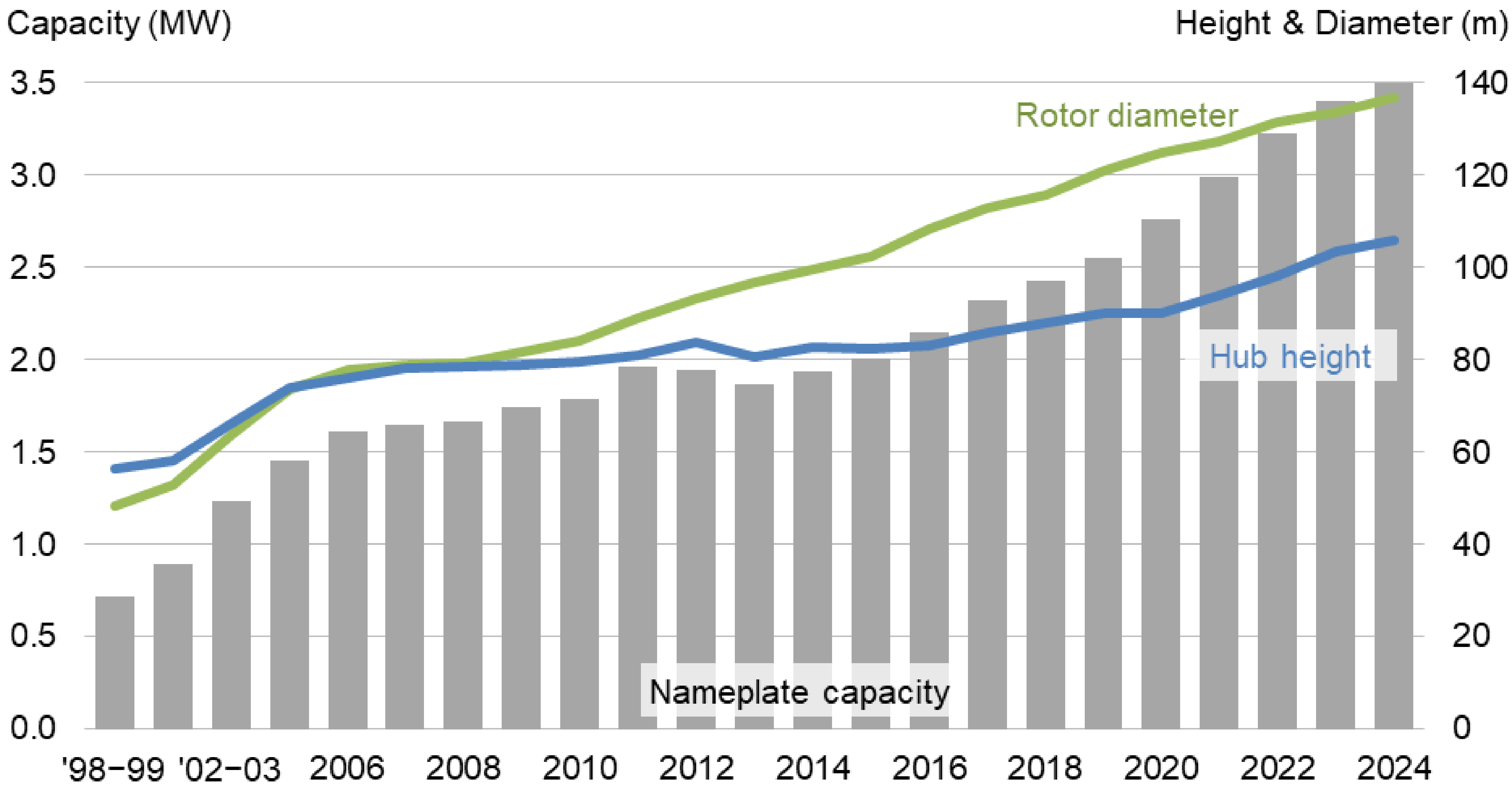


Source: Berkeley Lab estimates based on ACP

Note: Graphic on left shows distribution among growing cumulative fleet of projects installed. Pie chart shows distribution only among those projects built in 2024.

Technology Data

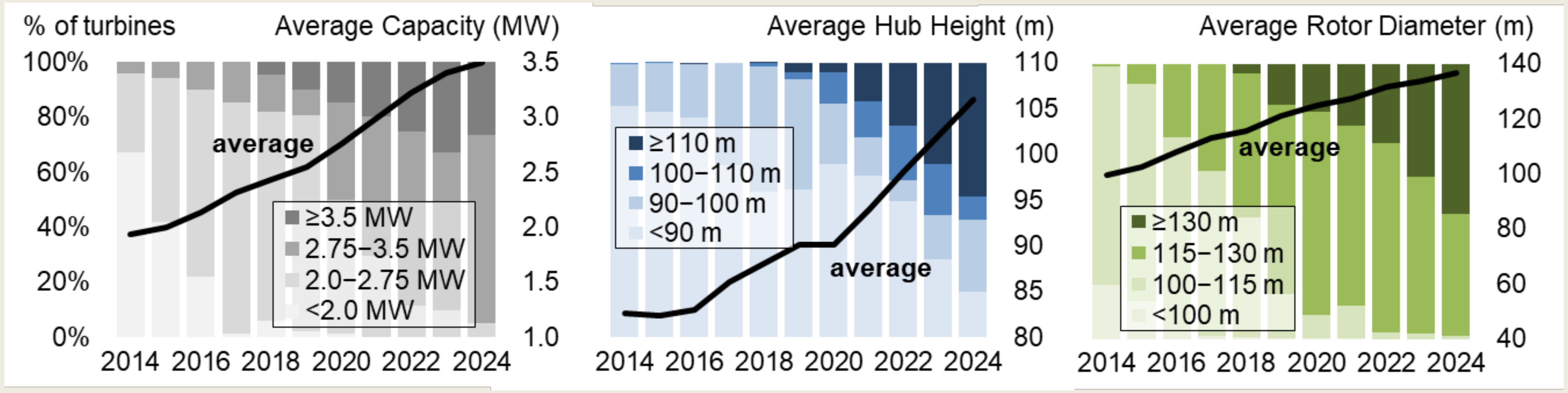
Average turbine capacity (3.5 MW in 2024), hub height (106 m in 2024), and rotor diameter (137 m in 2024) for land-based wind, over time



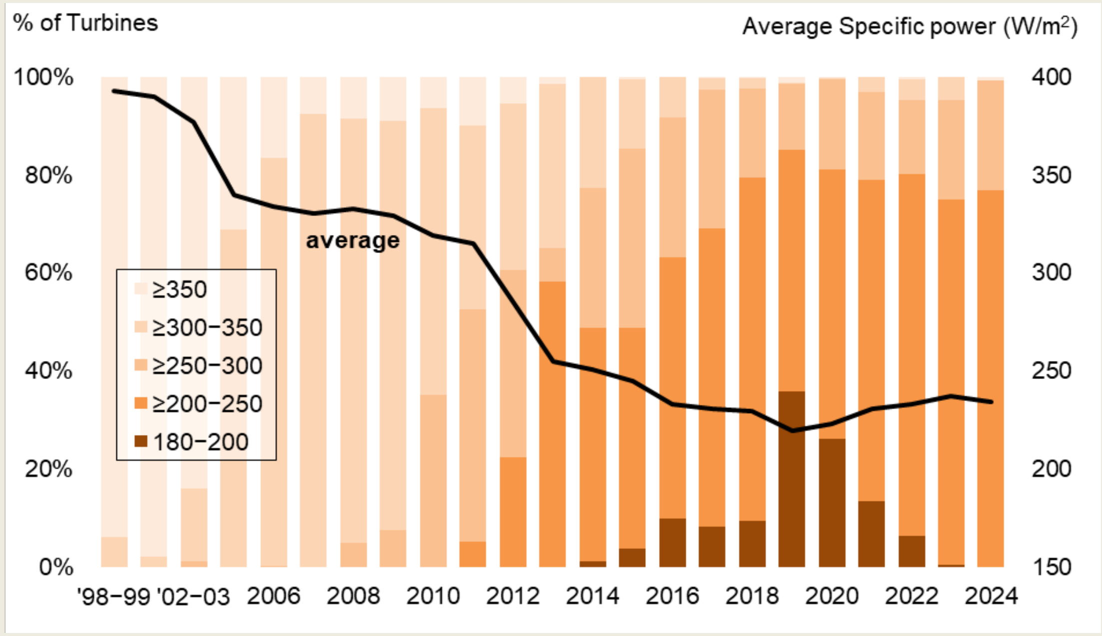
Graphic is based on new installations, each year

Sources: ACP, Berkeley Lab

Trends in turbine nameplate capacity, hub height, rotor diameter, and specific power

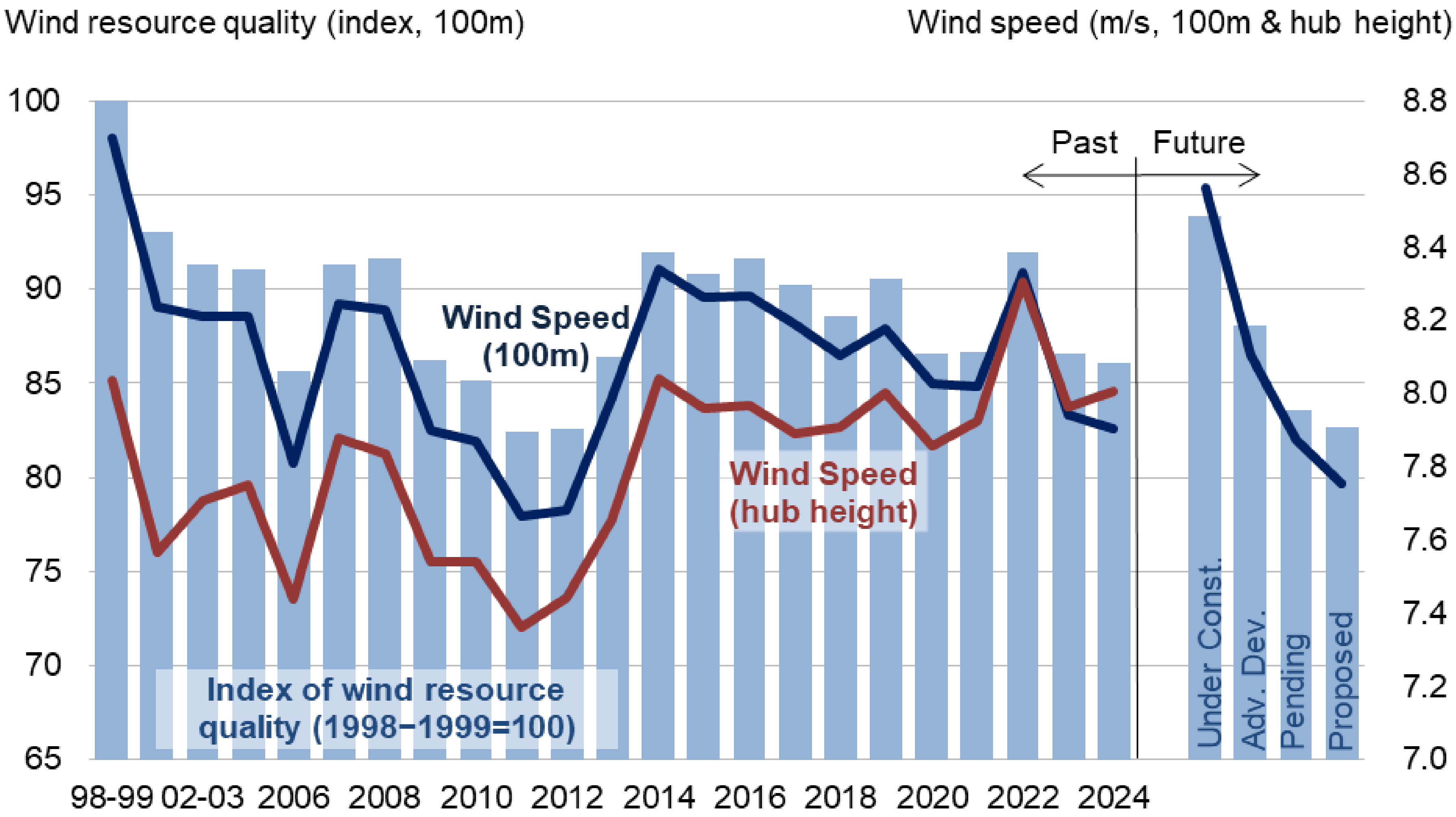


Specific power: turbine capacity divided by swept rotor area; lower specific power leads to higher capacity factors, as shown later



Sources: ACP, Berkeley Lab

Wind resource quality by year of installation at 100 meters and turbine hub height

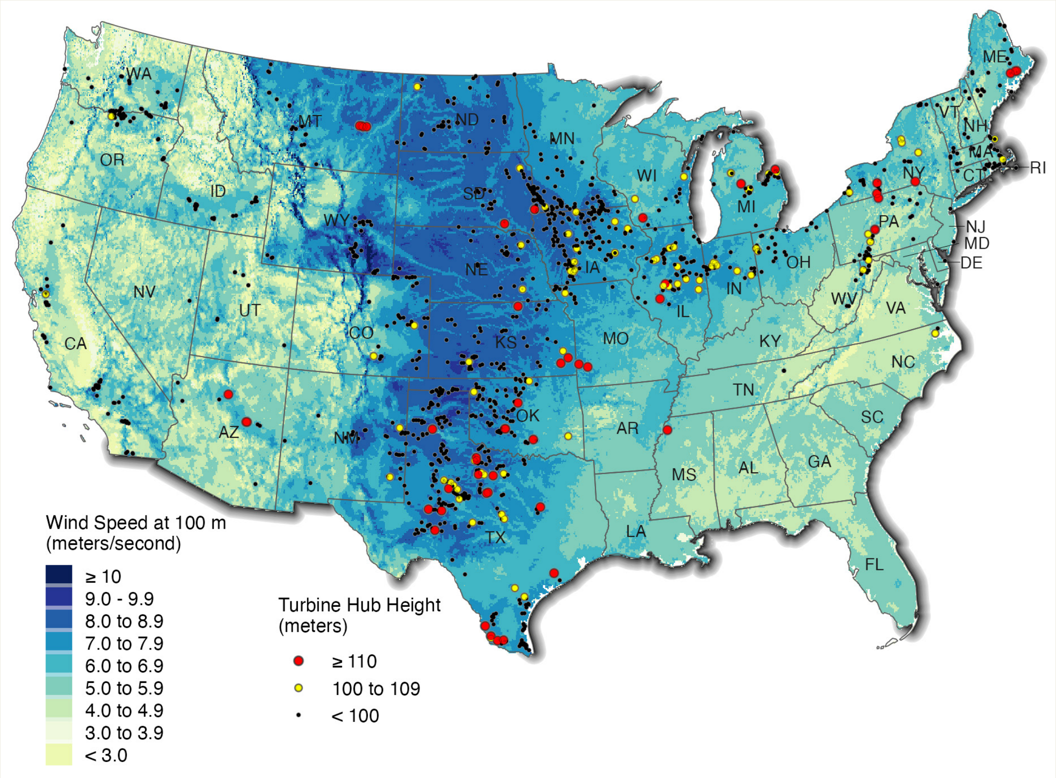


Sources: ACP, Berkeley Lab, AWS Truepower, FAA files

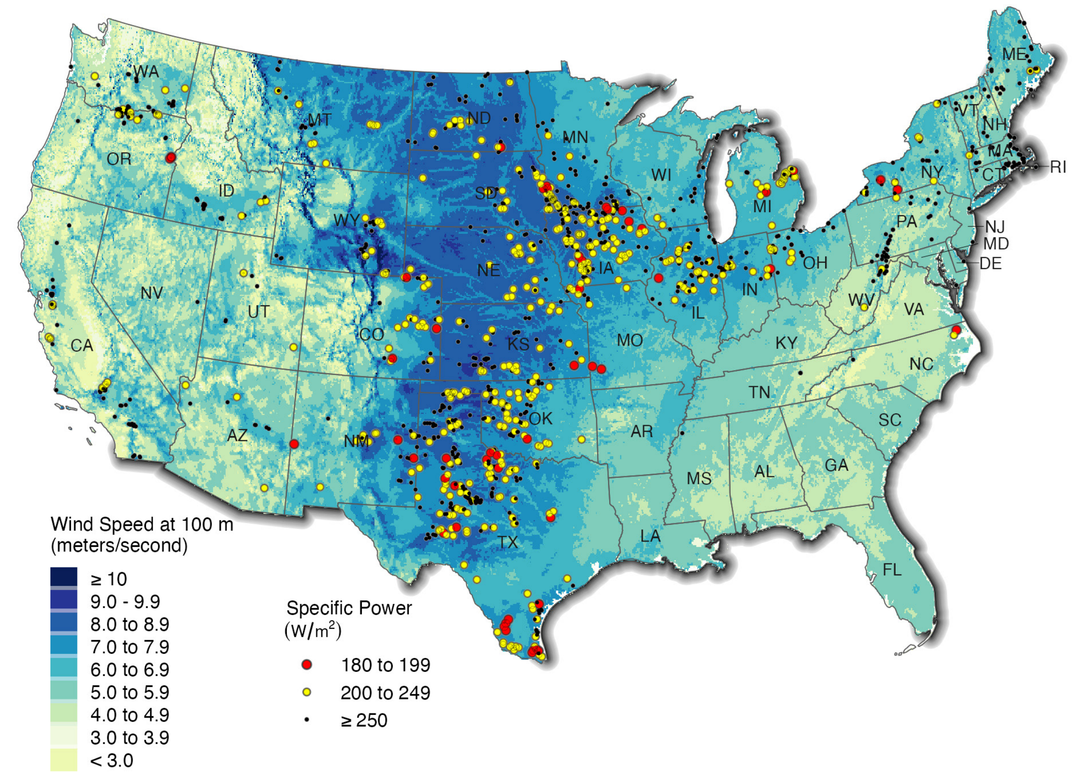
Notes: Turbines used in this figure have been screened to remove offshore turbines and those >1000ft. Wind speed at hub height is determined using a straight-line average between AWS Truepower wind speed estimates at 80 and 100m. The wind resource quality index is based on site estimates of gross capacity factor at 100 meters, with values indexed to projects built in 1998—1999; this quality index controls for site elevation and wind speed distributions but assumes a common turbine power curve.

Location of tall tower and low specific power turbine installations

Hub Height



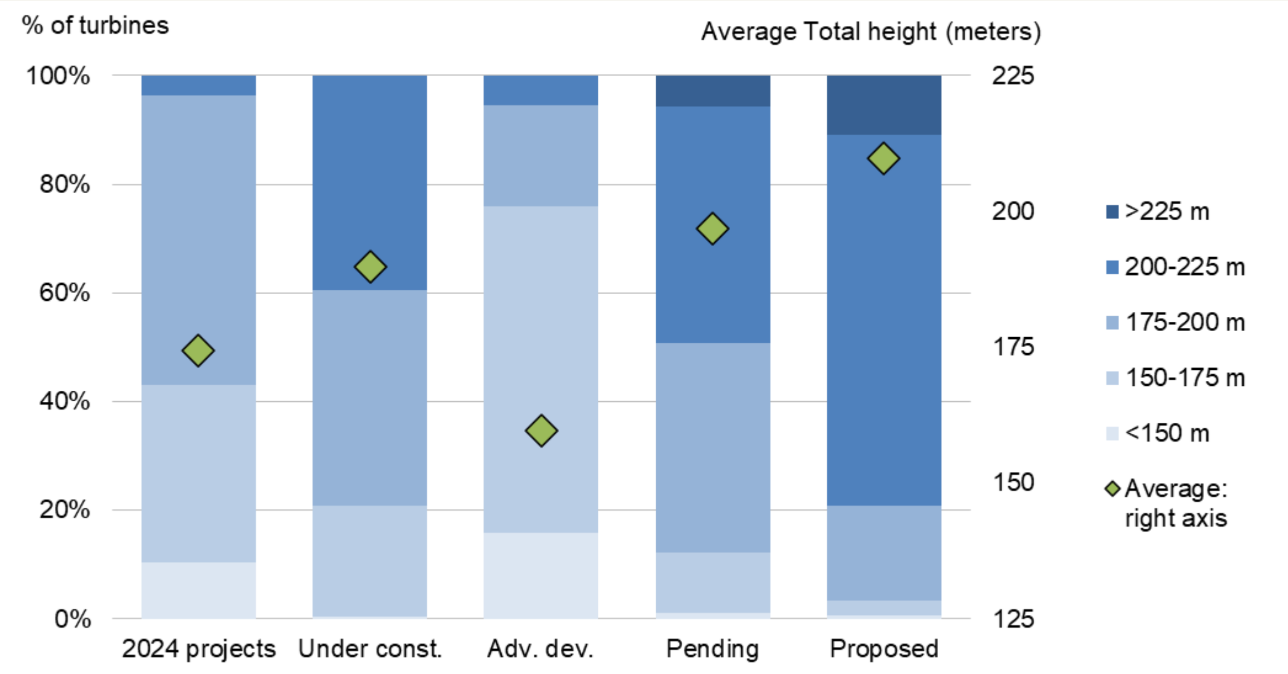
Specific Power



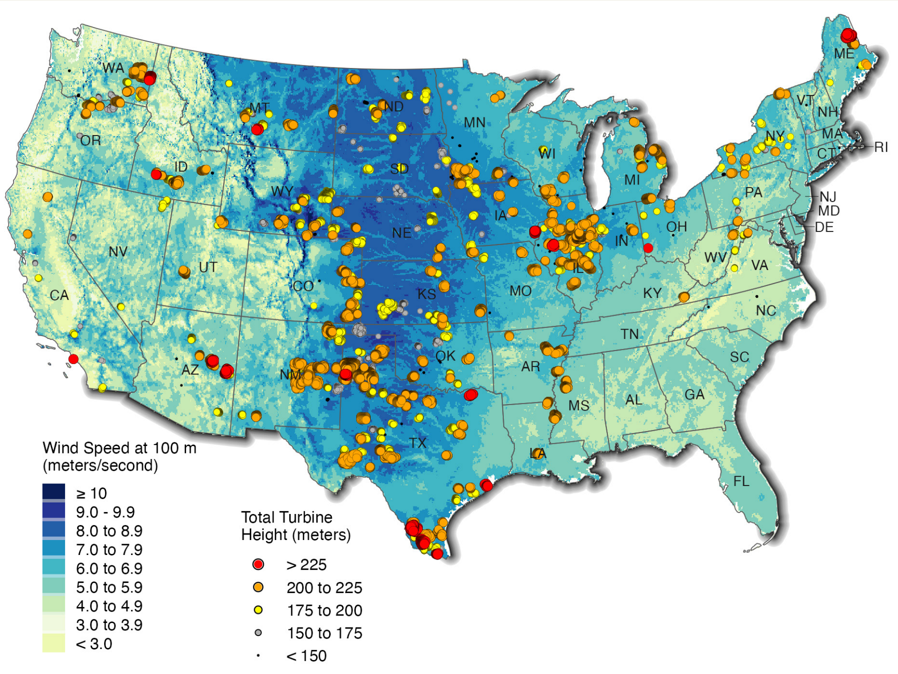
Sources: ACP, U.S. Wind Turbine Database, AWS Truepower, Berkeley Lab

Total turbine height trends based on to-be-built projects via FAA applications, and compared to FAA heights for 2024 installations

Average turbine height & height distribution



Location of turbines & total height



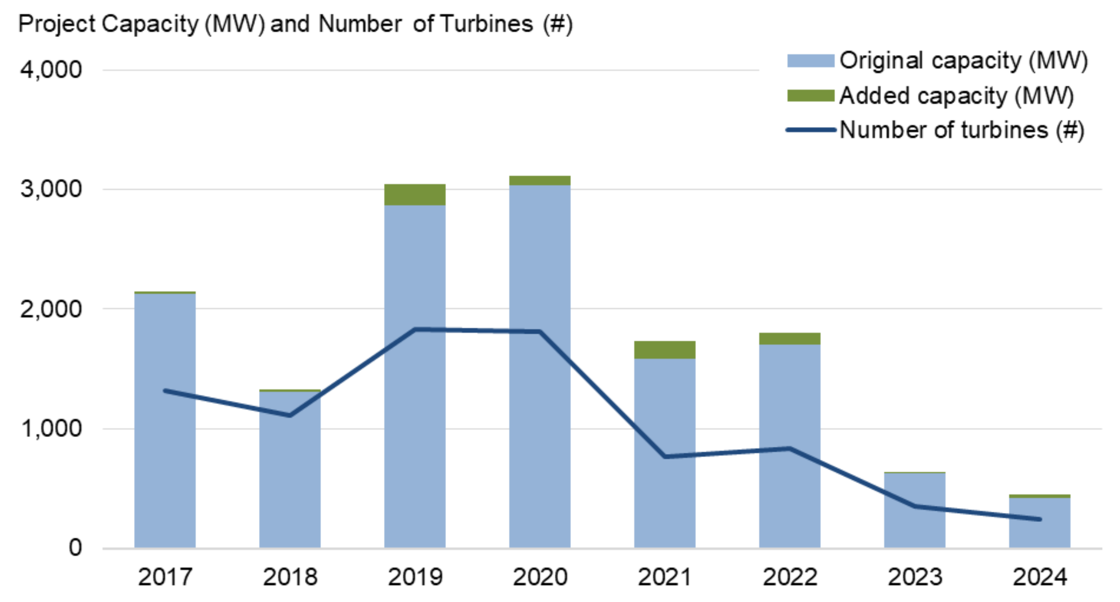
Note: blade tip height, not hub height

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

Trends in partial repowering and 2024 retrofitted turbine changes in average hub height, rotor diameter, capacity, and specific power

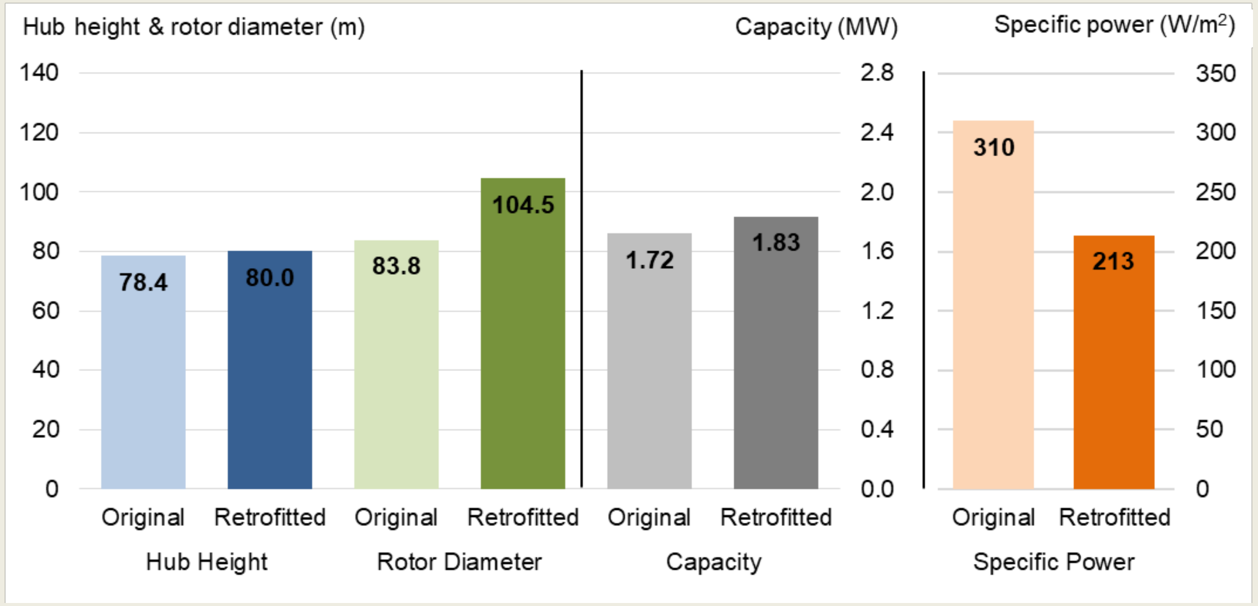
Partial Repowering by Year

(Figure shows wind project capacity repowered each year, 449 MW in 2024)



Technology Change with Partial Repowering

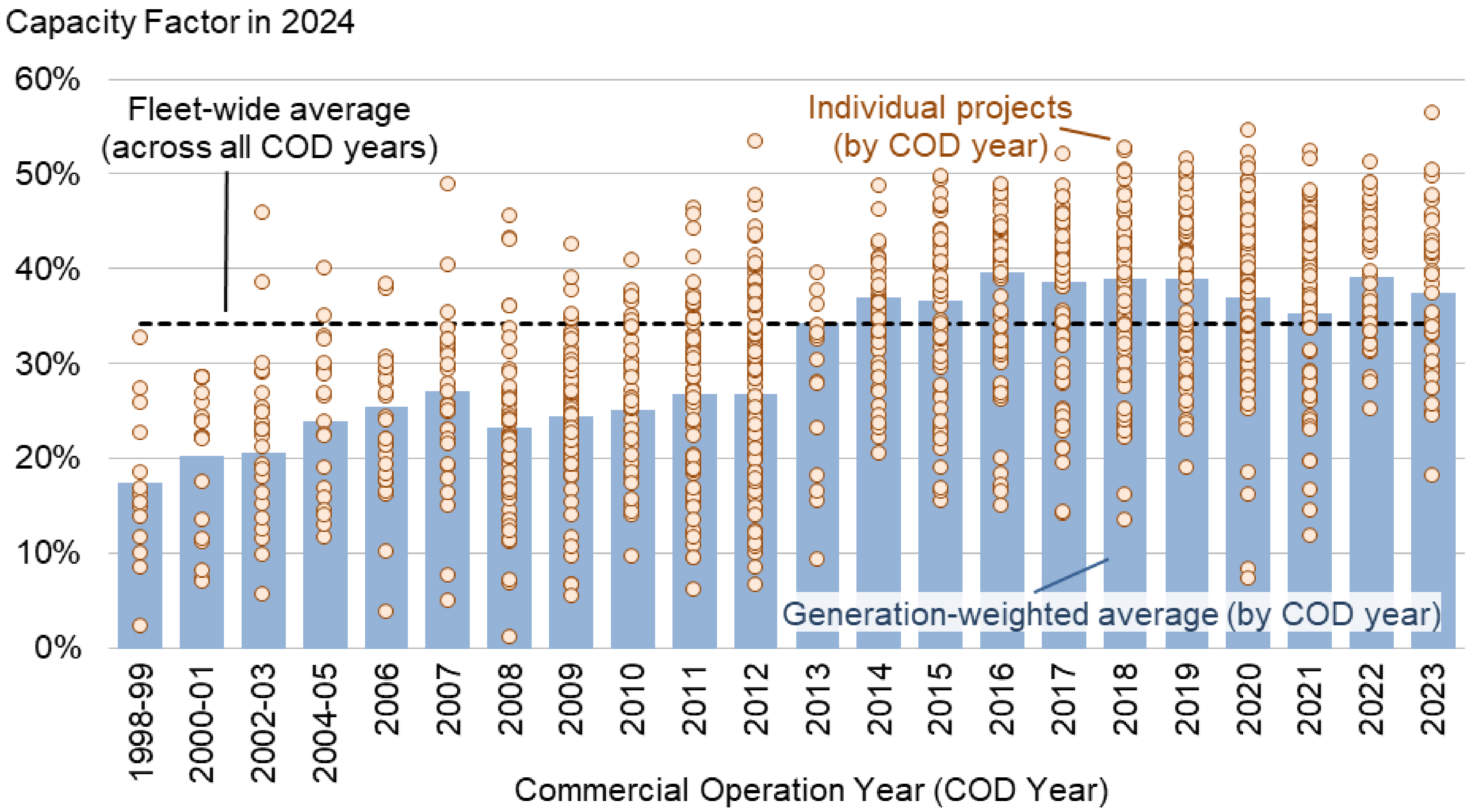
(Figure shows average technology change for wind turbines repowered in 2024)



Sources: ACP, Berkeley Lab, turbine manufacturers

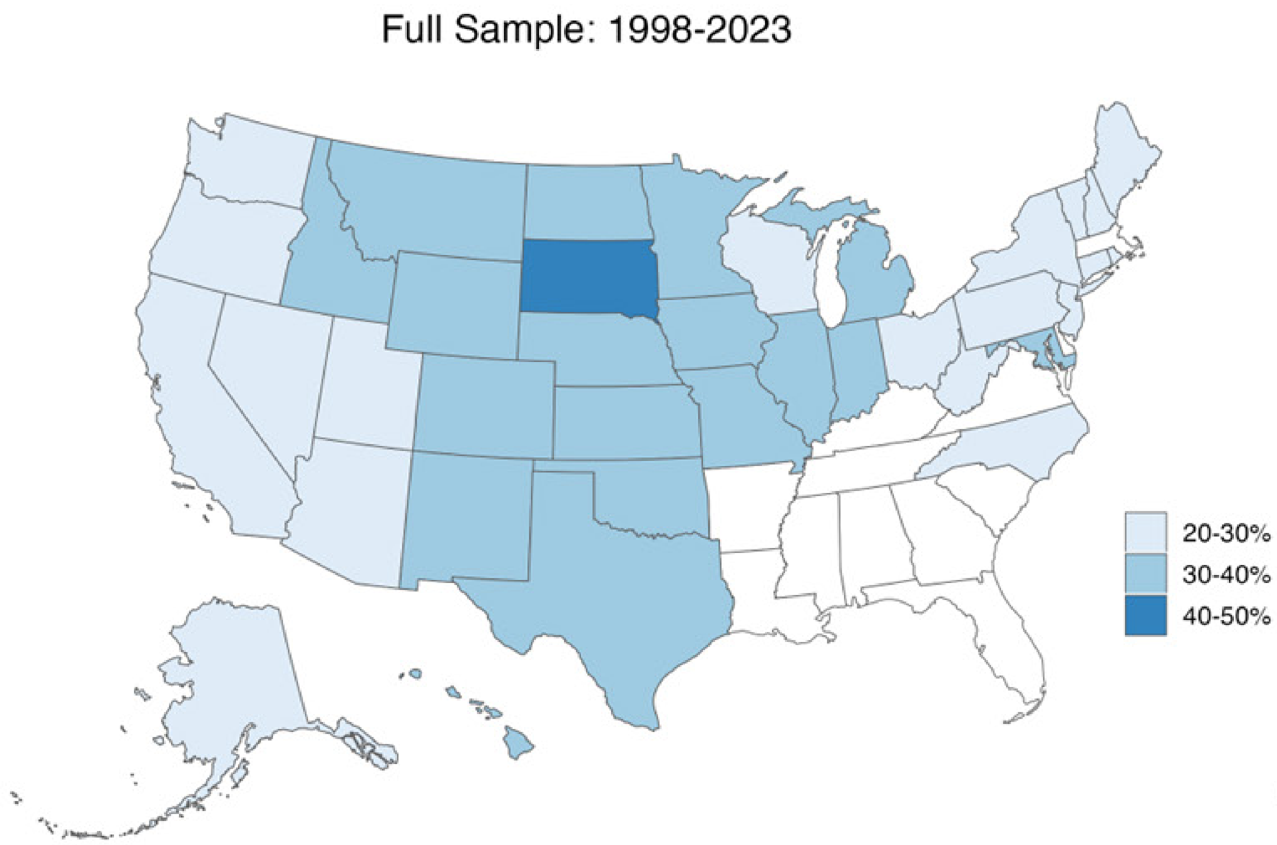
Performance Data

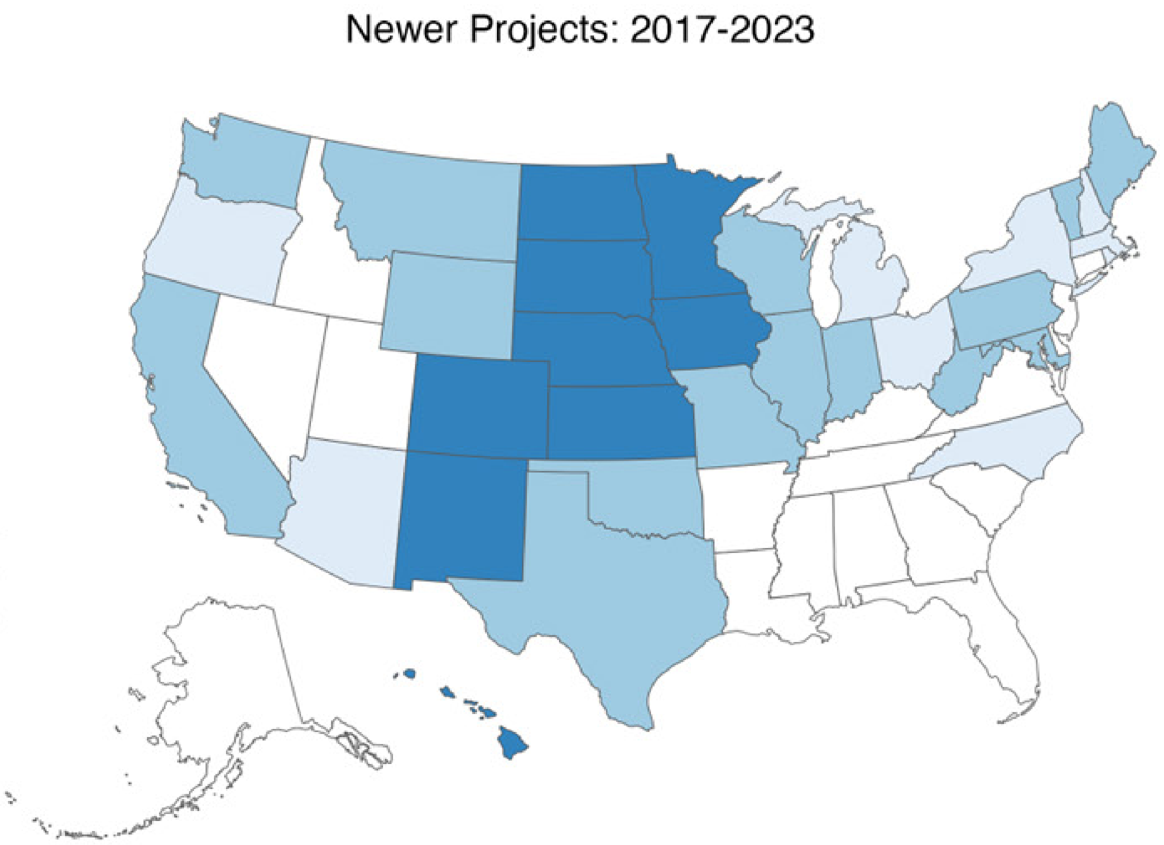
Calendar year 2024 capacity factors by commercial operation date: 37.5% for projects built in 2023, 34% fleet-wide for 1998-2023 projects



Source: EIA, FERC, Berkeley Lab

Average calendar year 2024 capacity factors by state: full sample (left) and newer projects (right)

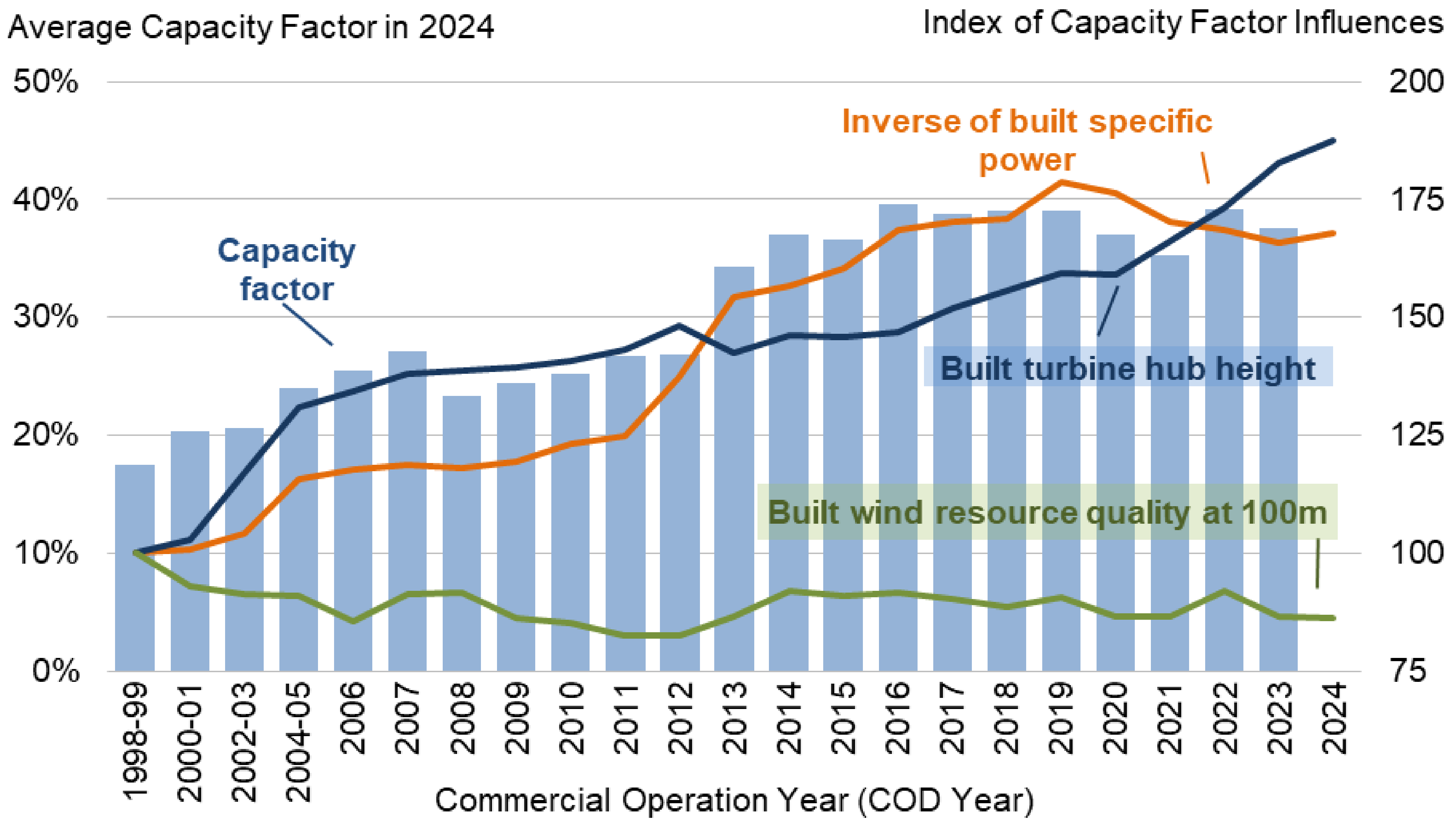




Source: EIA, FERC, Berkeley Lab

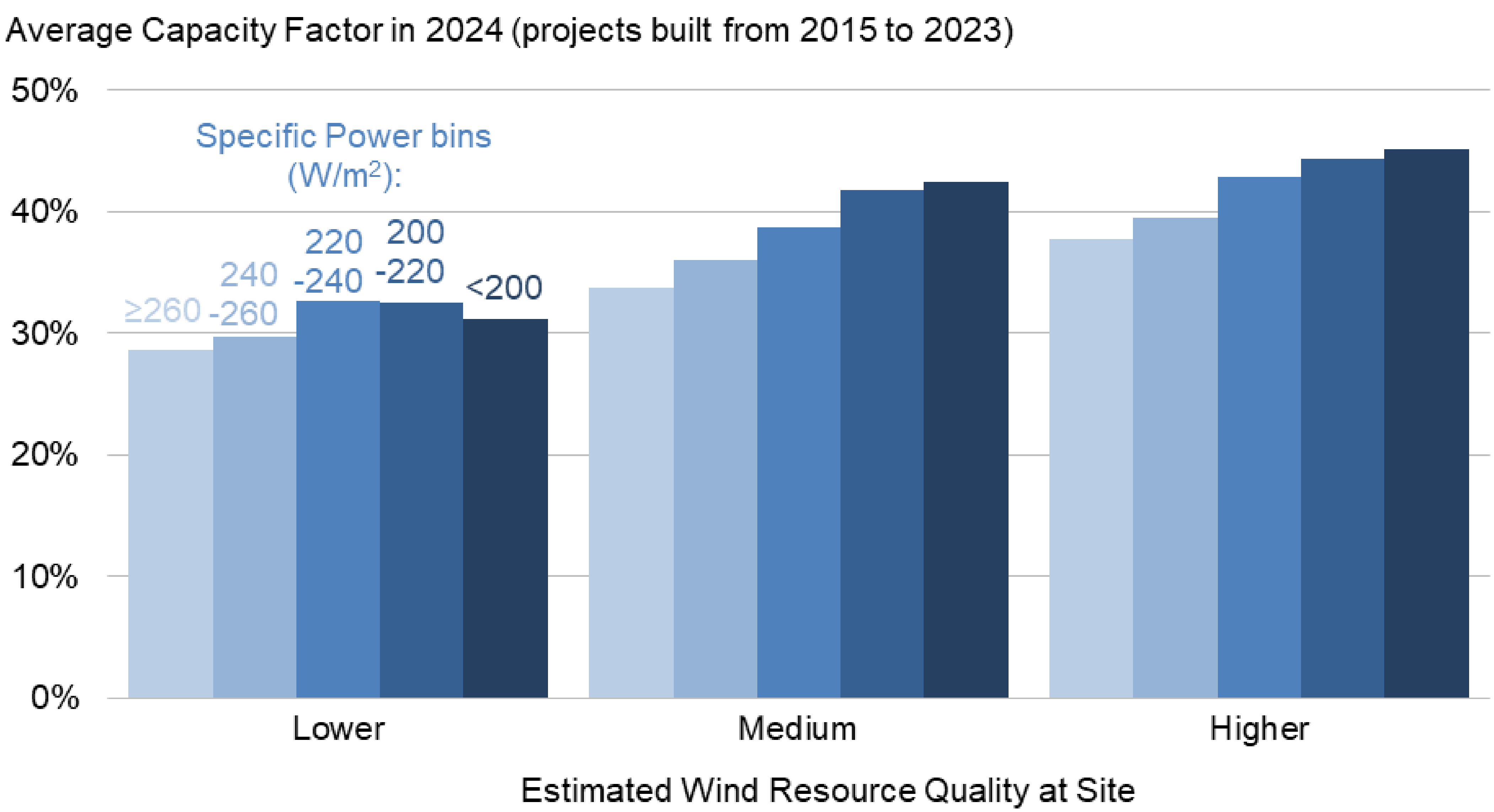
Note: States shaded in white have no projects in full sample (left) or in newer sample (right)

2024 capacity factors and various drivers by commercial operation date



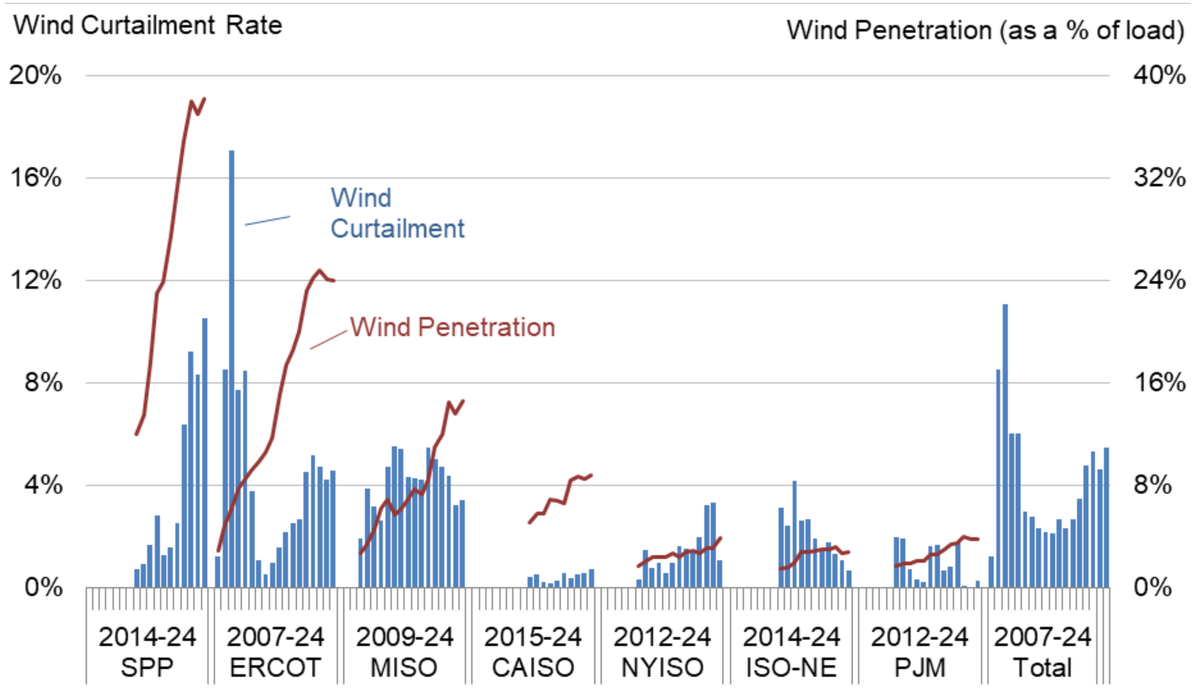
Source: EIA, FERC, Berkeley Lab

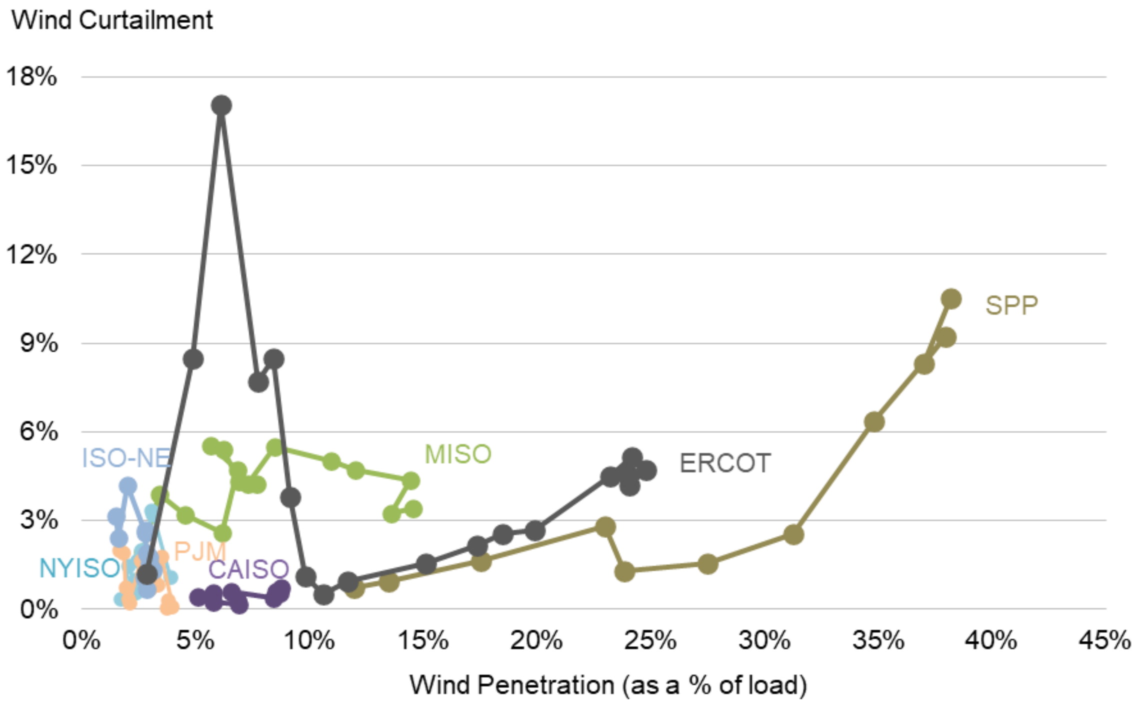
Calendar year 2024 capacity factors by wind resource quality and specific power



Source: EIA, FERC, Berkeley Lab

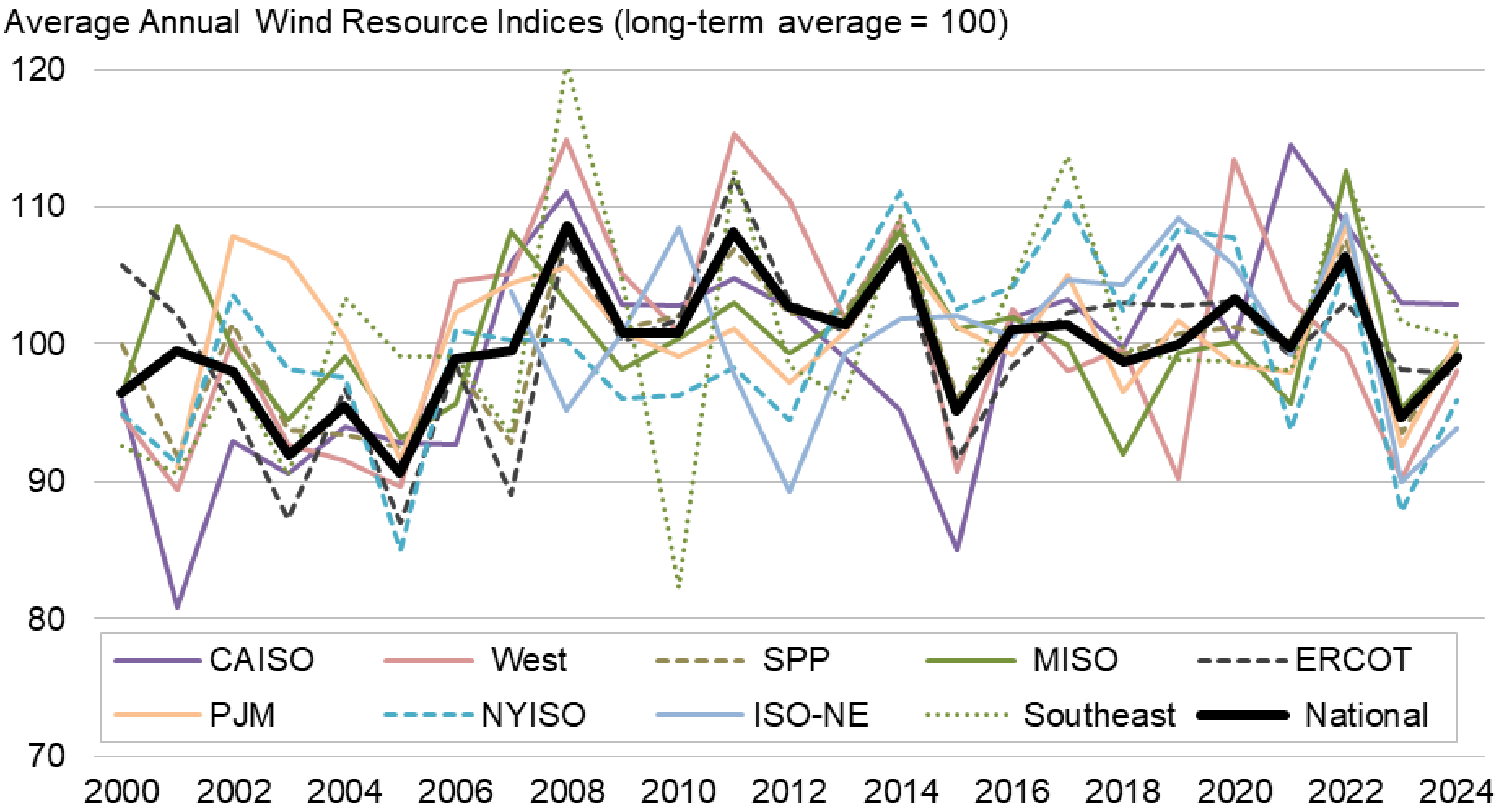
Wind curtailment and penetration rates by ISO: over time (left) and relative to wind penetration (right); highest in SPP at 10.5% in 2024





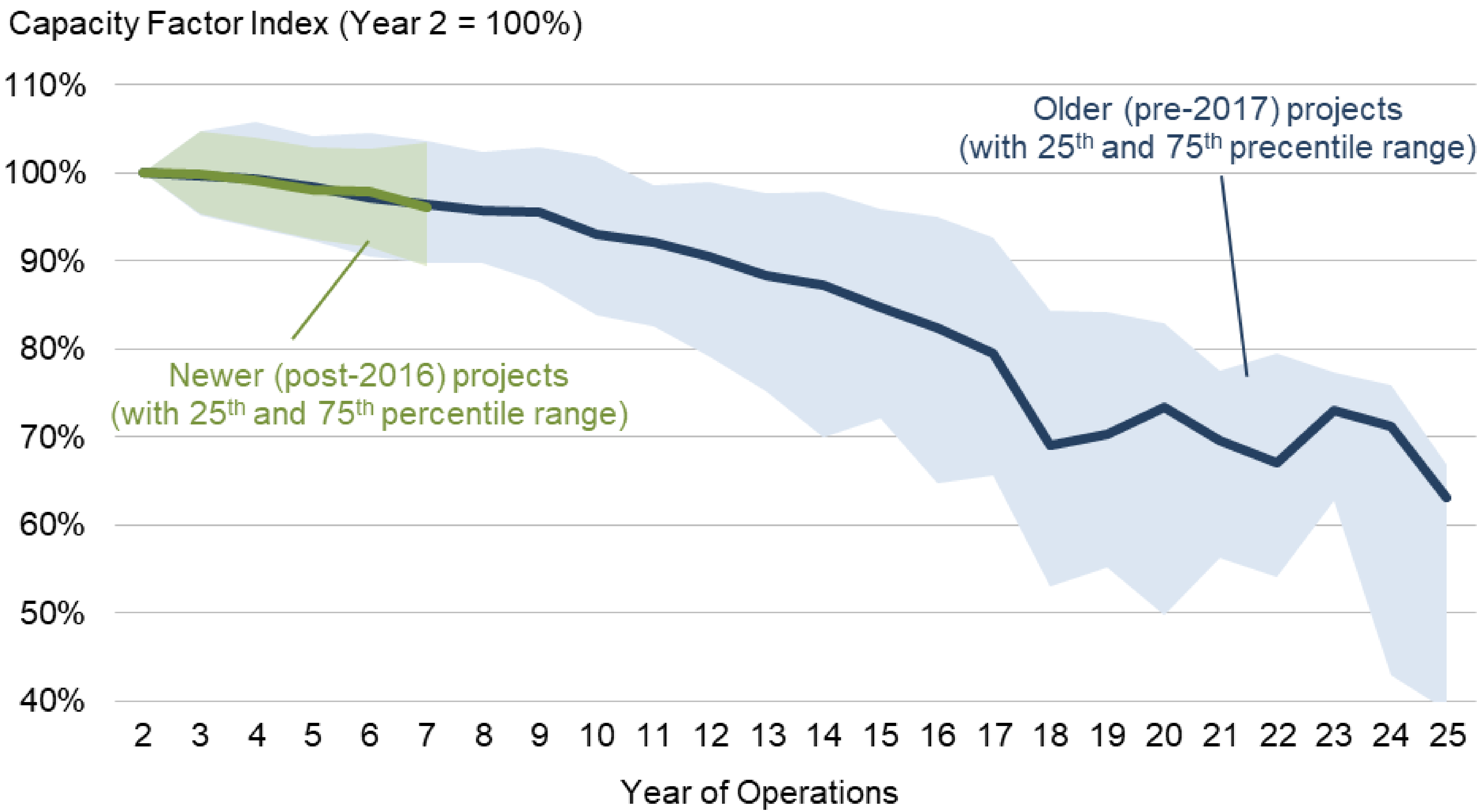
Sources: ERCOT, MISO, CAISO, NYISO, PJM, ISO-NE, SPP

Inter-annual variability in the wind resource by region and nationally



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

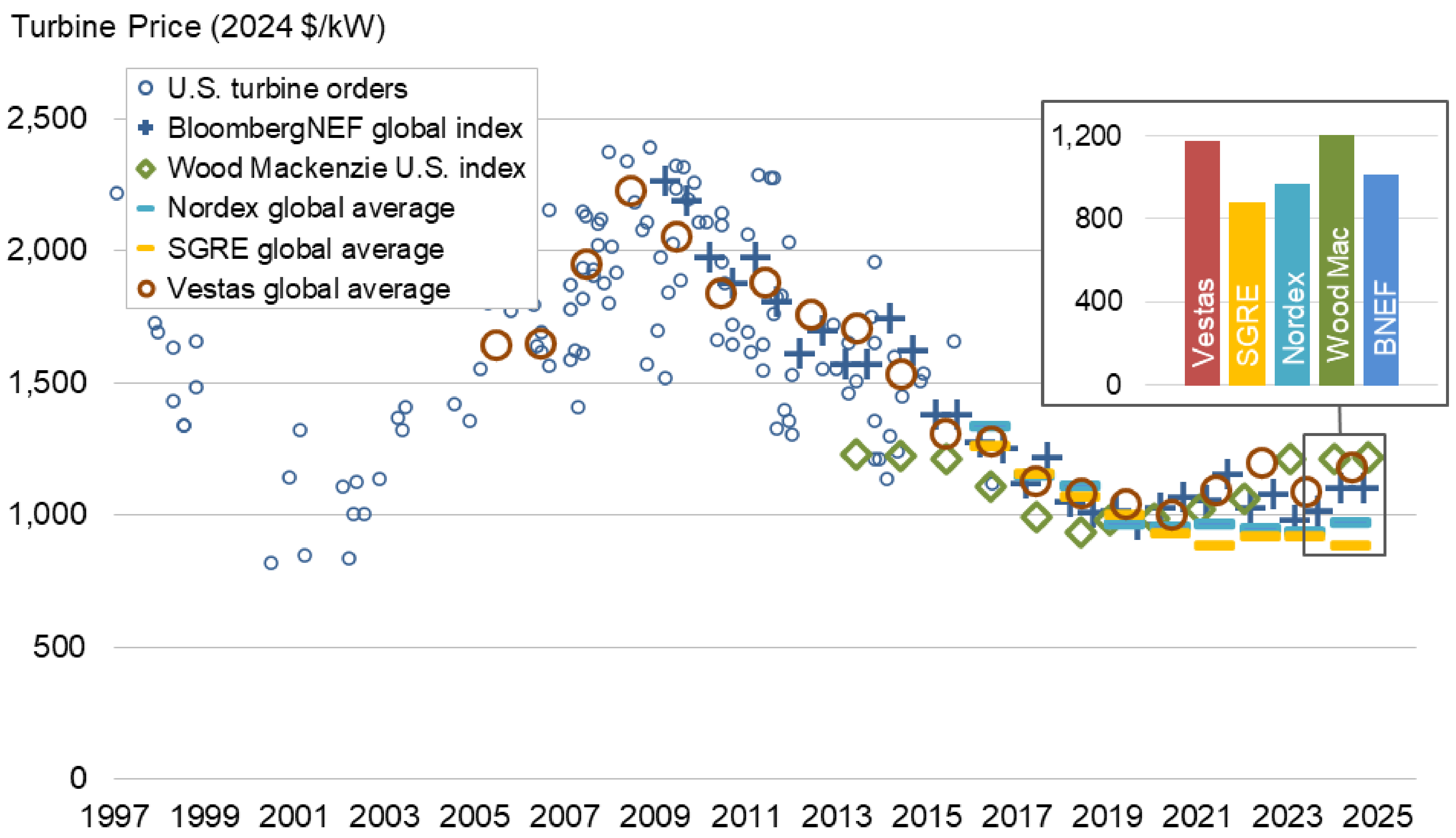
Changes in project-level capacity factors as projects age



Source: EIA, FERC, Berkeley Lab

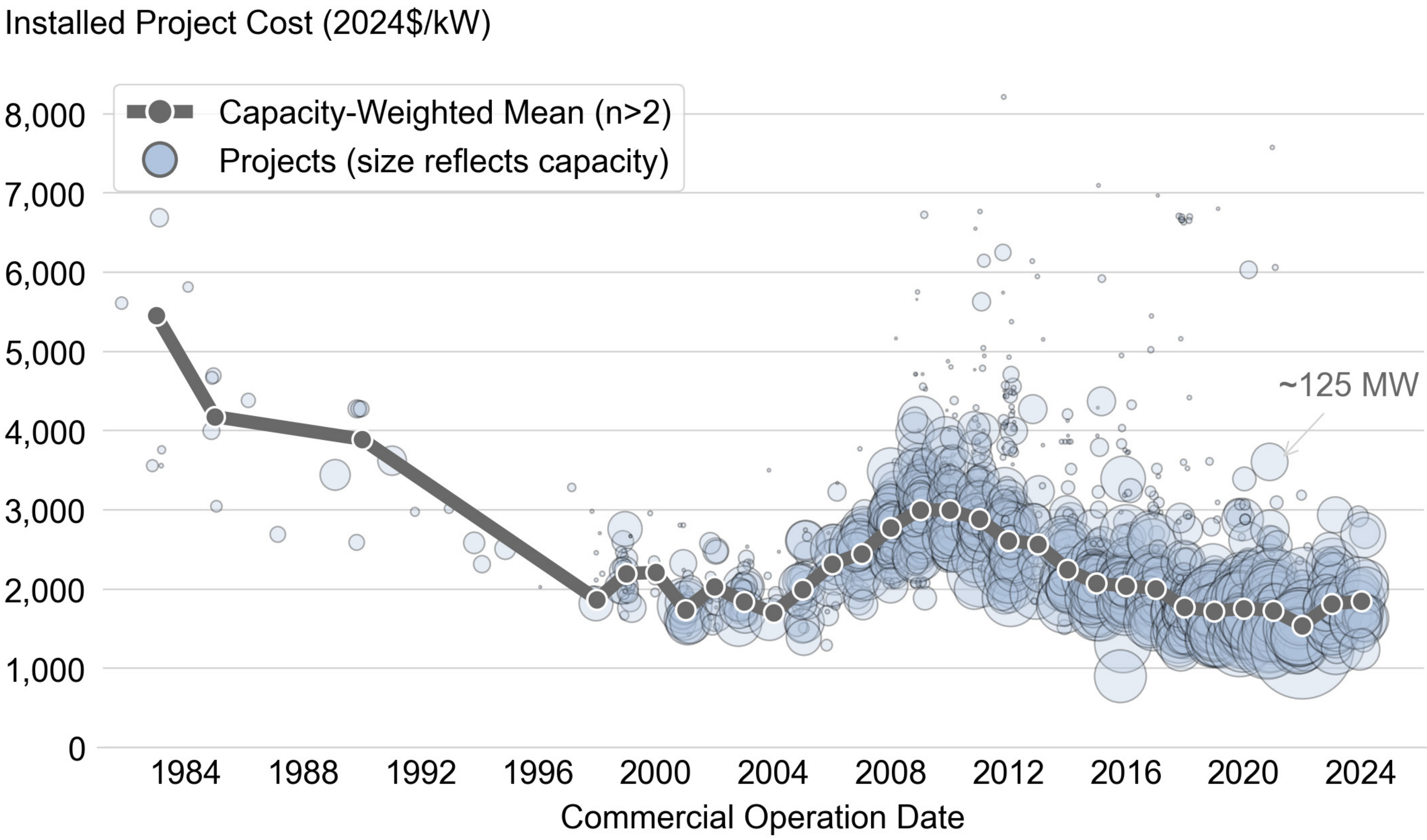
Cost Data

Reported wind turbine transaction prices over time: $1,070/kW average across sources in 2024



Sources: Berkeley Lab, annual financial reports, forecast providers

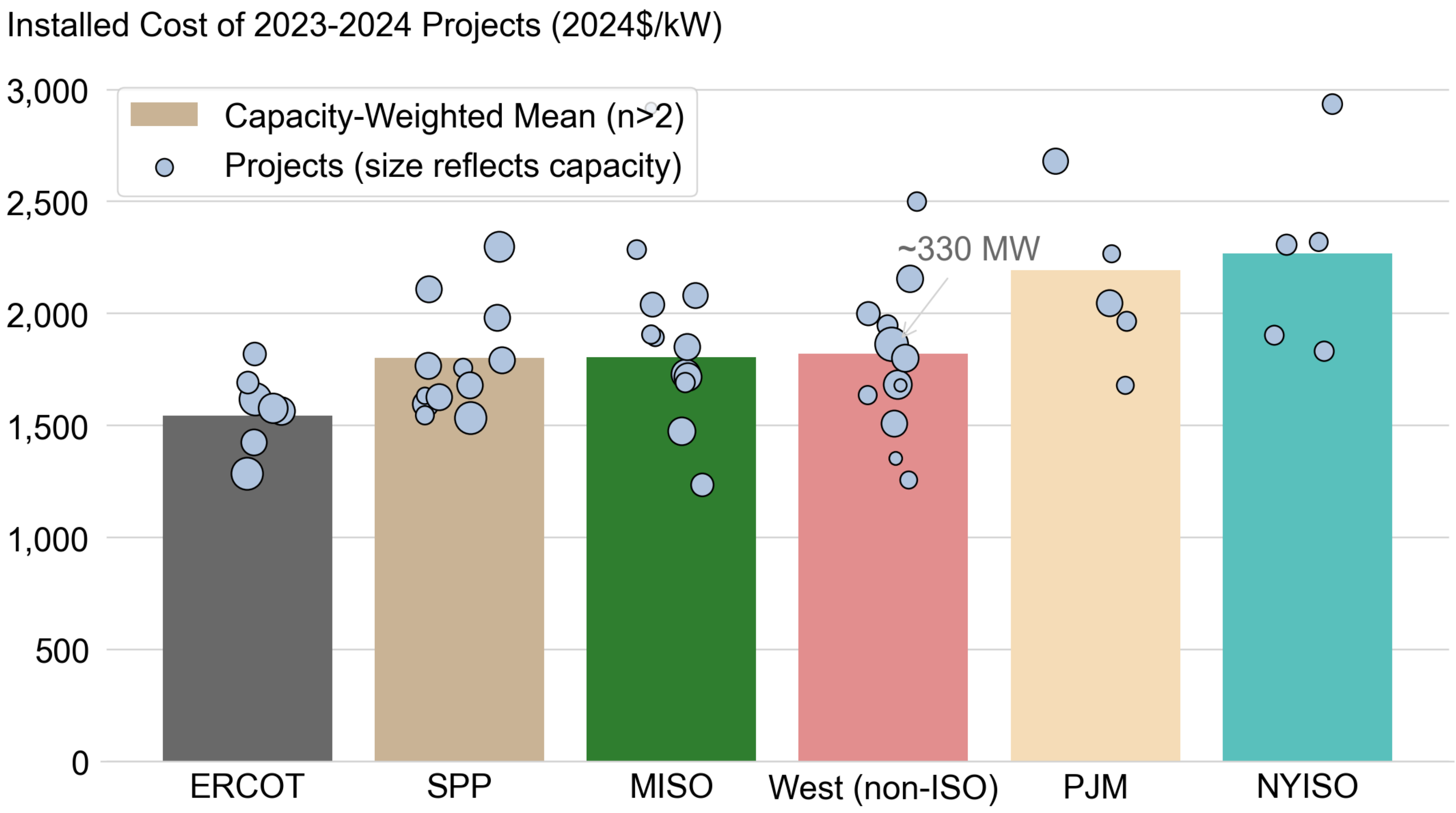
Installed wind power project costs over time: $1,850/kW average in 2024



Note: EIA CapEx estimates for projects with 2024 COD are still preliminary both in scope and accuracy of individual data points and may not be representative of final numbers that will be published later by EIA.

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

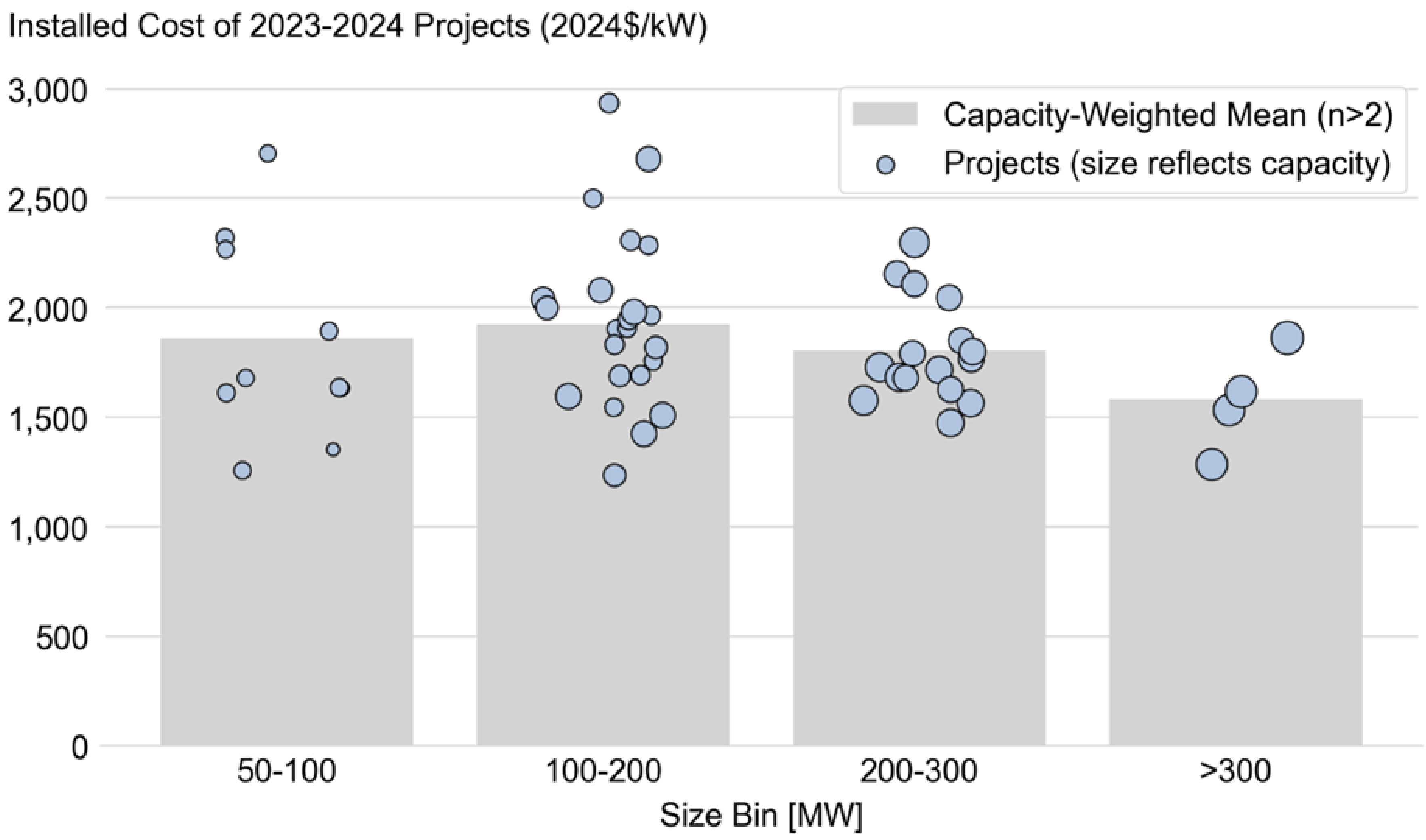
Installed wind project costs by region: 2023 and 2024 projects
Lowest in ERCOT at $1,540/kW; highest in NYISO at $2,270/kW



Note: EIA CapEx estimates for projects with 2024 COD are still preliminary both in scope and accuracy of individual data points and may not be representative of final numbers that will be published later by EIA.

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

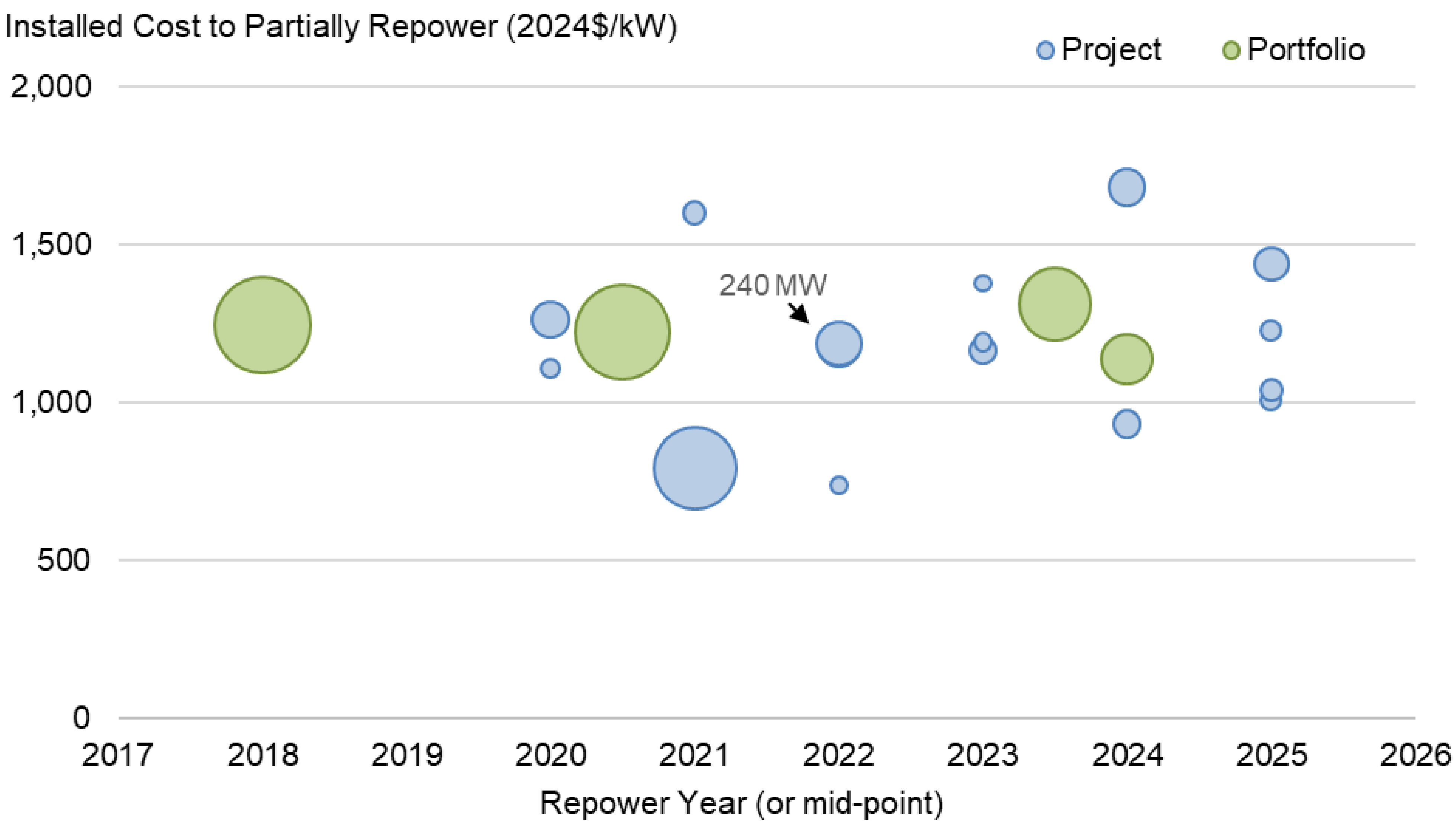
Installed wind project costs by project size: 2023 and 2024 projects



Note: EIA CapEx estimates for projects with 2024 COD are still preliminary both in scope and accuracy of individual data points and may not be representative of final numbers that will be published later by EIA.

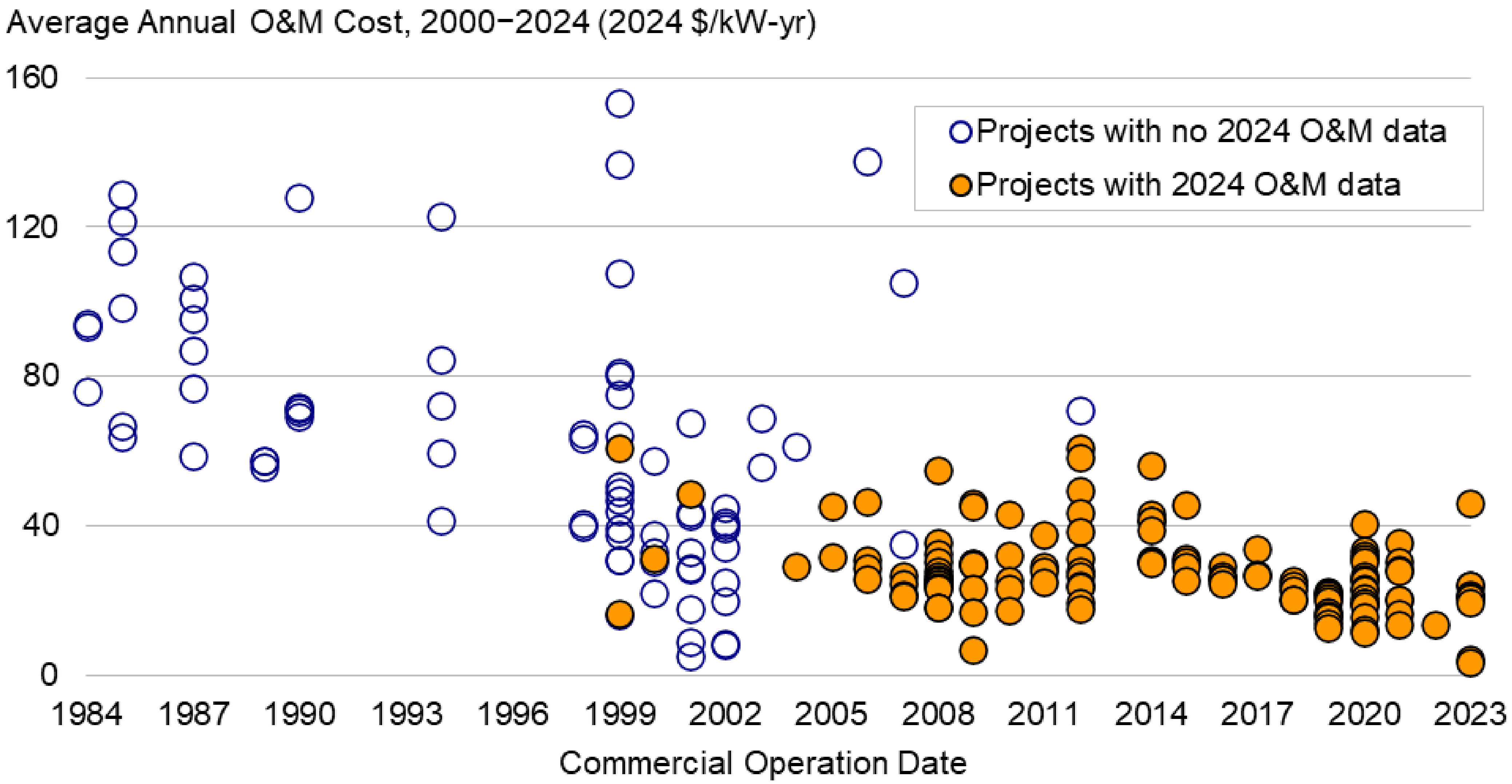
Sources: Berkeley Lab, EIA (some data points suppressed to protect confidentiality)

Upfront cost of partial wind project repowering: overall average across all years of $1,180/kW



Sources: Berkeley Lab, EIA

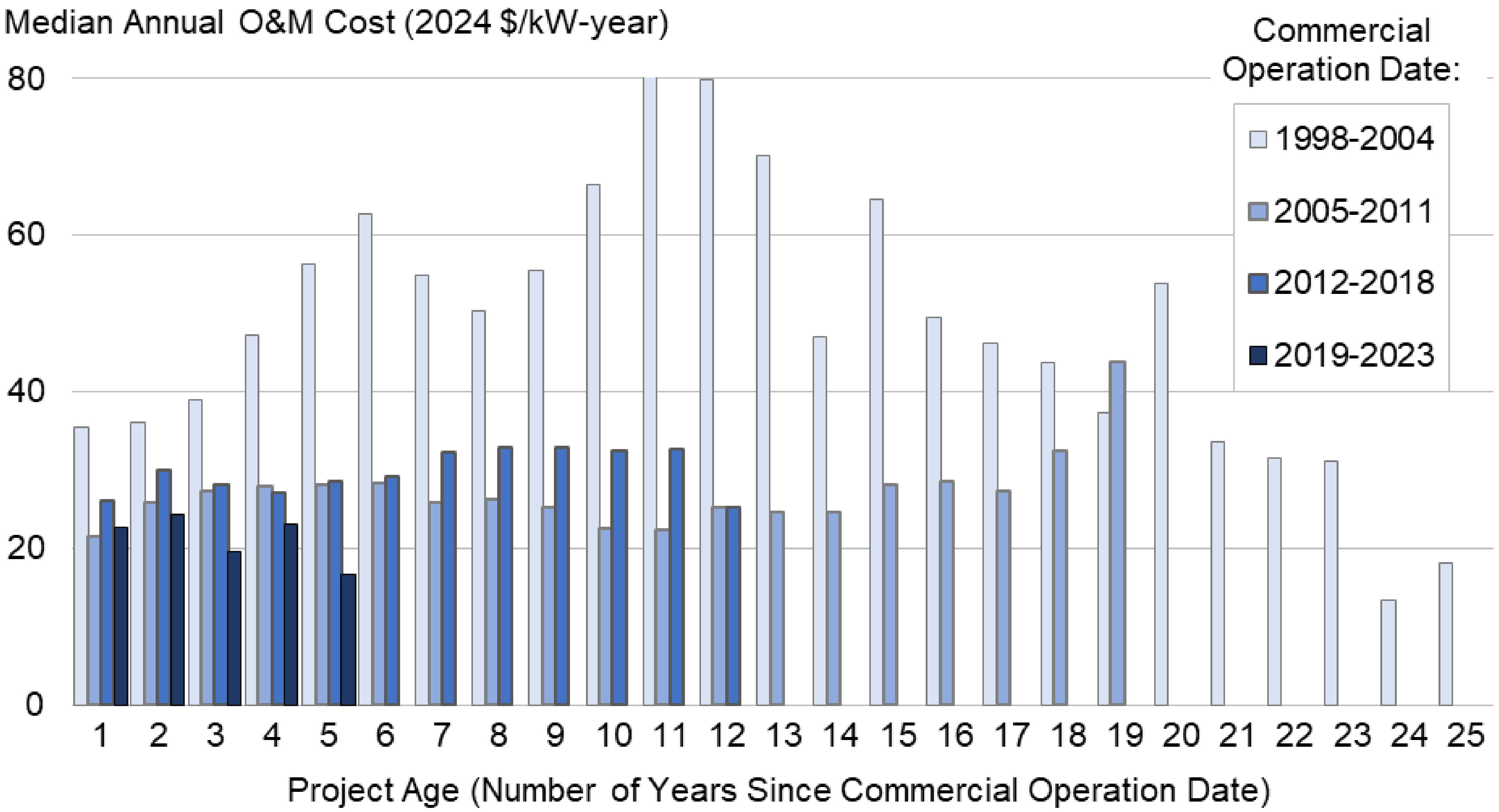
Average O&M costs for available data years from 2000 to 2024, by commercial online date



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 2000-24; O&M costs reported here do not include all operating costs.

Median annual O&M costs by project age and COD

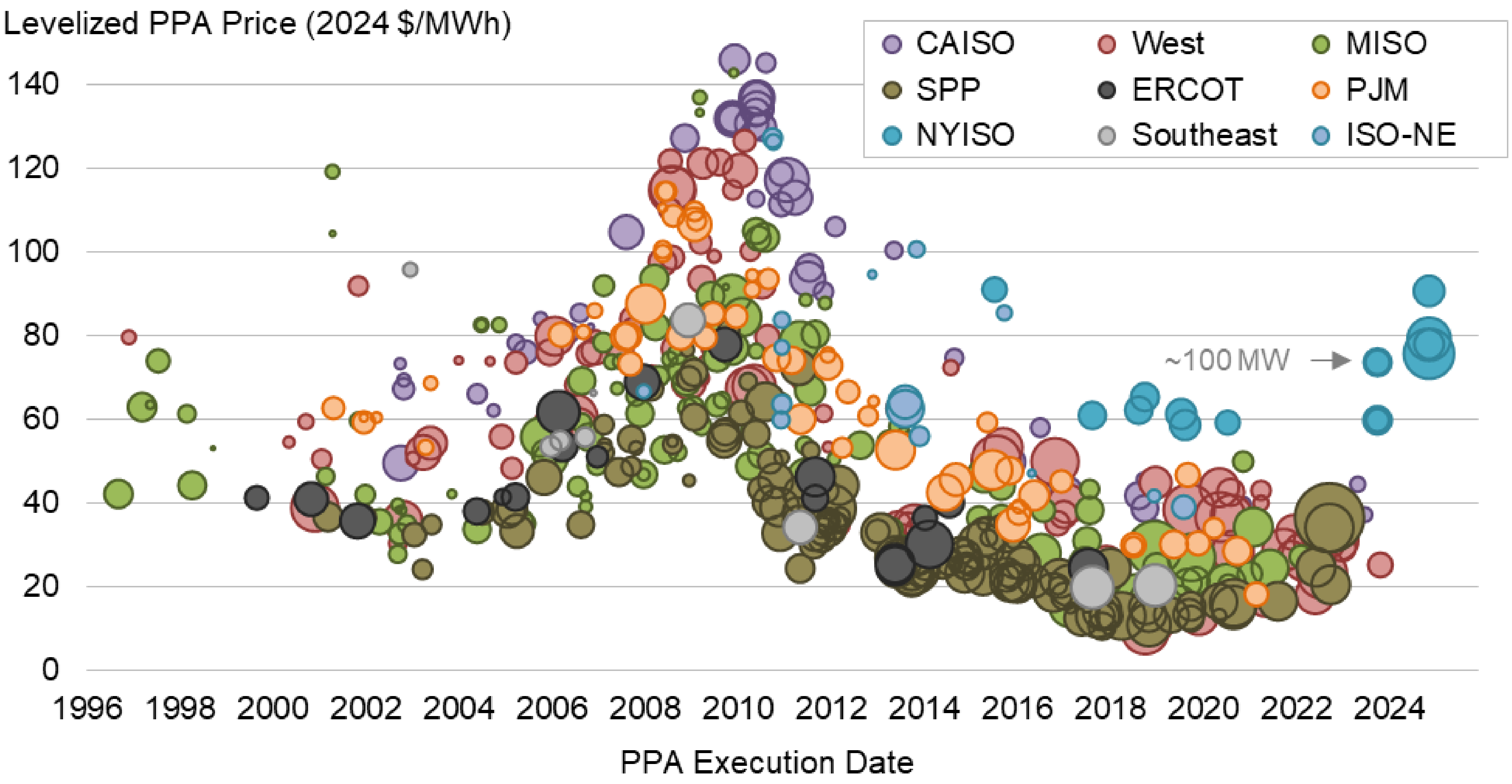


Source: Berkeley Lab; medians shown only for groups of two or more projects, and only projects >5 MW are included

Note: Sample size is limited, especially after year 15

Power Sales Price and Levelized Cost Data

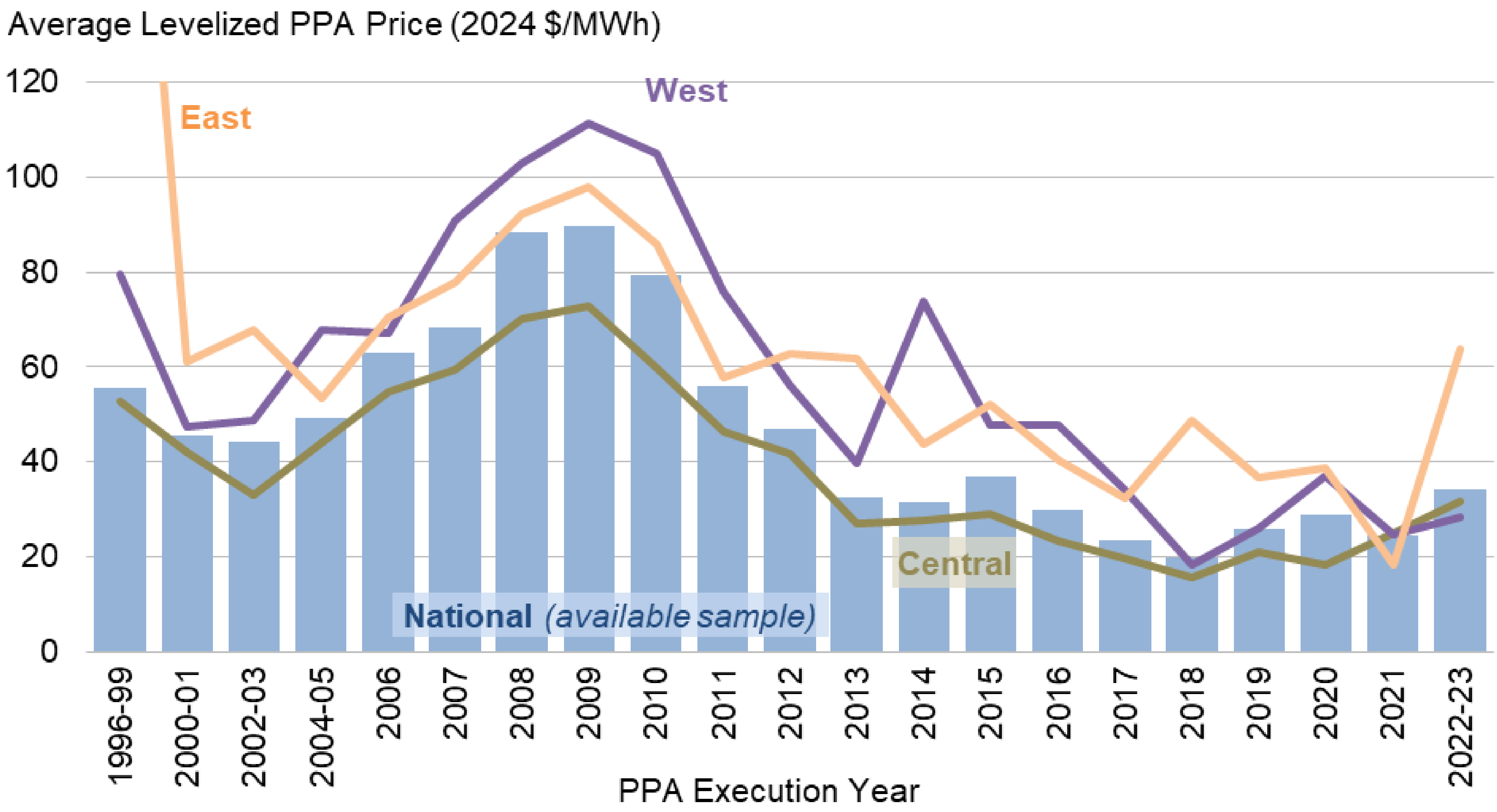
Levelized wind PPA prices by PPA execution date and region (full sample): real $/MWh



Note: Smallest bubble sizes reflect smallest-volume PPAs (<5 MW), whereas largest reflect largest-volume PPAs (>500 MW)

Source: Berkeley Lab, FERC

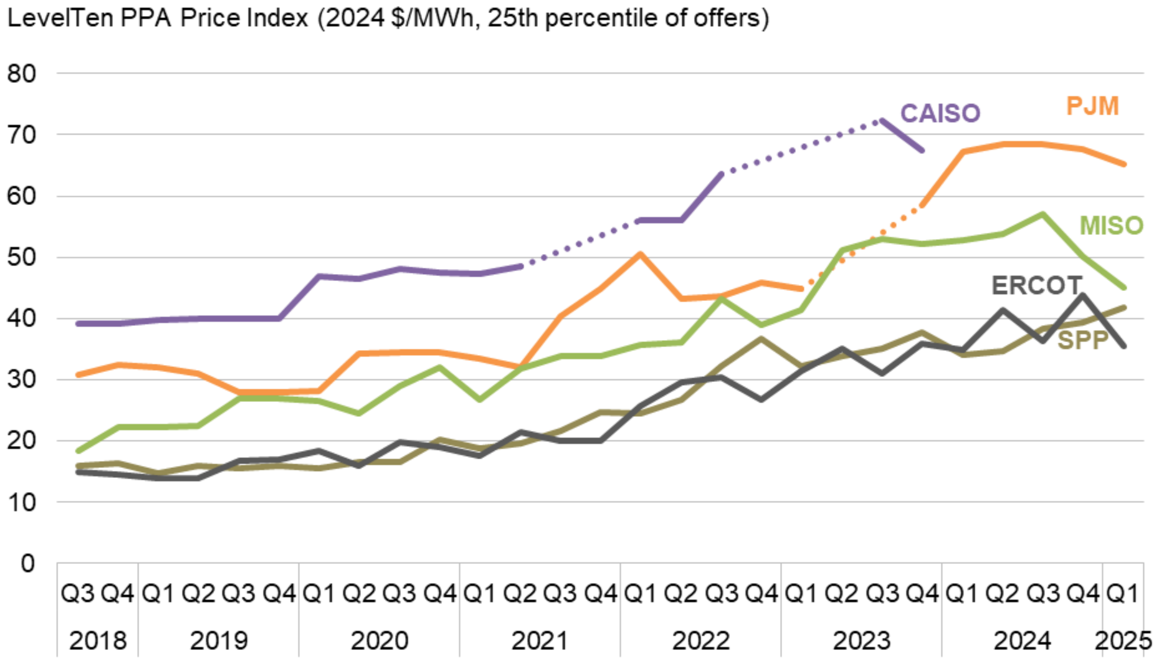
Generation-weighted average levelized wind PPA prices by PPA execution date and region

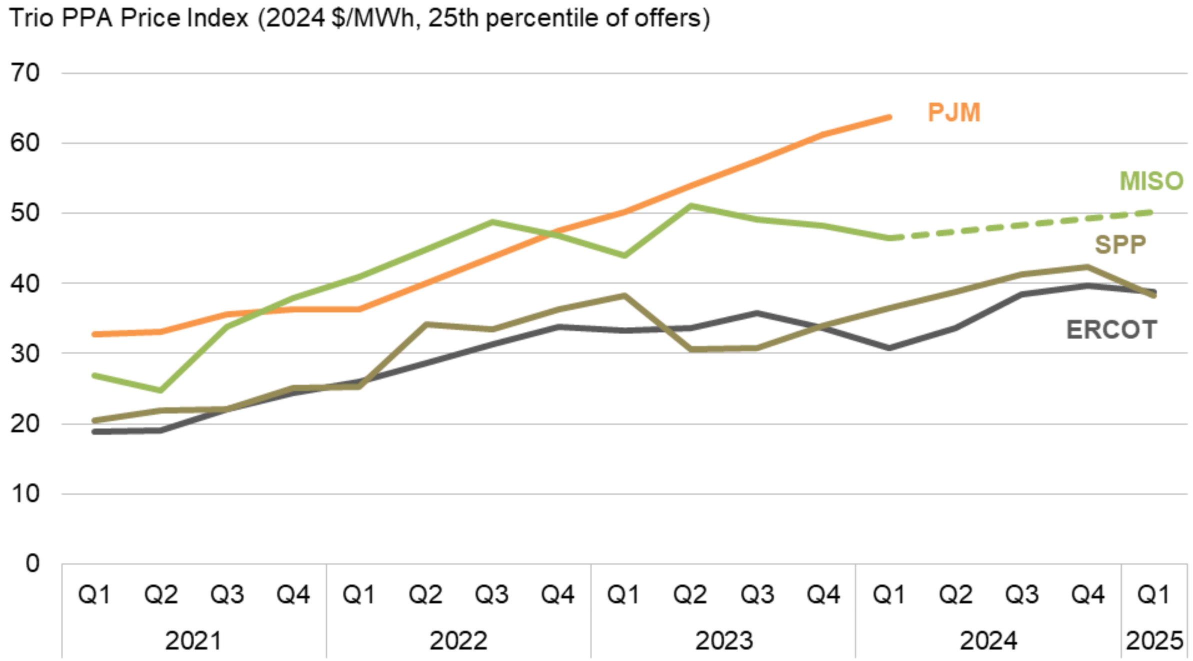


Source: Berkeley Lab, FERC

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

LevelTen Energy (left) and Trio (right) wind PPA price indices





Sources: LevelTen Energy and Trio, converting nominal dollar LevelTen data to levelized real 2024$.
Notes: Dashed lines represent interpolations between data points where intermediate data are missing
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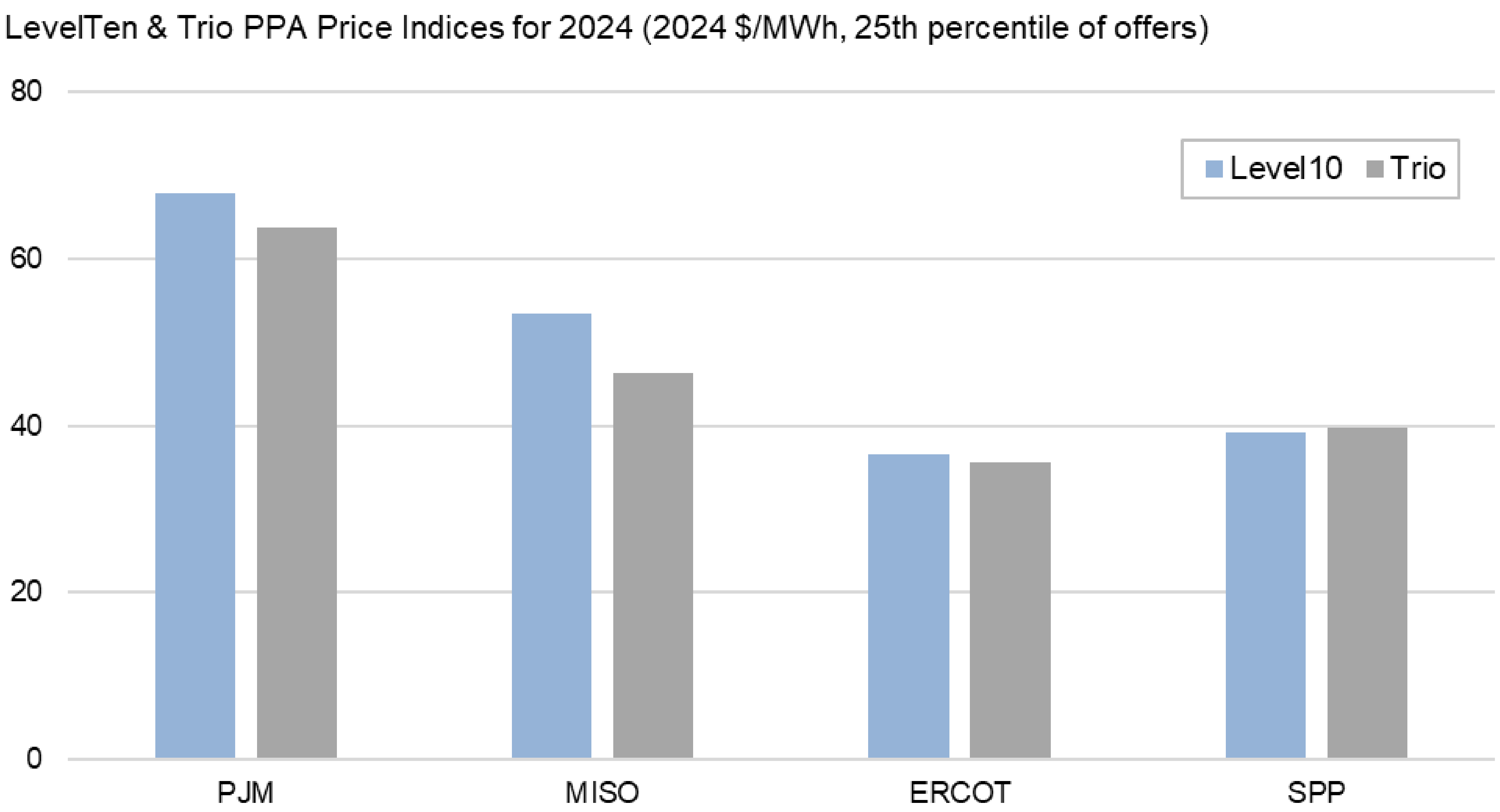
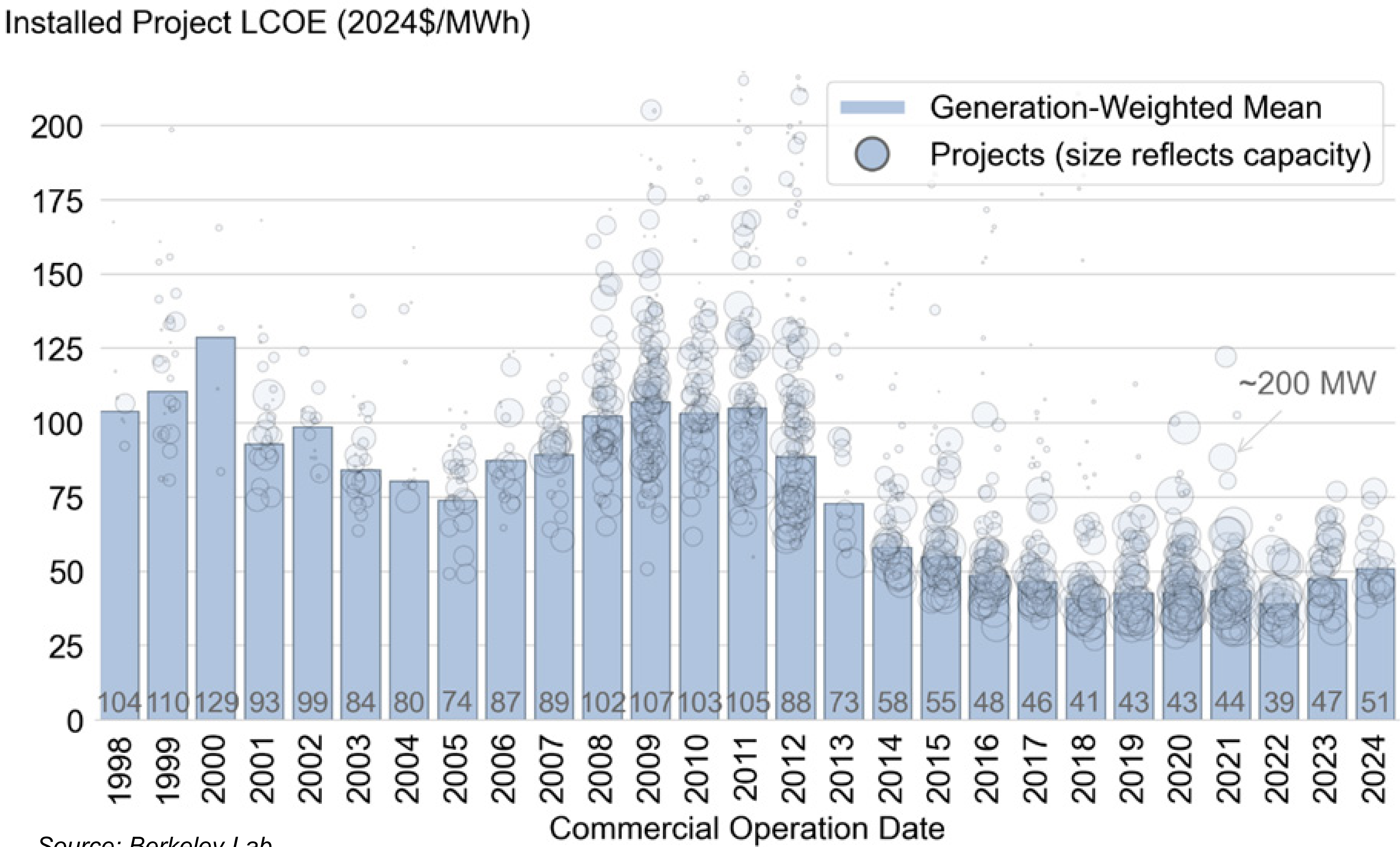
LevelTen Energy and Trio regional wind PPA price indices for 2024



Sources: LevelTen Energy and Trio, converting nominal dollar LevelTen data to levelized real 2024$.

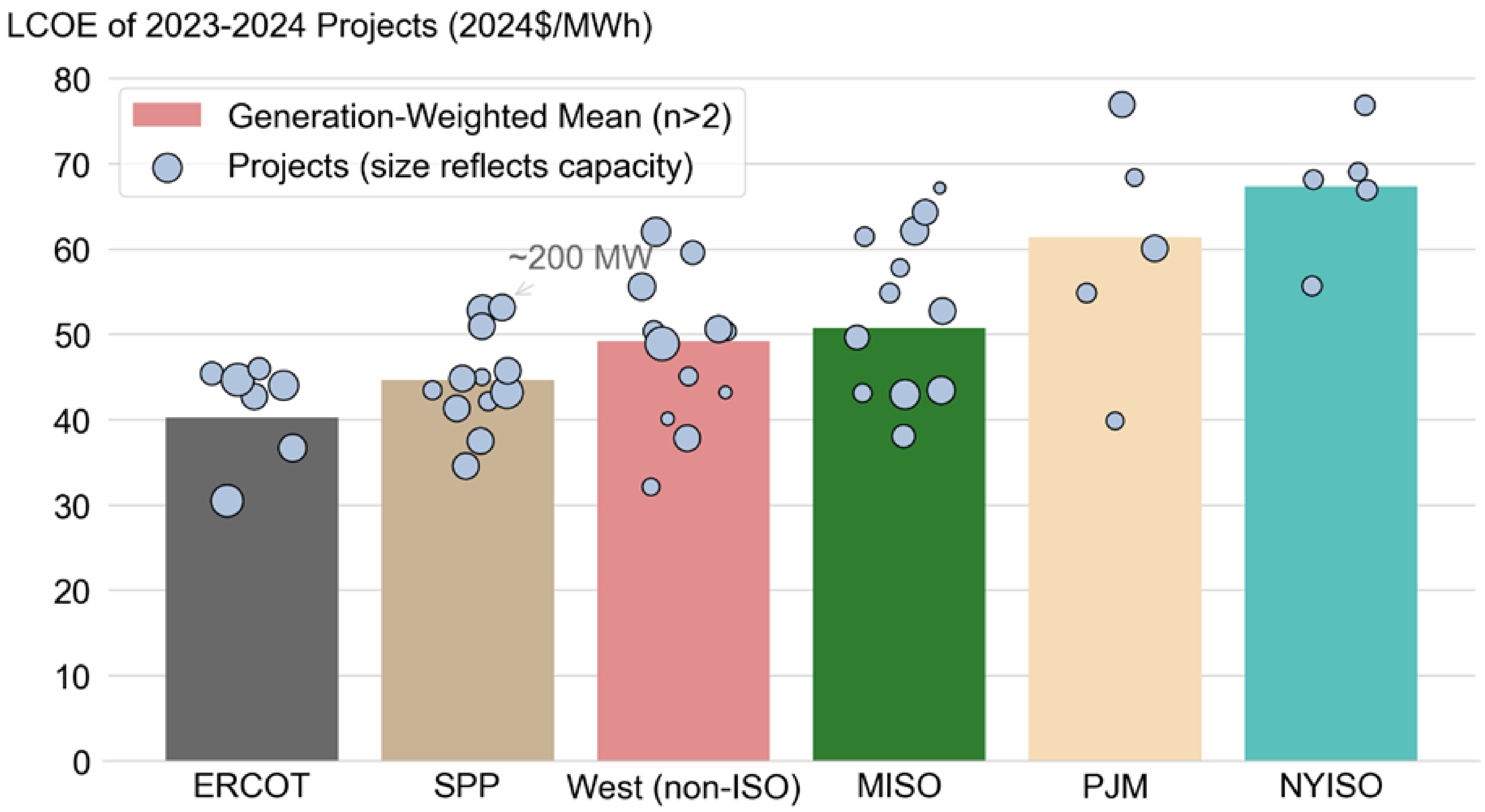
Estimated levelized cost of wind energy by commercial online date



Source: Berkeley Lab

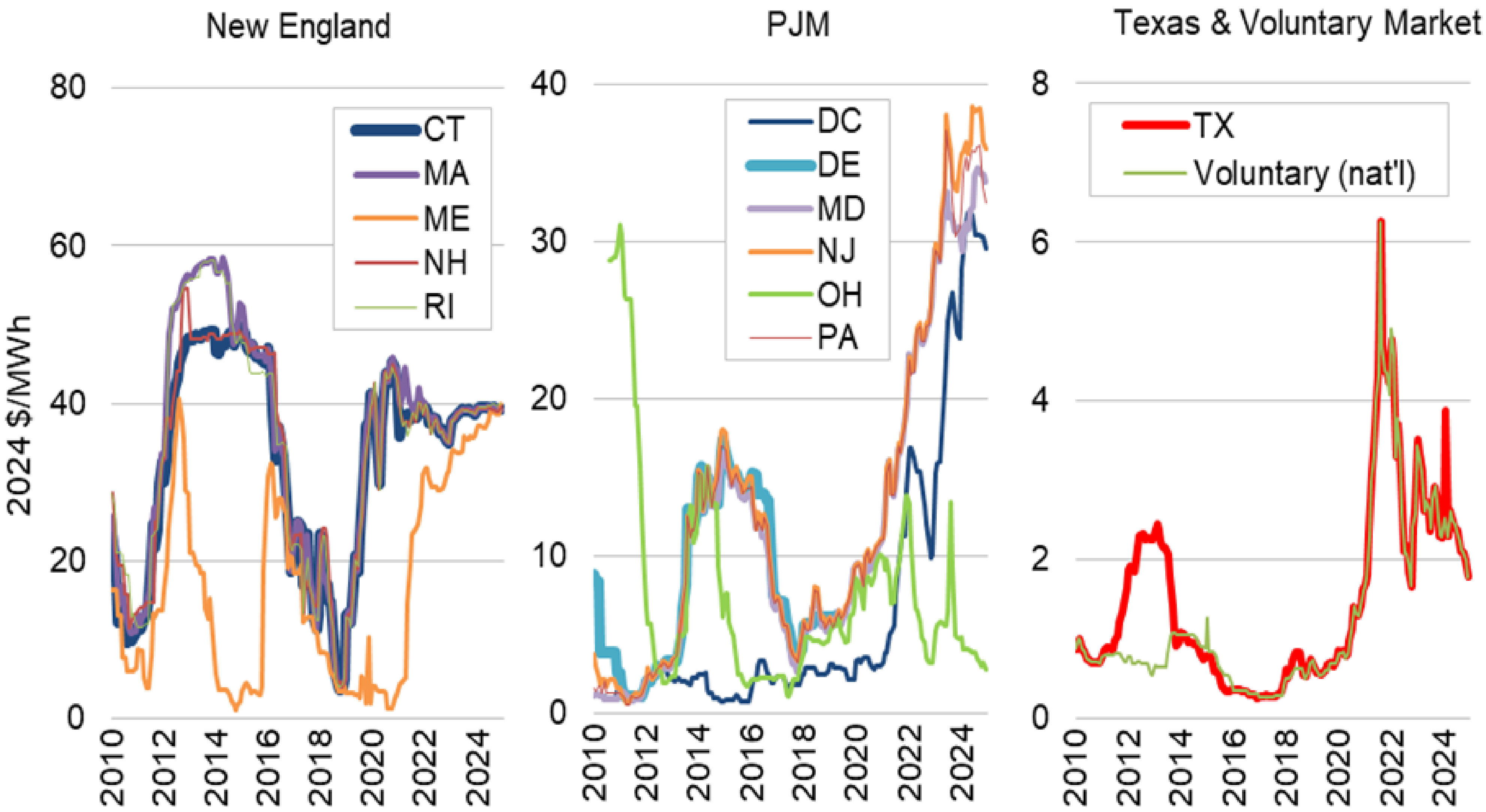
Note: Yearly estimates reflect variations in installed cost, capacity factors, operational costs, cost of financing, and project life; includes accelerated depreciation but excludes PTC.

LCOE of wind power plants by region: 2023 and 2024 plants lowest in ERCOT at $40/MWh, highest in NYISO at $67/MWh



Source: Berkeley Lab

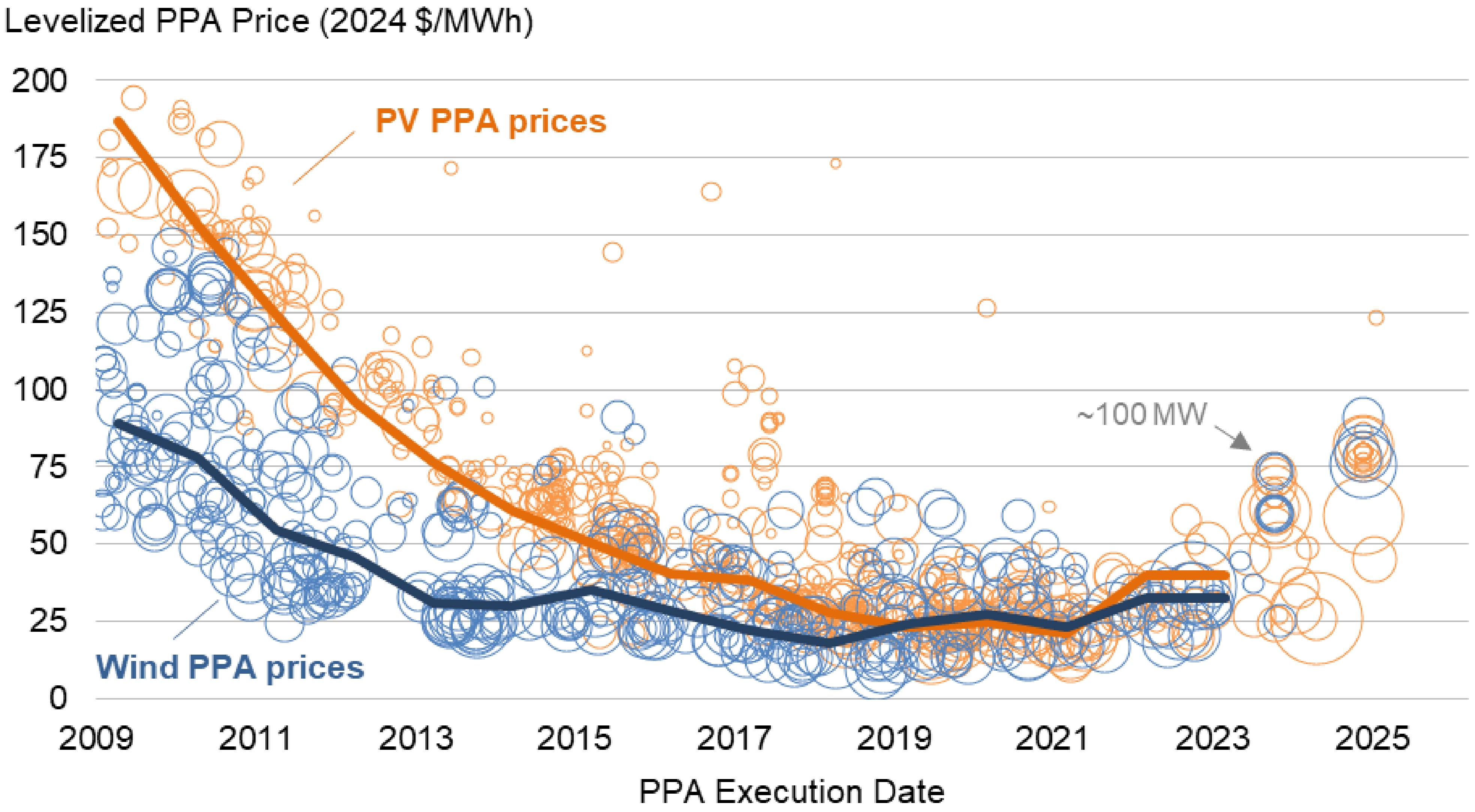
Historical renewable energy certificate (REC) prices



Source: Marex Spectron

Cost and Value Data

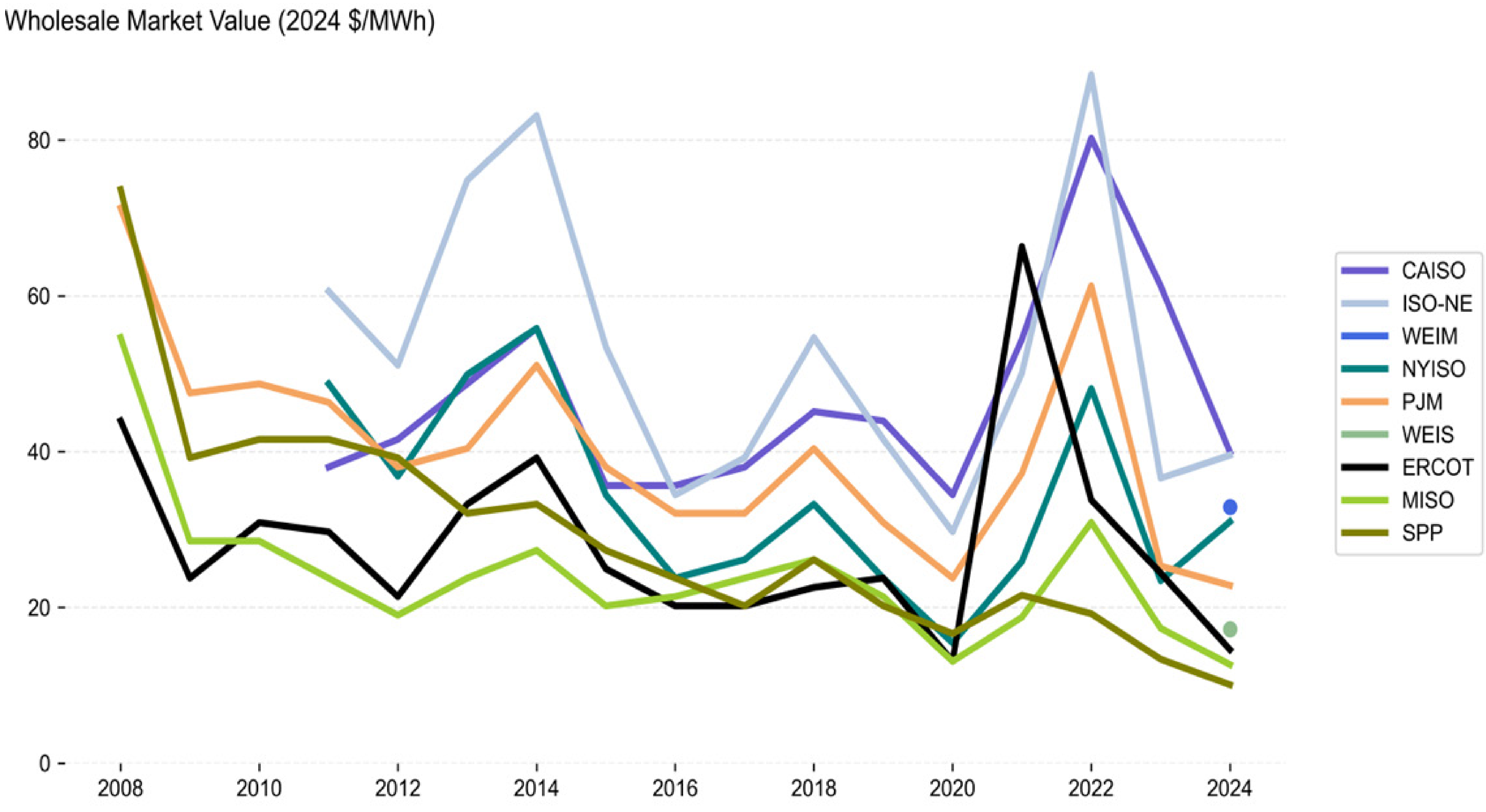
Levelized wind and solar PPA prices



Source: Berkeley Lab, FERC, EIA

Note: Smallest bubble sizes reflect smallest-volume PPAs (<5 MW), whereas largest reflect largest-volume PPAs (>500 MW)

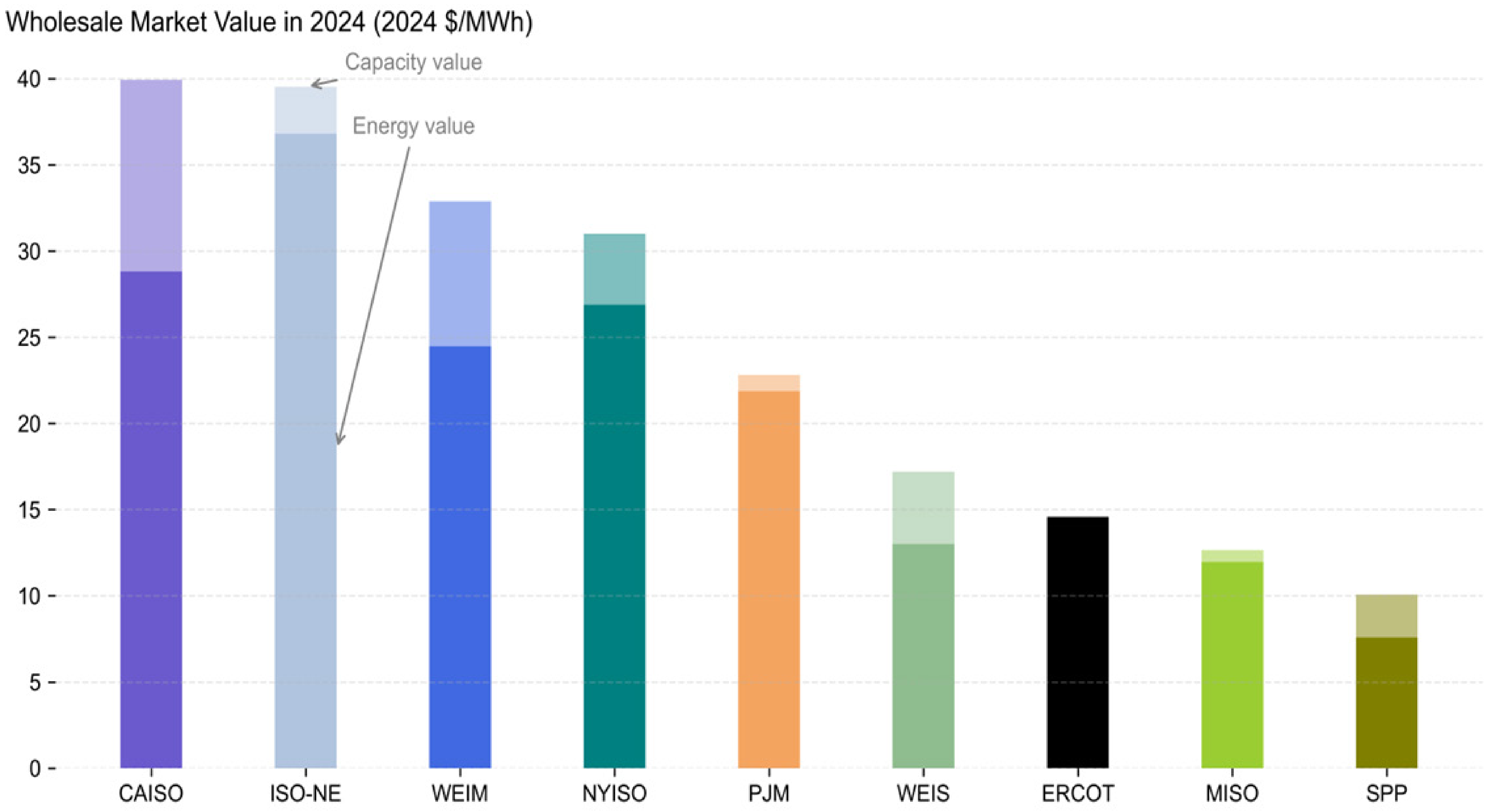
Regional wholesale market value of wind over time



Sources: *Berkeley Lab, ABB, ISOs*

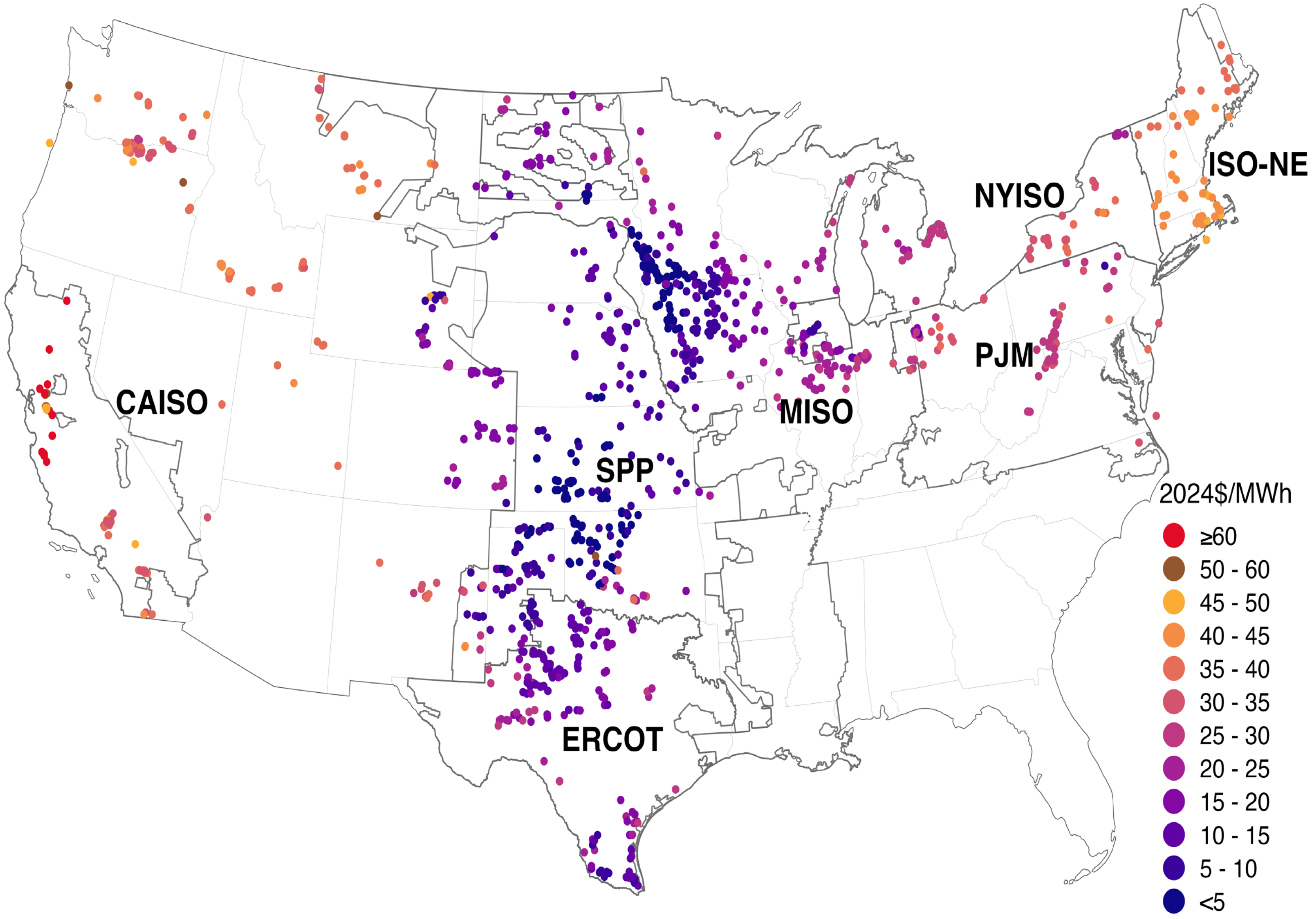
Wholesale market value considers hourly local wholesale energy price and hourly wind output, along with capacity value where available

Wholesale market value of wind in 2024, by region: lowest in SPP at $10/MWh, highest in CAISO at $40/MWh



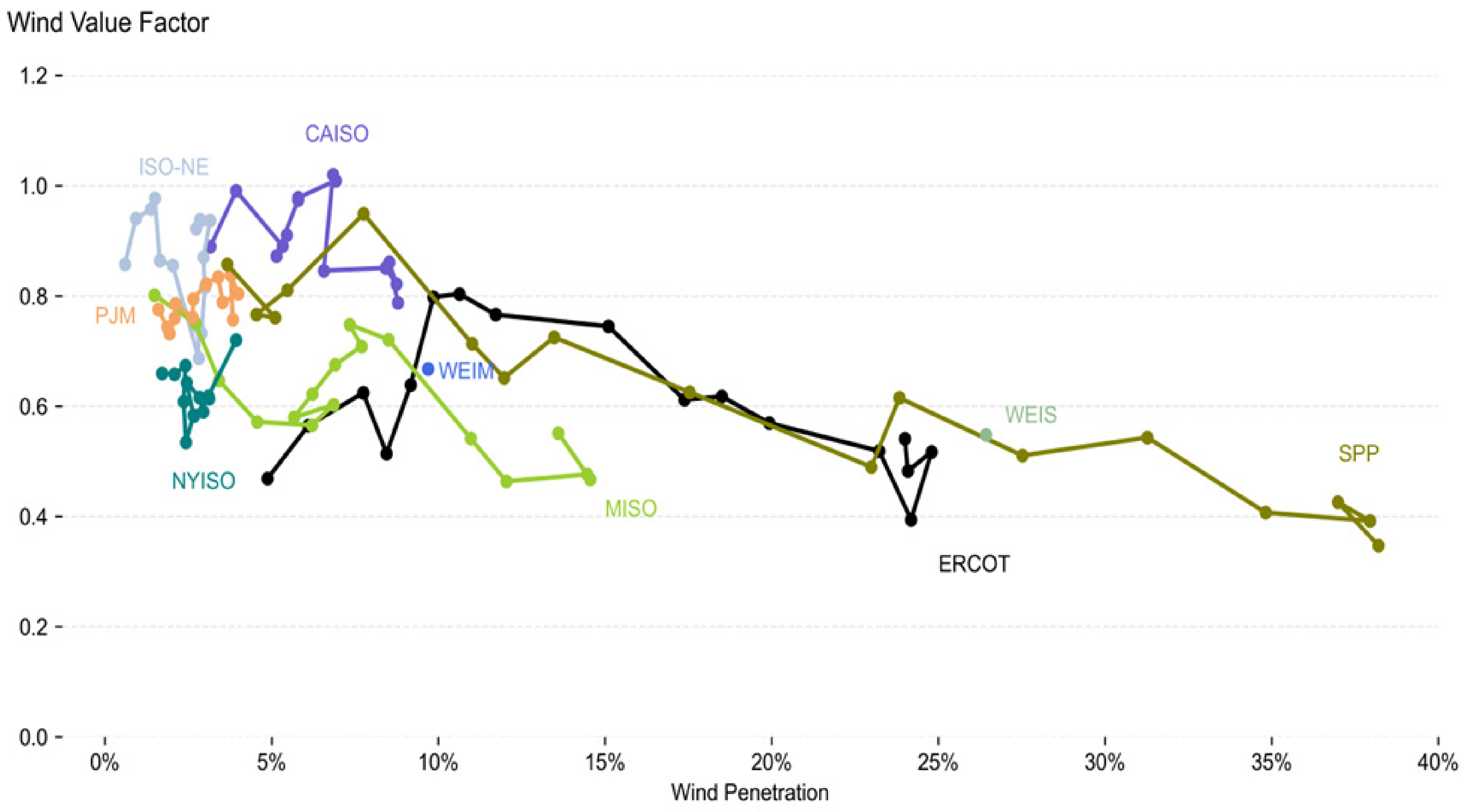
Sources: Berkeley Lab, ABB, ISOs

Wholesale market value of wind in 2024, by plant



Sources: Berkeley Lab, ABB, ISOs

Average “value factor” of wind (value relative to flat block) of wind energy, by region and with penetration

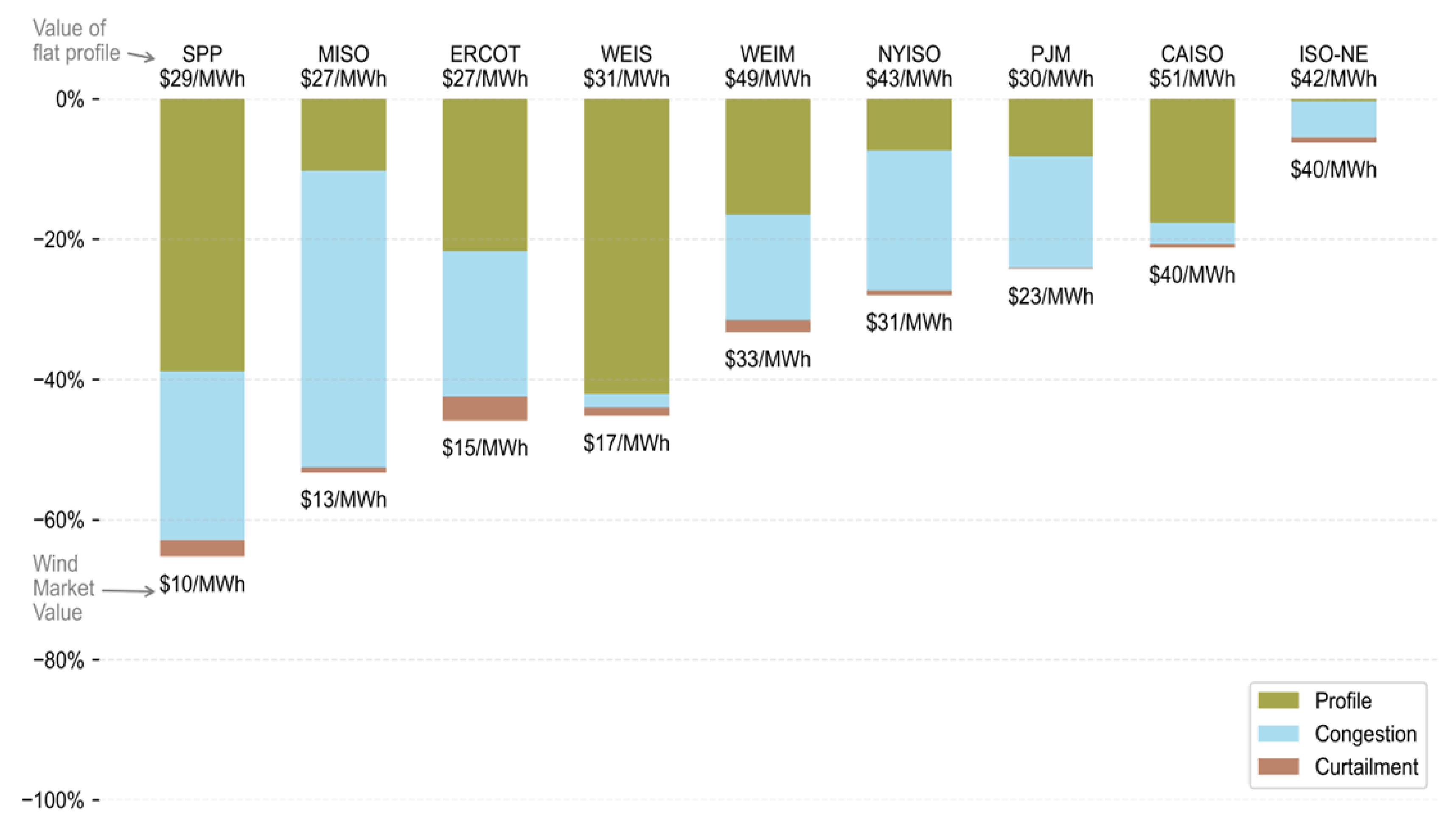


Sources: Berkeley Lab, ABB, ISOs

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 as impacted by output profile, transmission congestion, and curtailment

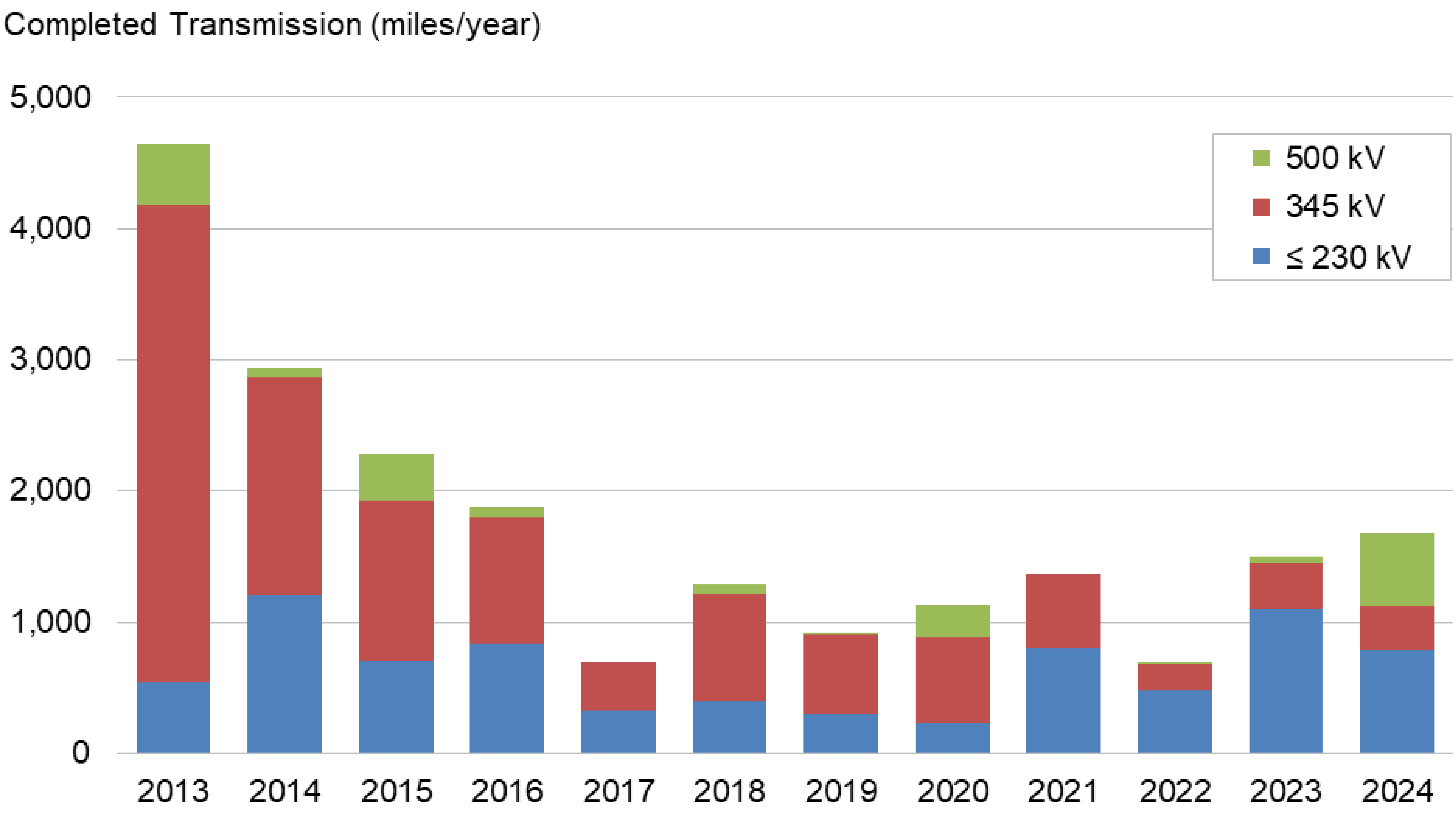
Average market value de-rate of wind in 2024 relative to a flat block varied by region



Sources: Berkeley Lab, ABB, ISOs

Note: generalized flat block is 24x7 average price across all pricing nodes in region

Miles of transmission projects completed, by year and voltage



Source: FERC

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The data file and visualizations can be found at:

- windreport.lbl.gov

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