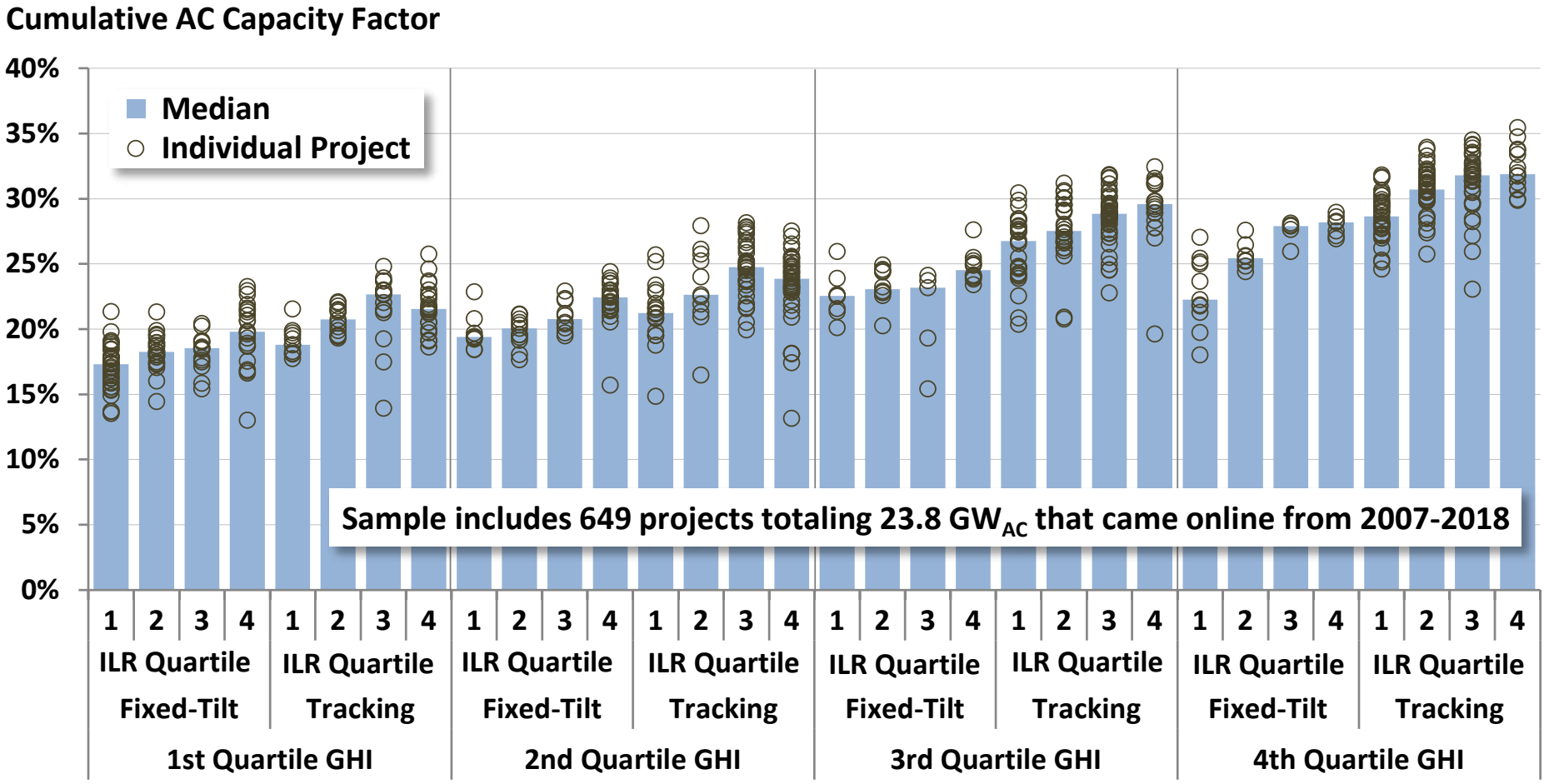
Performance (Capacity Factors)

Cumulative capacity factor by resource strength, fixed-tilt vs. tracking, and inverter loading ratio (ILR)

25% capacity factor sample-wide, but with large project-level range from 14%-35%

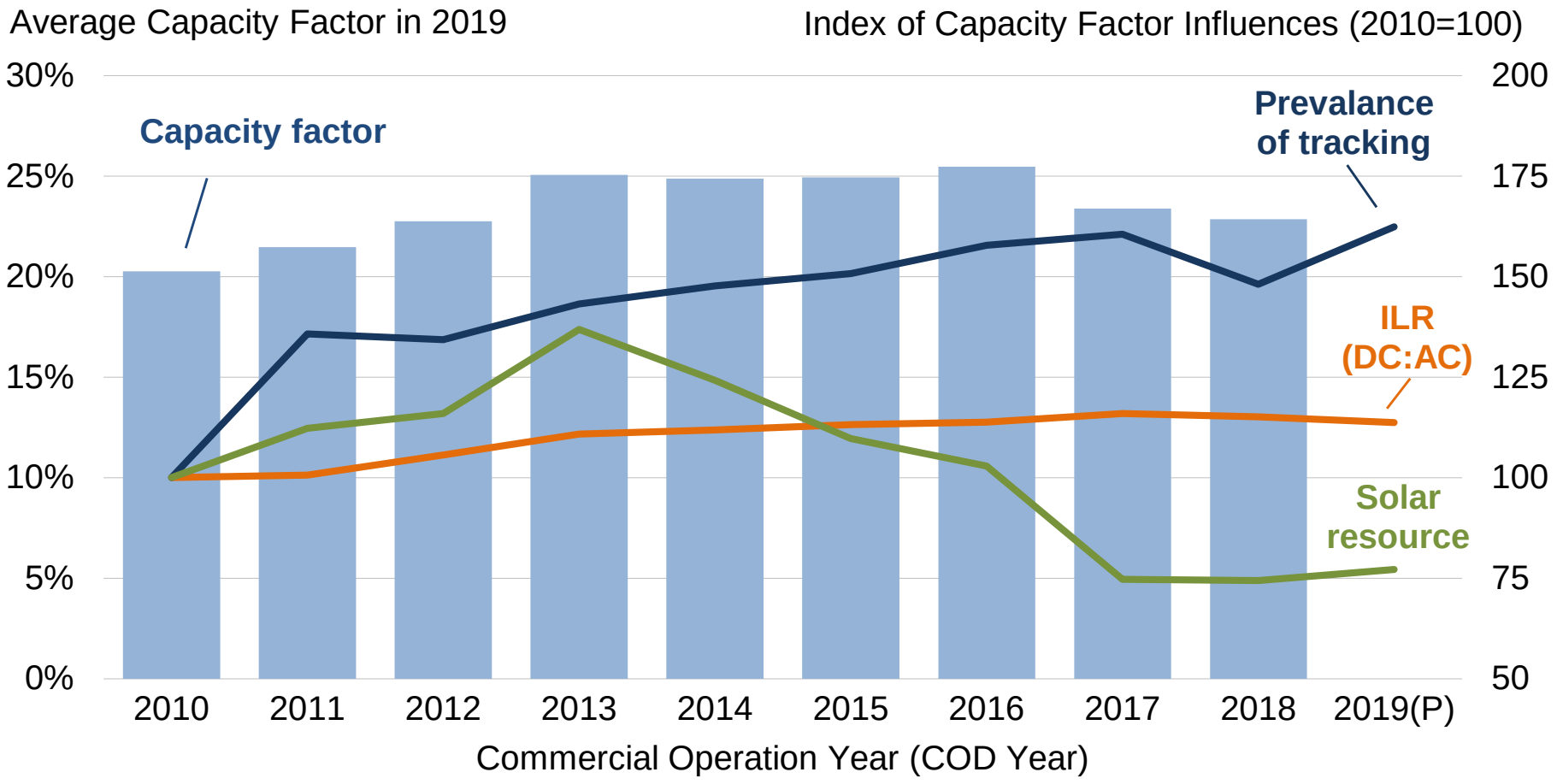


Source: EIA, FERC, Berkeley Lab

Interactive data visualization: https://emp.lbl.gov/pv-capacity-factors

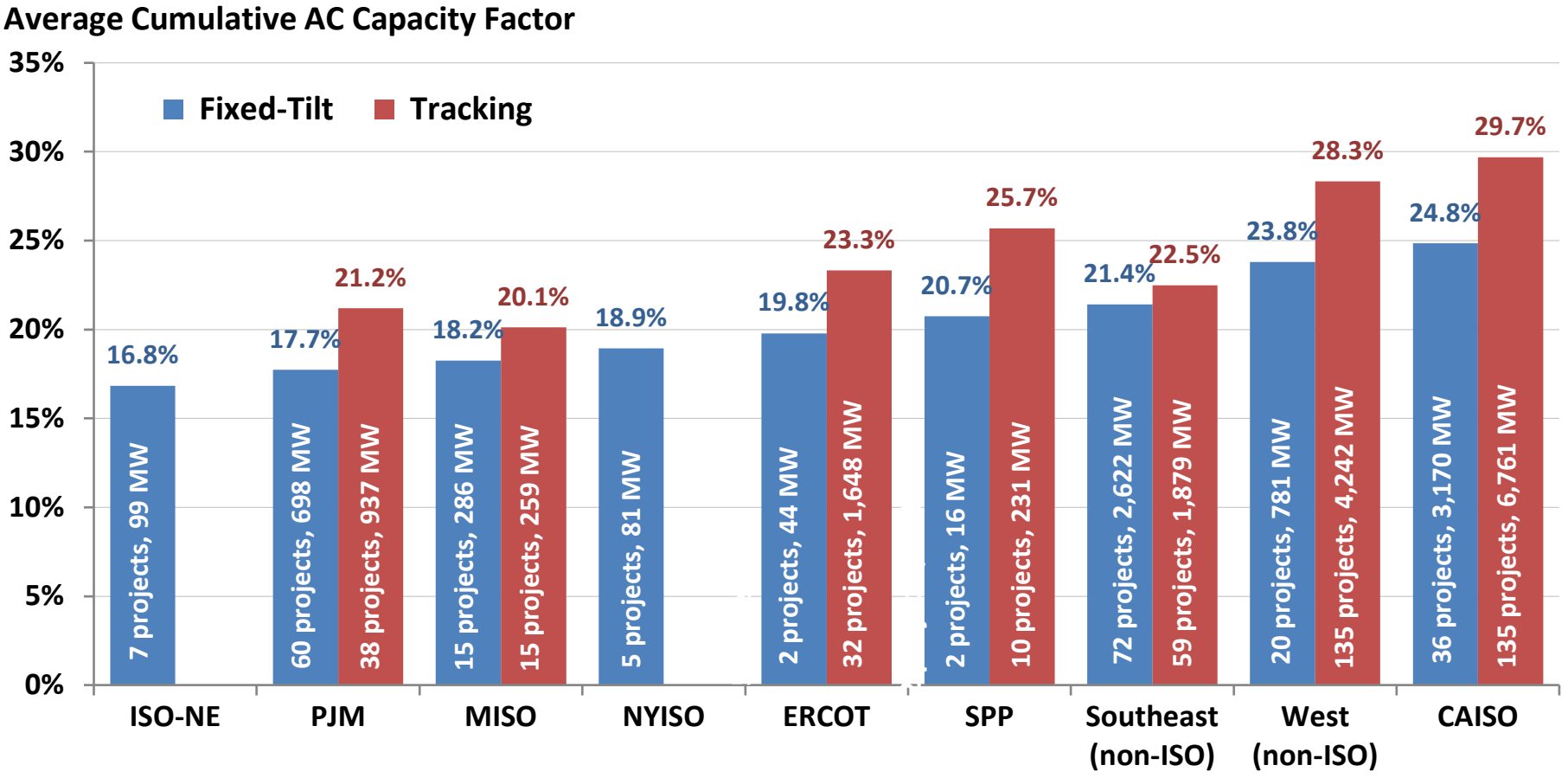
Utility-scale PV capacity factors and various drivers by commercial operation date

Flat-to-declining trend since 2013 reflects the expansion of the market into less-sunny regions of the United States (as depicted by the green "solar resource" line)



Source: EIA, FERC, Berkeley Lab

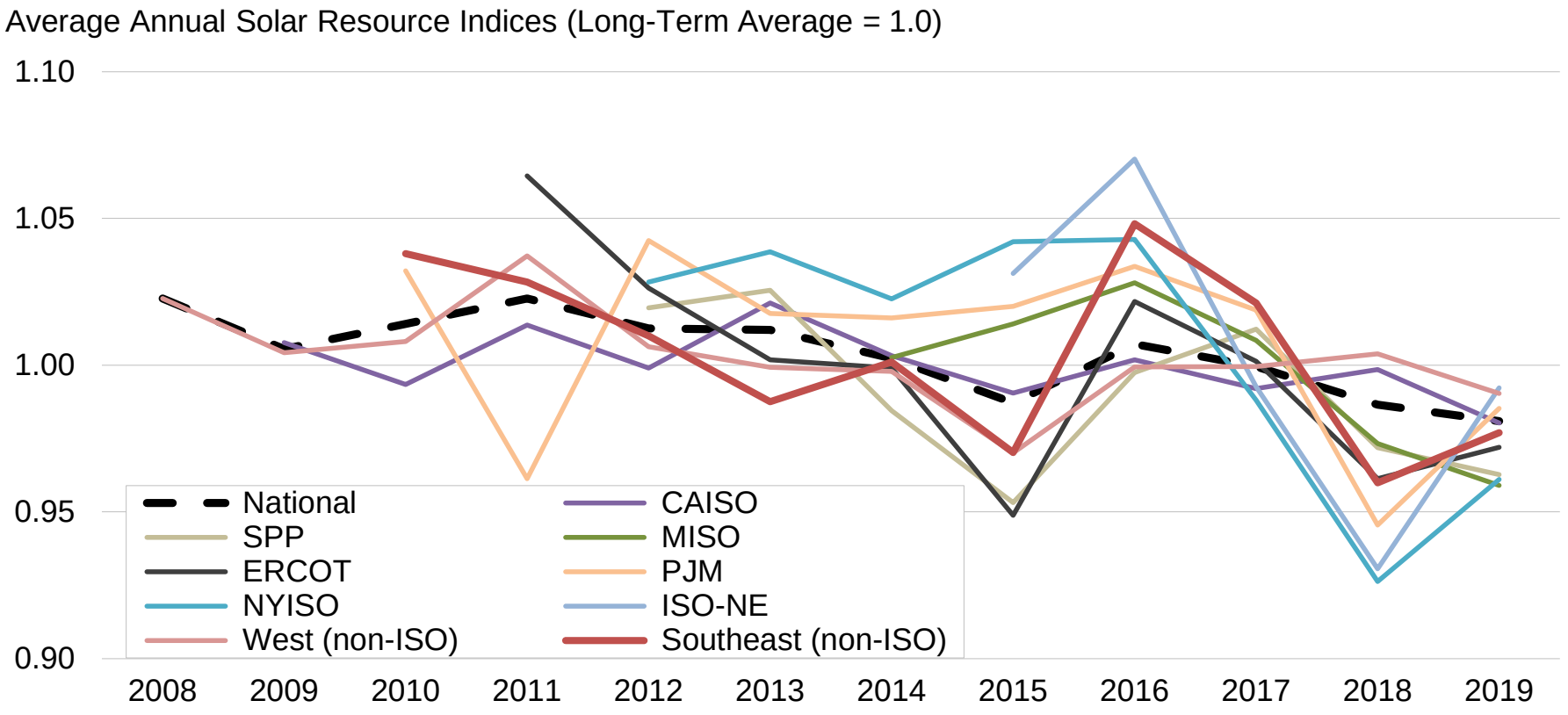
Cumulative capacity factor by region and fixed-tilt vs. tracking



Source: EIA, FERC, Berkeley Lab

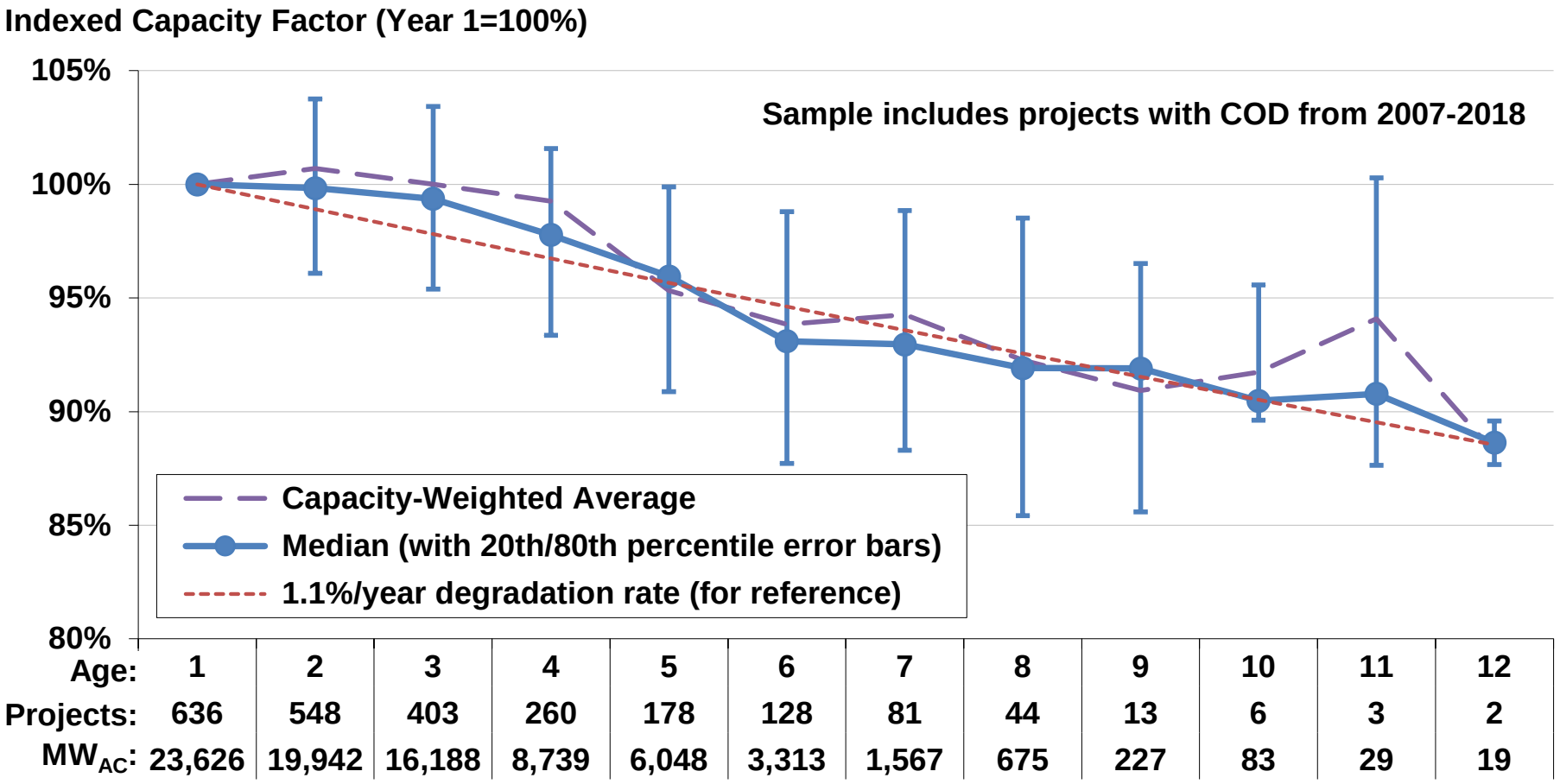
The high-insolation regions (West and CAISO) have the greatest number of projects using tracking, as well as the highest capacity factors.

Inter-annual variability in the solar resource among the sample, by region and nationally



Source: NSRDB, Berkeley Lab

Changes in fleet-wide capacity factors as projects age



Age:	1	2	3	4	5	6	7	8	9	10	11	12
Projects:	636	548	403	260	178	128	81	44	13	6	3	2
MW_{AC}:	23,626	19,942	16,188	8,739	6,048	3,313	1,567	675	227	83	29	19

Source: EIA, FERC, Berkeley Lab

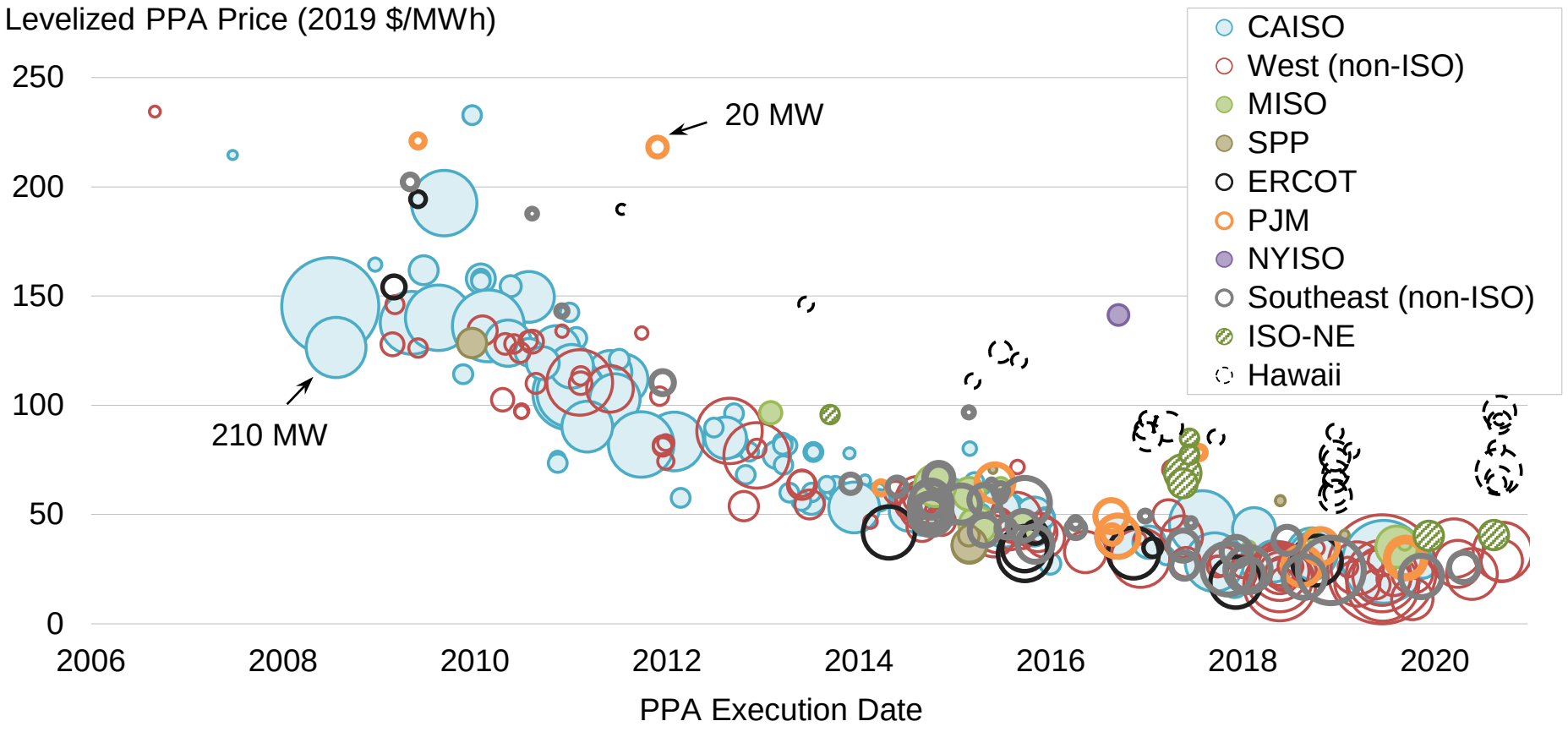
For more analysis on utility-scale PV project performance as plants age, see:
https://emp.lbl.gov/publications/system-level-performance-and

Power Purchase Agreement (PPA) Prices and LCOE

Solar power sales price and LCOE analysis: data sets and methodology

- Berkeley Lab collects data on long-term power purchase agreement (PPA) prices for utility-scale solar and wind energy
- Solar sample includes 338 contracts totaling 23.1 GW_{AC} from projects built from 2007 to the present, or planned for future installation
- Prices reflect the bundled price of electricity and RECs as sold by the project owner under a PPA
  - Dataset excludes merchant plants, projects that sell renewable energy certificates (RECs) separately, and most direct retail sales
  - Prices reflect receipt of state and federal incentives (e.g., the ITC), and various market influences; as a result, prices do not reflect solar generation costs
- We also present LevelTen Energy data on PPA offers; these are often for shorter contract durations, and levelization details are unclear
- Levelized cost of energy is calculated based on following assumptions
  - Project-level CapEx and capacity factor data presented elsewhere in this deck
  - Levelized OpEx declines from \$35/kW_{DC}-yr in 2007 to \$17/kW_{DC}-yr in 2019 (2019\$); project life increases from 21.5 years in 2007 to 32.4 years in 2019 (from previous LBNL research)
  - Weighted average cost of capital (WACC) based on 10% equity return over time; debt interest rate varies with the market over time; constant 60%/40% debt/equity ratio
  - Combined income tax of 40% pre-2018 and 27% post-2017; 5-yr MACRS; 2% inflation

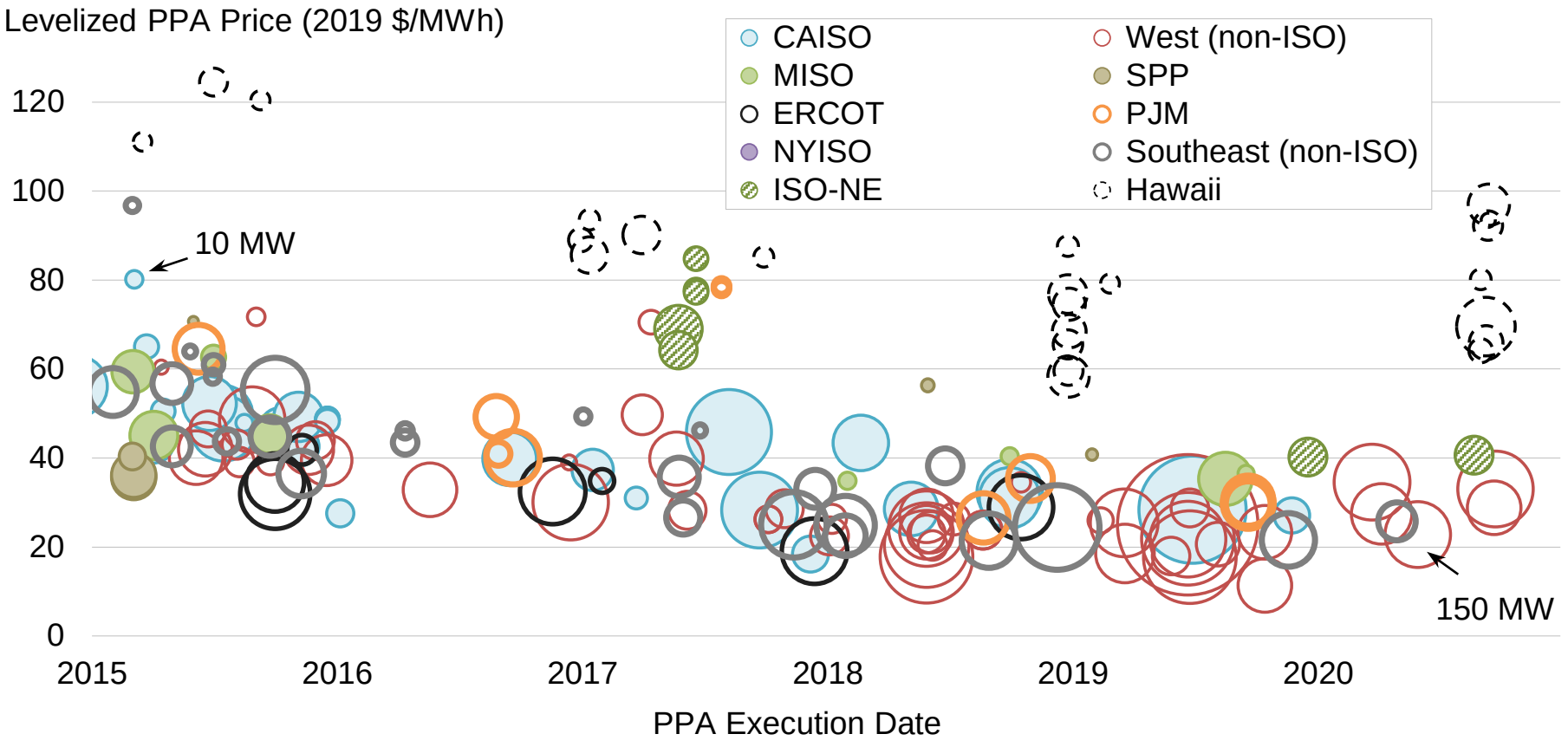
Levelized utility-scale PV PPA prices by PPA execution date and region (full sample)



Source: Berkeley Lab, FERC

Interactive data visualizations: https://emp.lbl.gov/pv-ppa-prices and https://emp.lbl.gov/capex-lcoe-and-ppa-prices-region

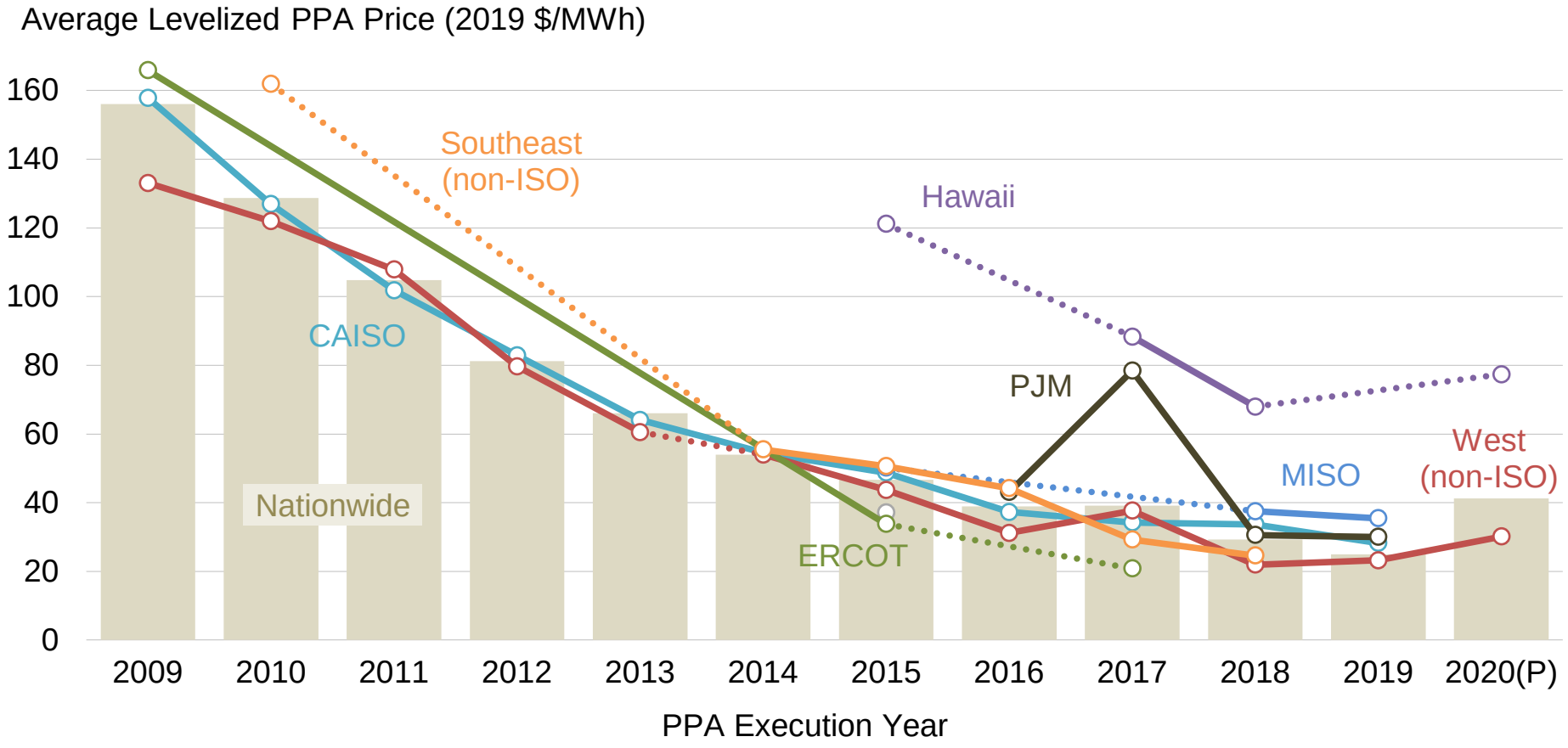
Levelized utility-scale PV PPA prices by PPA execution date and region (recent sub-sample of the data shown on prior slide)



Source: Berkeley Lab, FERC

Interactive data visualizations: https://emp.lbl.gov/pv-ppa-prices and https://emp.lbl.gov/capex-lcoe-and-ppa-prices-region

Generation-weighted average levelized PPA prices by PPA execution date: national and regional averages

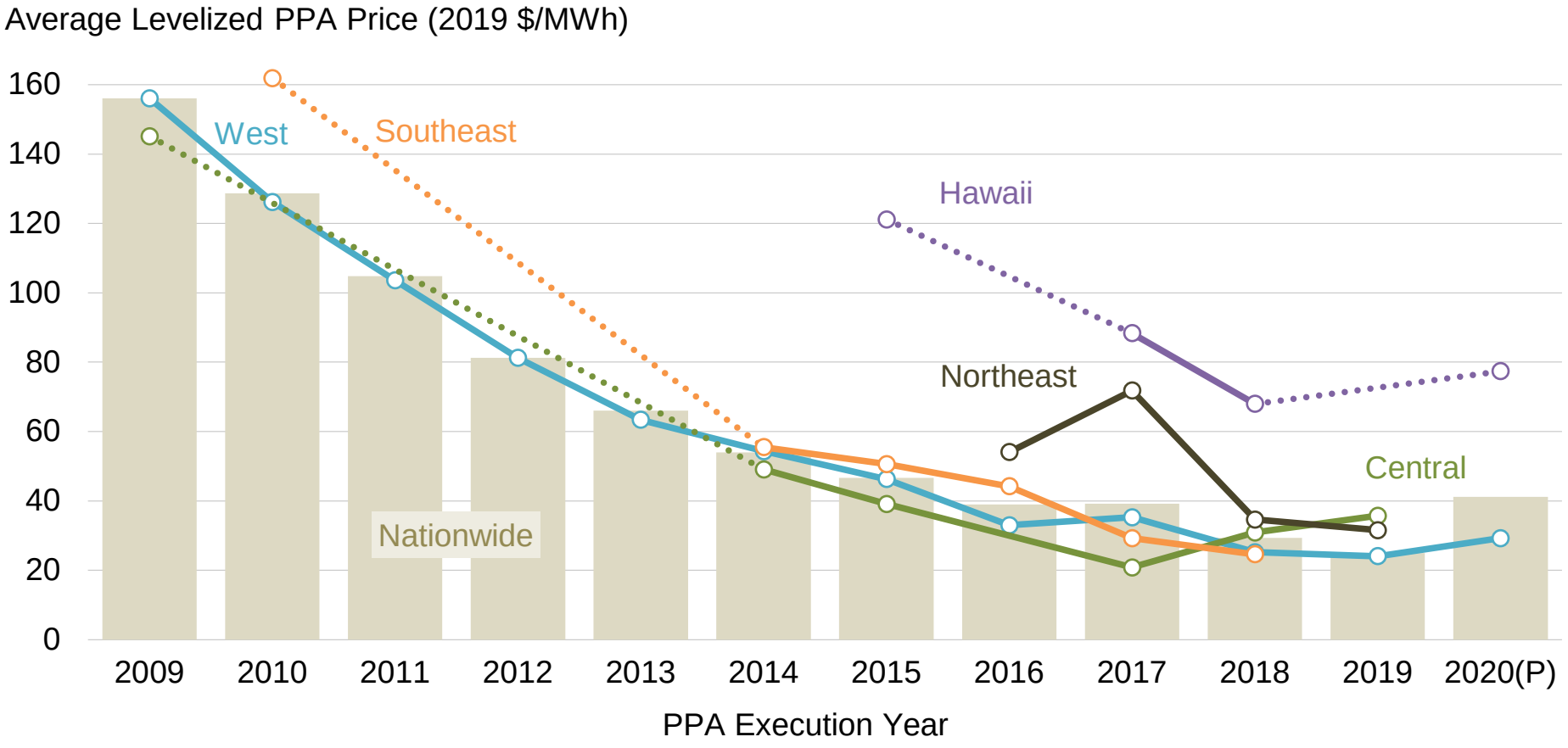


Source: Berkeley Lab, FERC

Note: Region-years with <2 projects are excluded from the graph. The dashed portions of lines span intermediate years that have no data (e.g., 2016 in Hawaii, or 2011-2013 in the Southeast). 2020 data are preliminary (P).

Interactive data visualizations: https://emp.lbl.gov/pv-ppa-prices and https://emp.lbl.gov/capex-lcoe-and-ppa-prices-region

Generation-weighted average levelized PPA prices by PPA execution date: national and consolidated regional averages

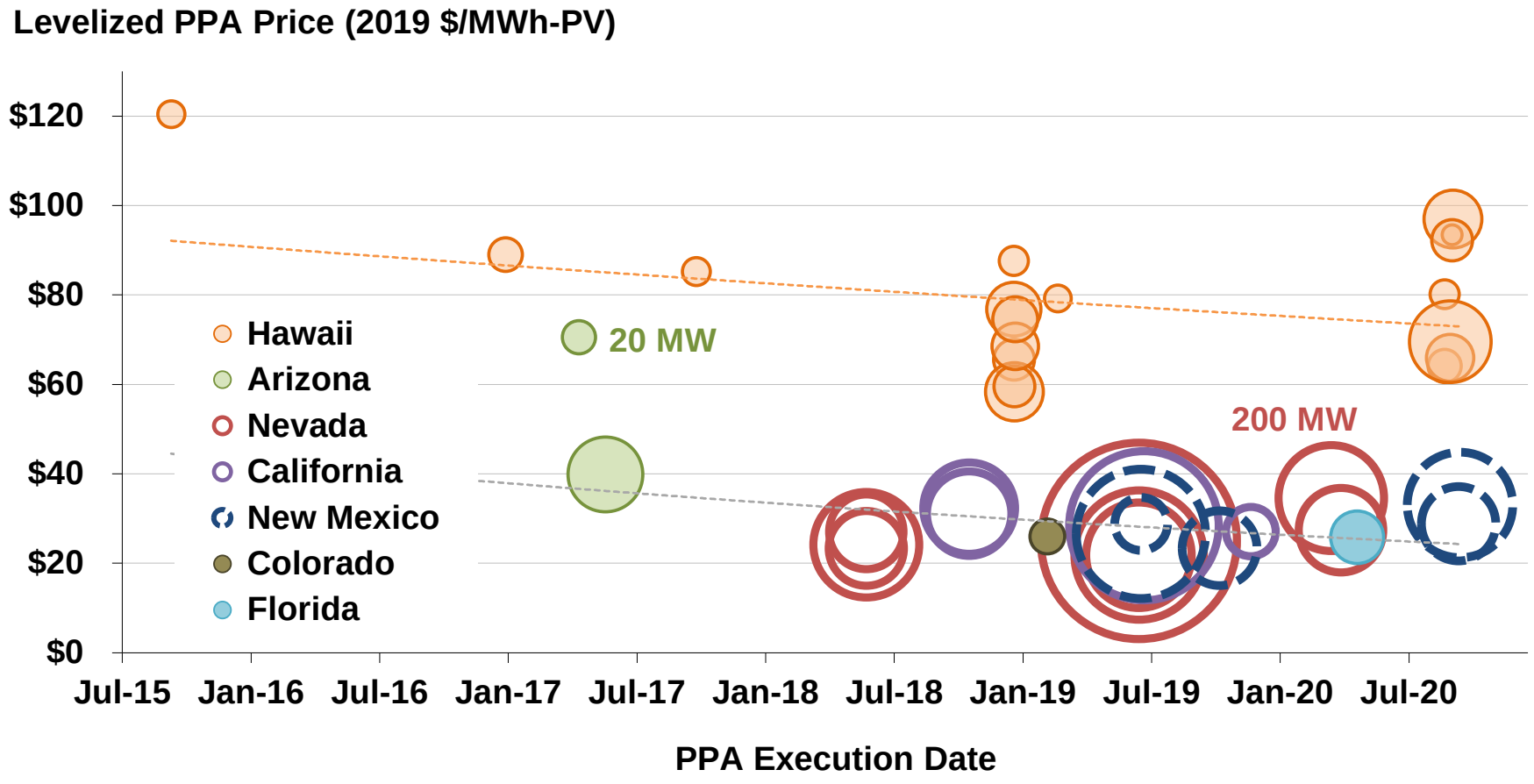


Source: Berkeley Lab, FERC

Note: West = CAISO and West (non-ISO); Central = MISO, SPP and ERCOT; Northeast = PJM, NYISO and ISO-NE; Southeast = Southeast (non-ISO). Region-years with <2 projects are excluded from the graph. The dashed portions of lines span intermediate years that have no data (e.g., 2016 in Hawaii, or 2011-2013 in the Southeast). 2020 data are preliminary (P).

Interactive data visualizations: https://emp.lbl.gov/pv-ppa-prices and https://emp.lbl.gov/capex-lcoe-and-ppa-prices-region

Levelized PPA price of PV+battery hybrid projects in the sample

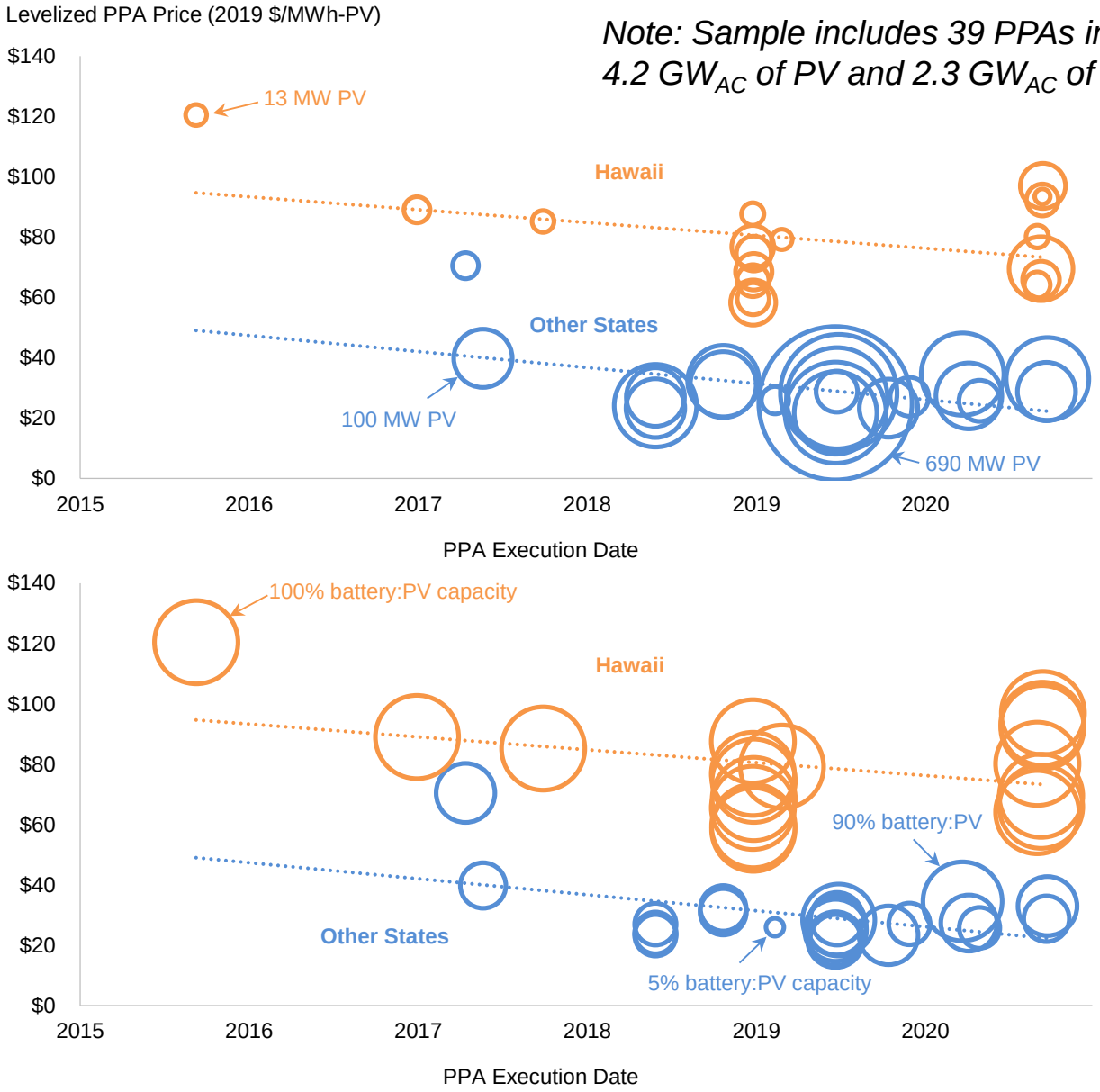


Source: Berkeley Lab, FERC

Note: Sample includes 39 PPAs in 7 states totaling 4.2 GW_{AC} of PV and 2.3 GW_{AC} of batteries

See public data file (at utilityscalesolar.lbl.gov) for details on >110 operating and planned PV+battery hybrid projects in 20 states

Levelized PPA price of PV+battery hybrid projects in the sample

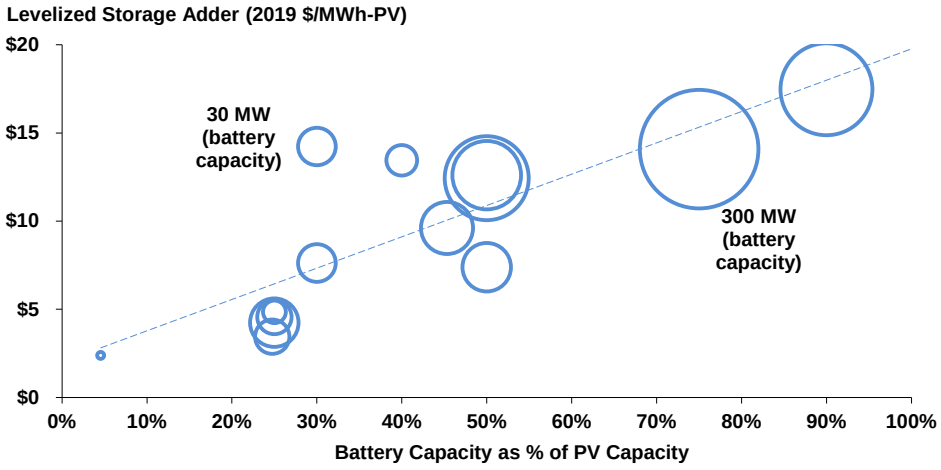


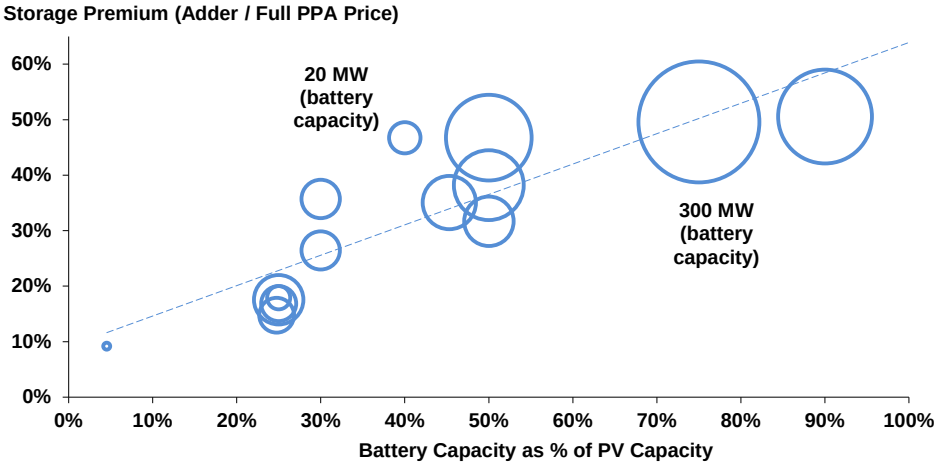
Note: Sample includes 39 PPAs in 7 states totaling 4.2 GW_{AC} of PV and 2.3 GW_{AC} of batteries

Hawaii generally has smaller PV projects than the mainland (top graph), but with larger relative battery sizing (100% battery:PV capacity, bottom graph)

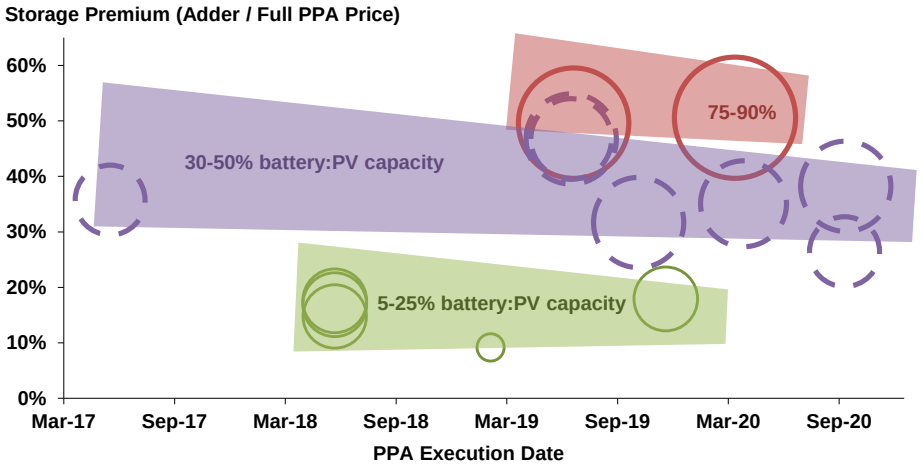
See public data file (at utilityscalesolar.lbl.gov) for details on >110 operating and planned PV+battery hybrid projects in 20 states

Levelized storage adder ($/MWh-PV) and premium (%) by battery:PV capacity ratio and PPA execution date





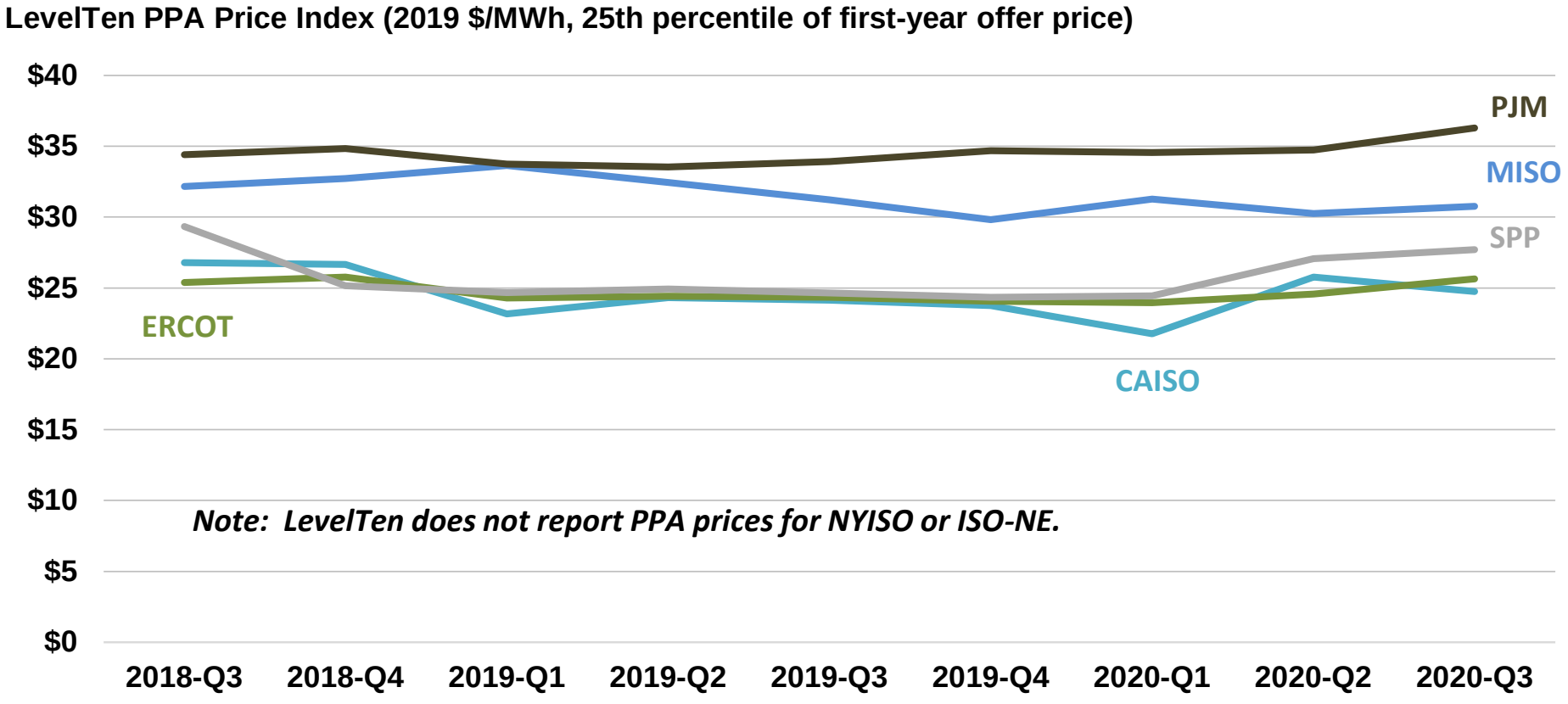
See public data file (at utilityscalesolar.lbl.gov) for details on >110 operating and planned PV+battery hybrid projects in 20 states



Source: Berkeley Lab, FERC

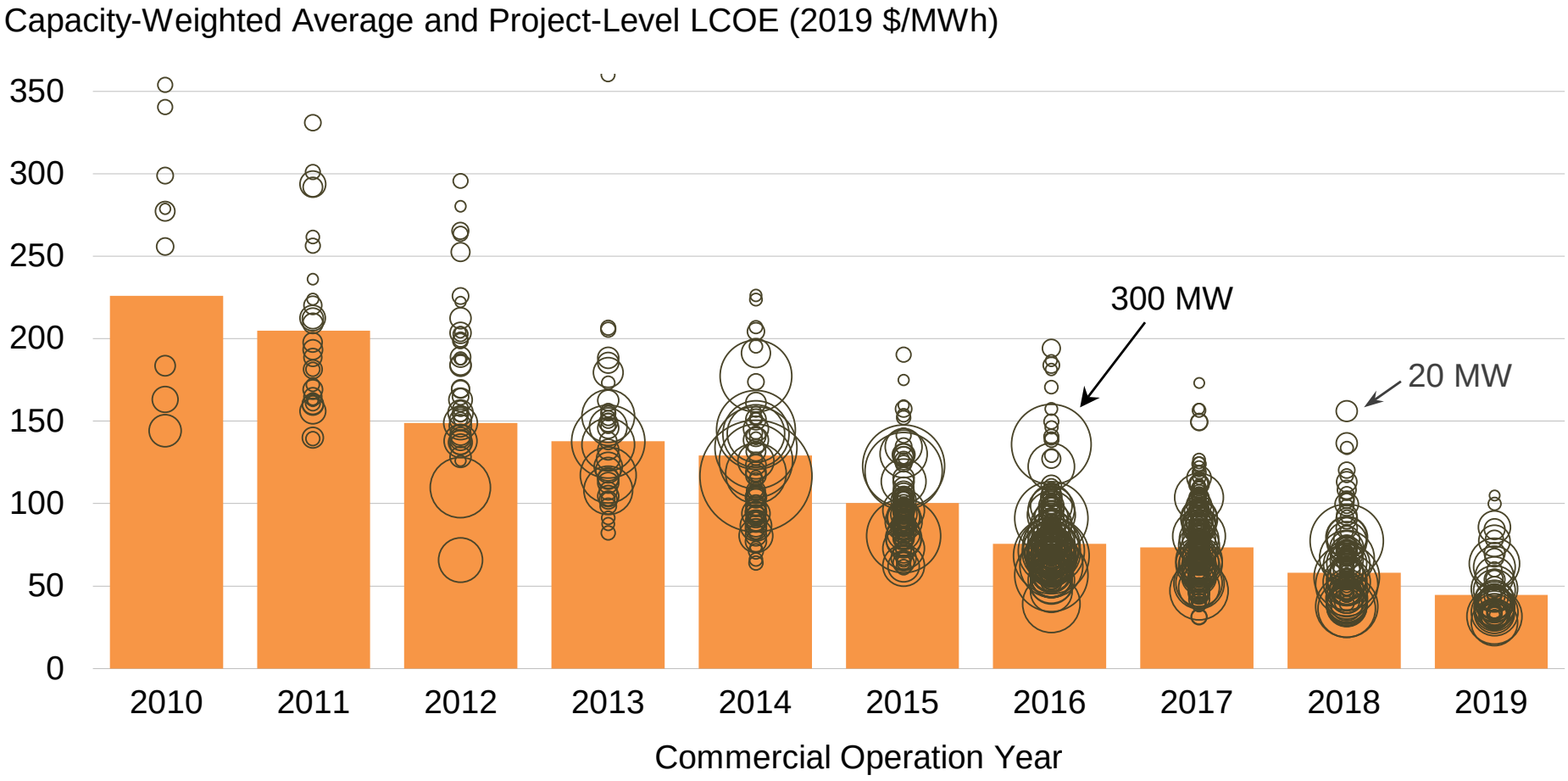
Note: Sample includes 14 PPAs in 5 states totaling 2.0 GW_{AC} of PV and 1.0 GW_{AC} of batteries

LevelTen Energy utility-scale PV PPA price indices



Source: LevelTen Energy

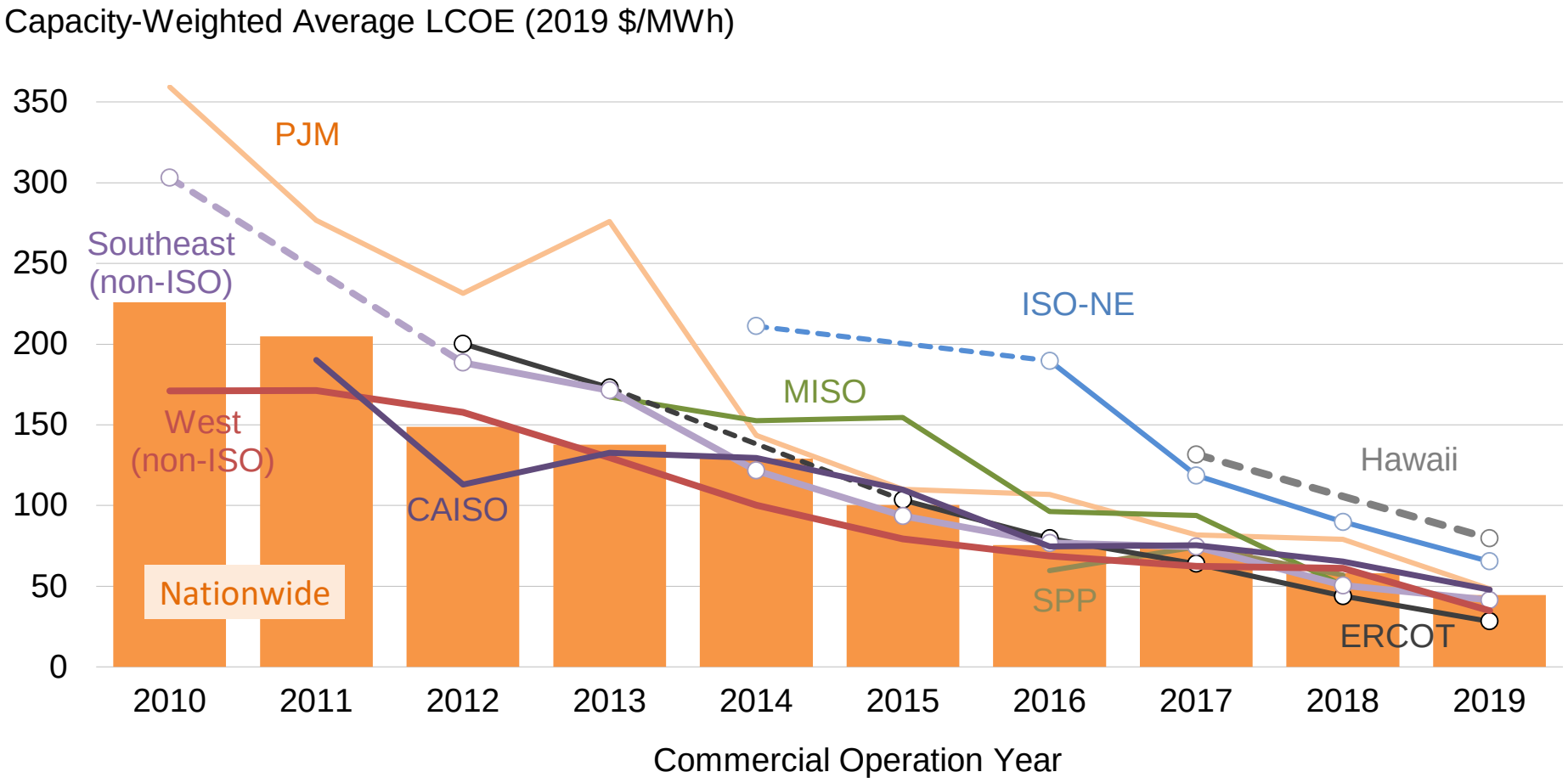
LCOE of utility-scale PV by commercial operation date



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 the ITC.

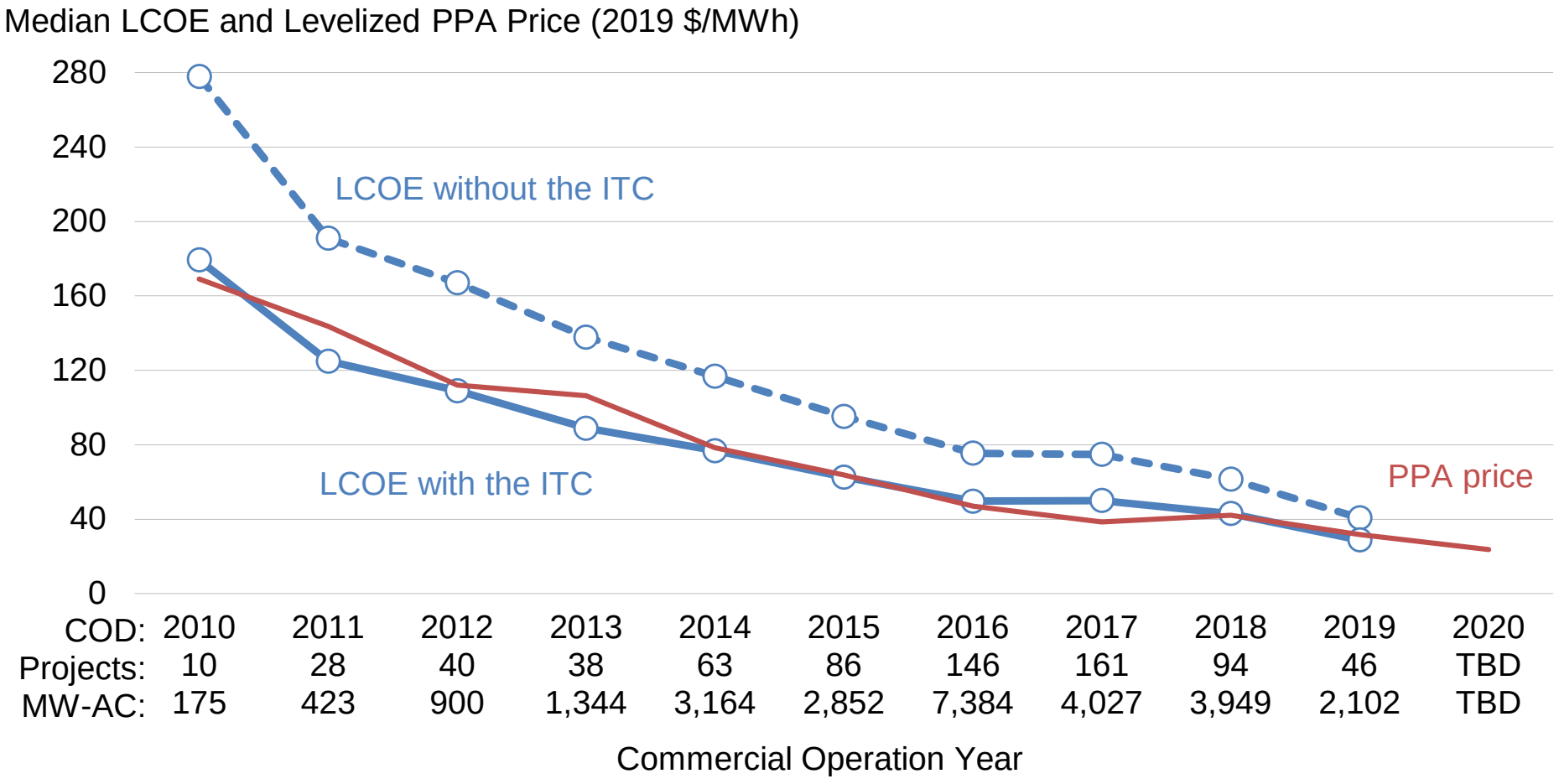
LCOE of utility-scale PV by commercial operation date



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 the ITC. The dashed portions of lines span intermediate years that have no data (e.g., 2018 in Hawaii, 2015 in ISO-NE).

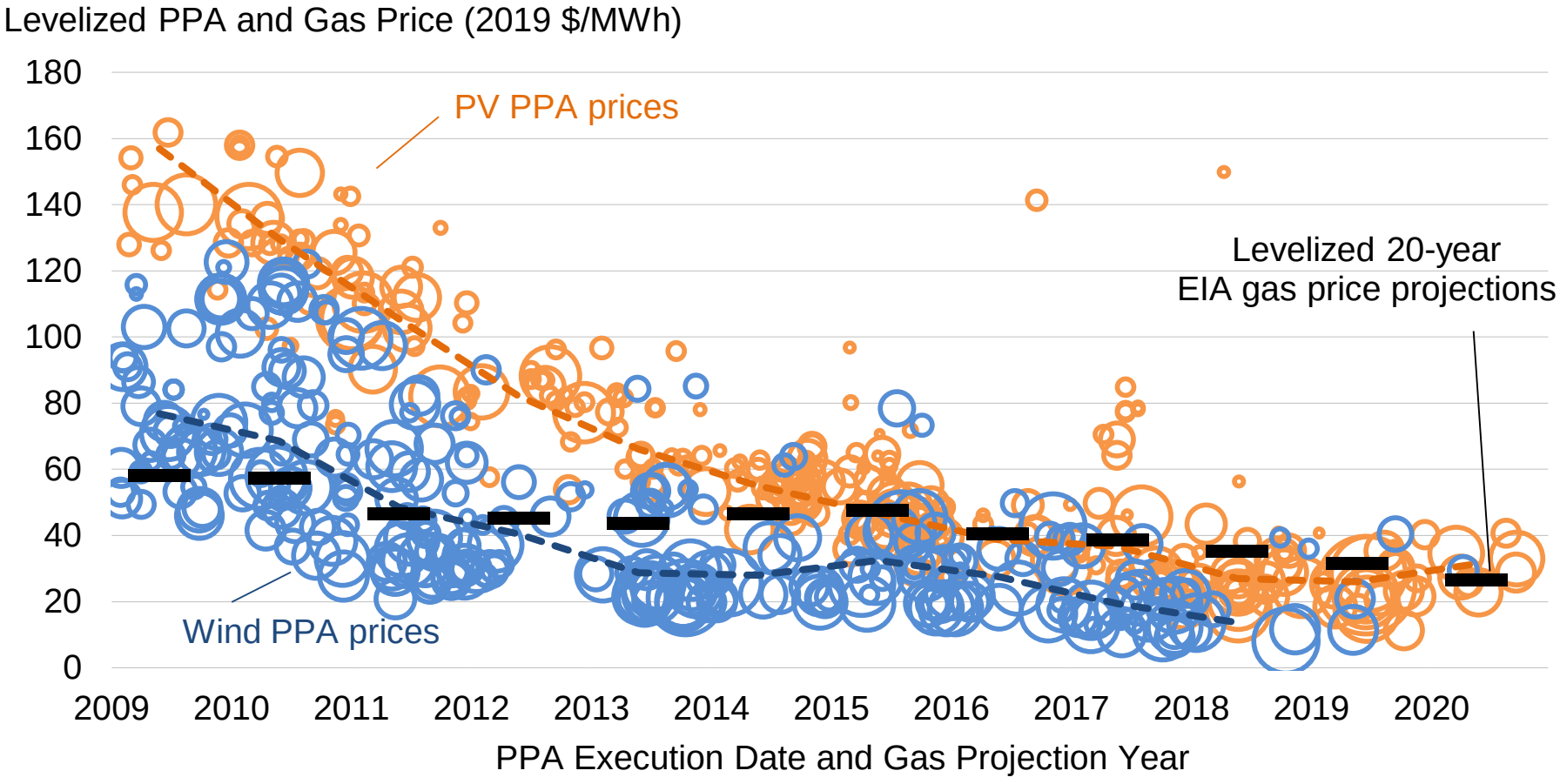
Comparison of LCOE and PPA prices for utility-scale PV



Source: Berkeley Lab

Close agreement between median PPA price and LCOE (with the ITC) suggests an efficient cost-based PPA market and pass-through of the ITC

Levelized PV and wind PPA prices and levelized gas prices



Source: Berkeley Lab, FERC, Energy Information Administration

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