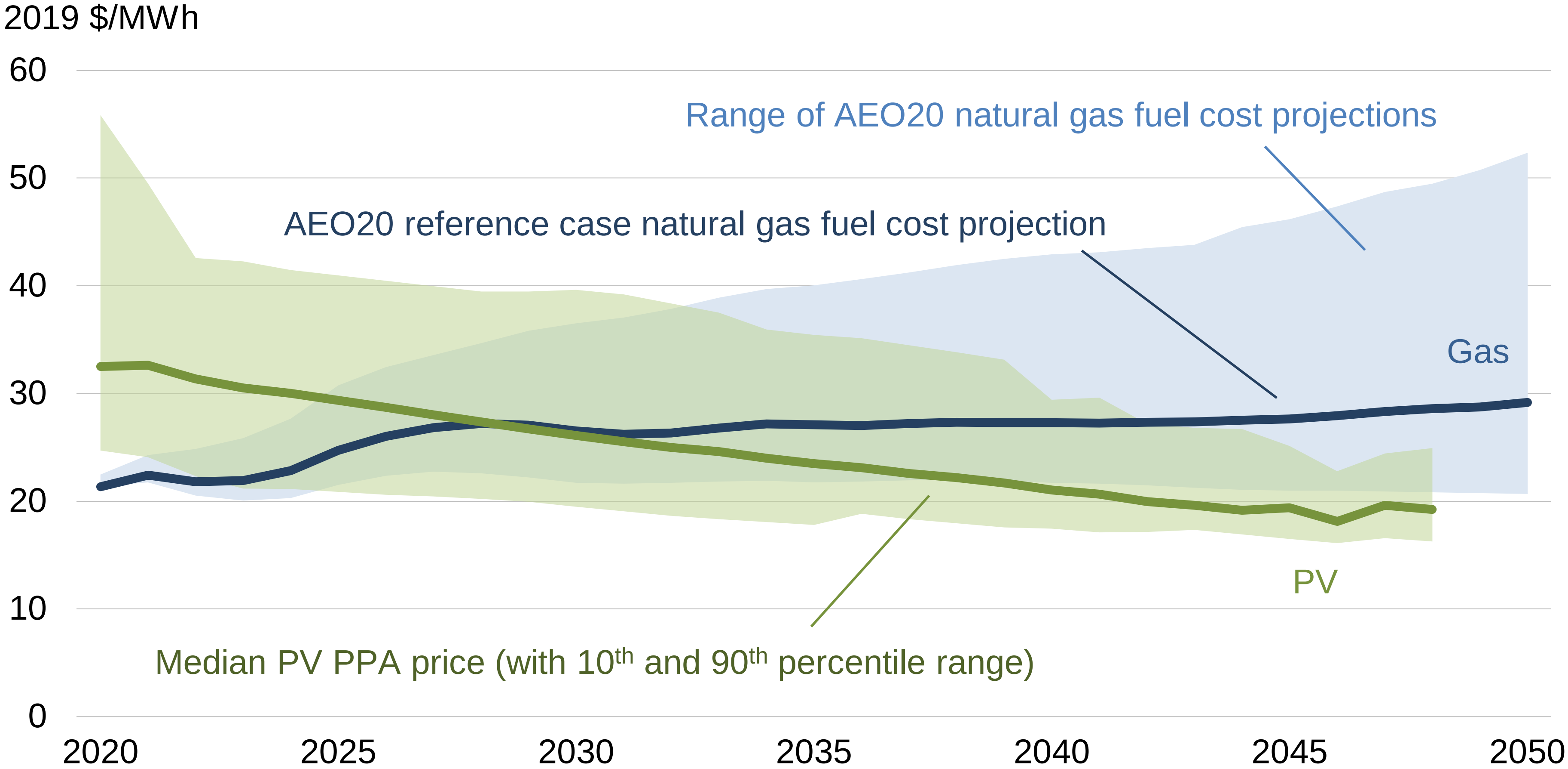
Utility-scale PV PPA prices and natural gas fuel costs by calendar year over time

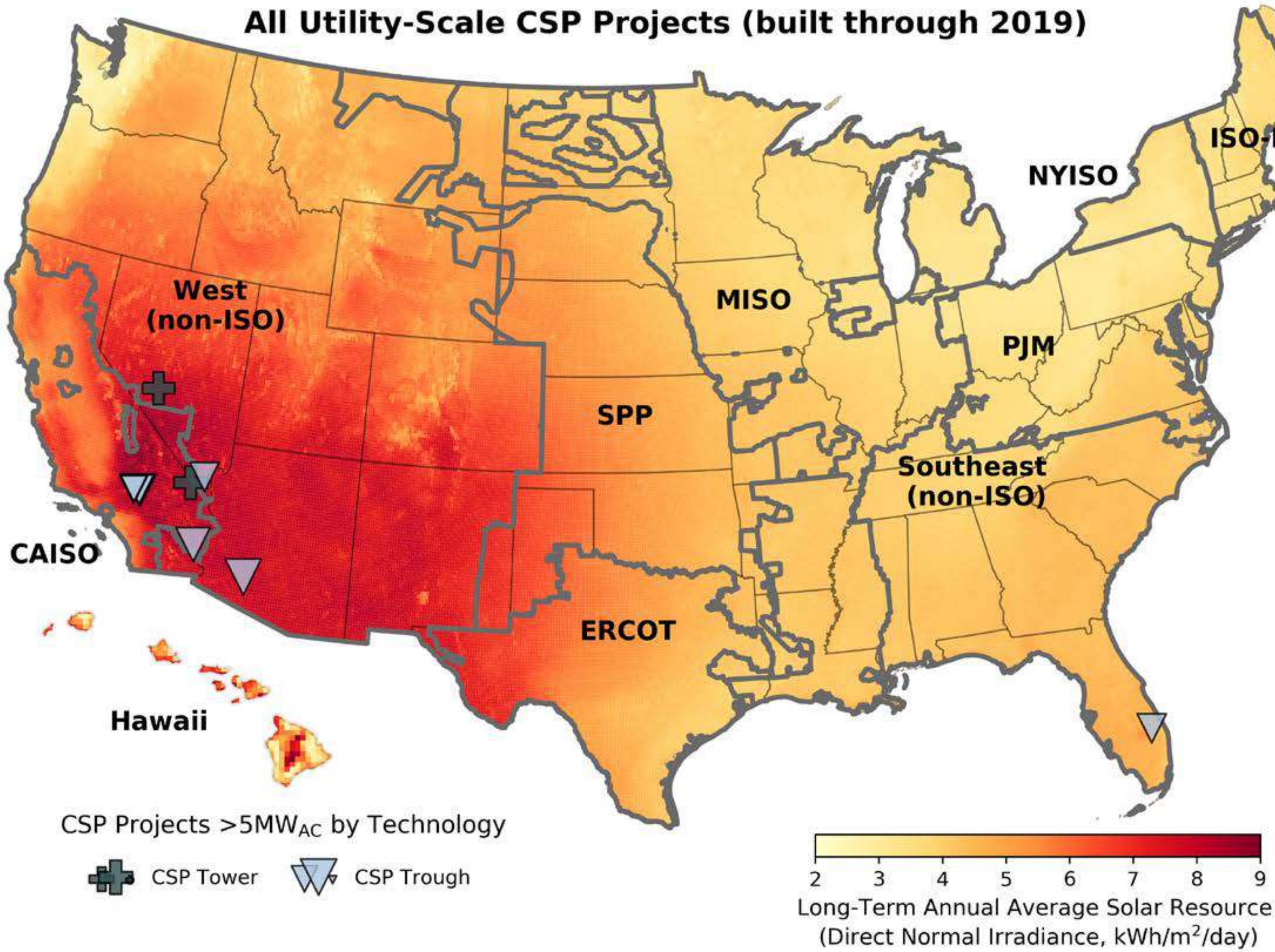


Source: Berkeley Lab, FERC, Energy Information Administration

Notes: PV PPA price median and range reflect 56 PPAs executed 2018-2020. AEO 2020 delivered gas price projections are converted from $/MMBtu to 2019 $/MWh using the heat rates implied by the modeling output. Price comparisons shown are far from perfect—see earlier 2019 report for details.

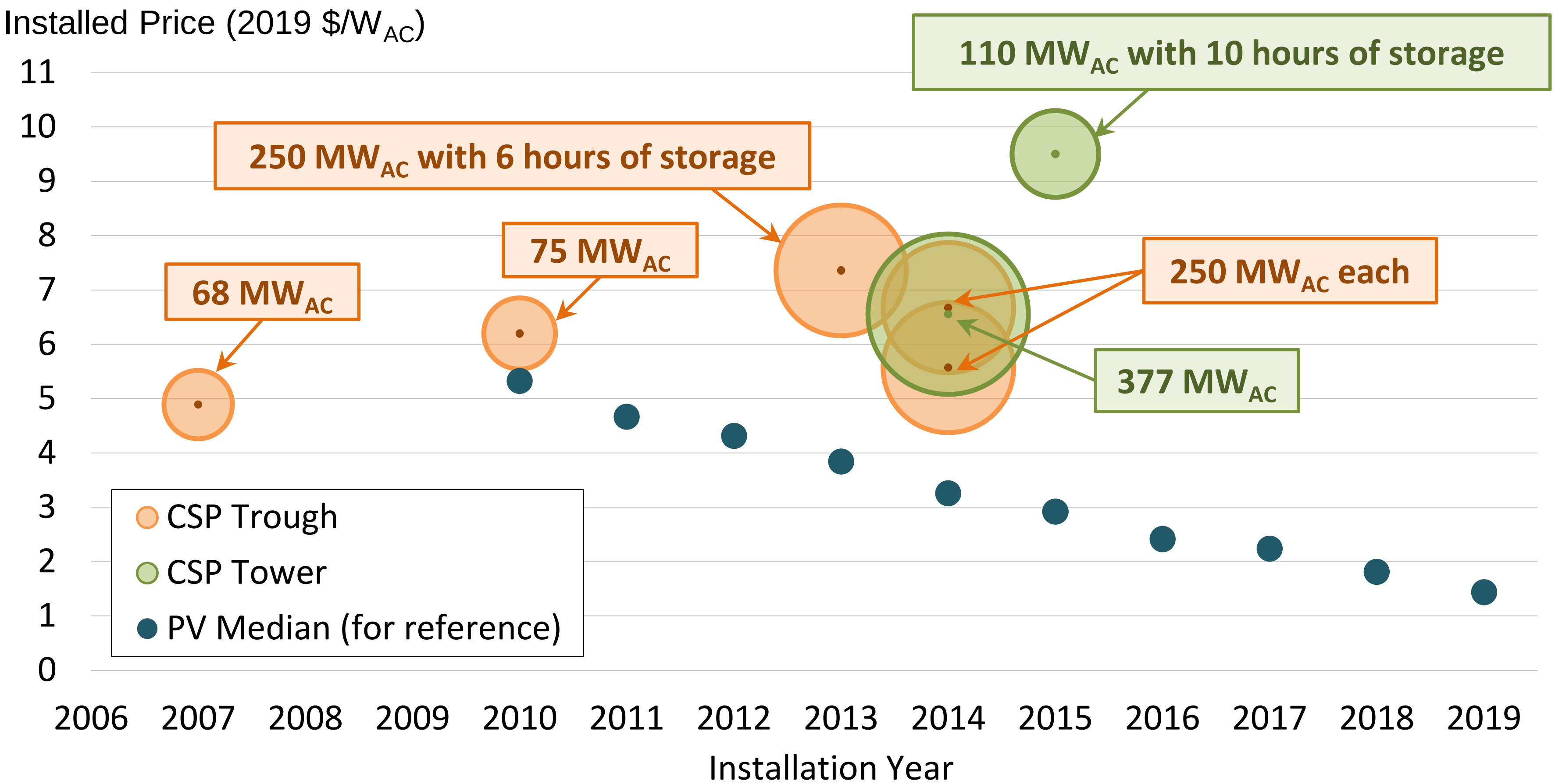
Concentrating Solar Thermal Power (CSP) Plants

Location of CSP projects versus Direct Normal Irradiance (DNI)



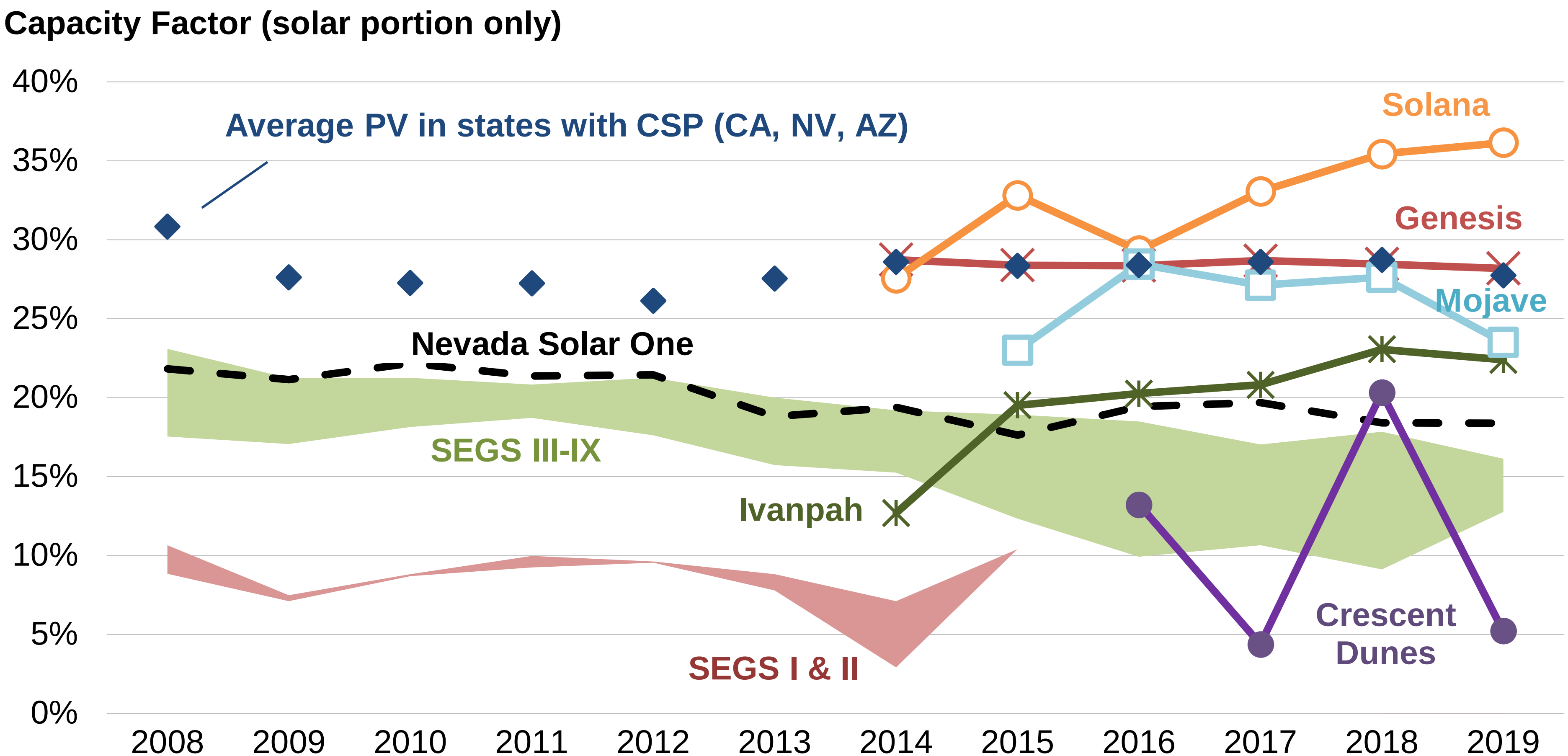
Sources: Berkeley Lab, EIA

Installed price of CSP projects over time



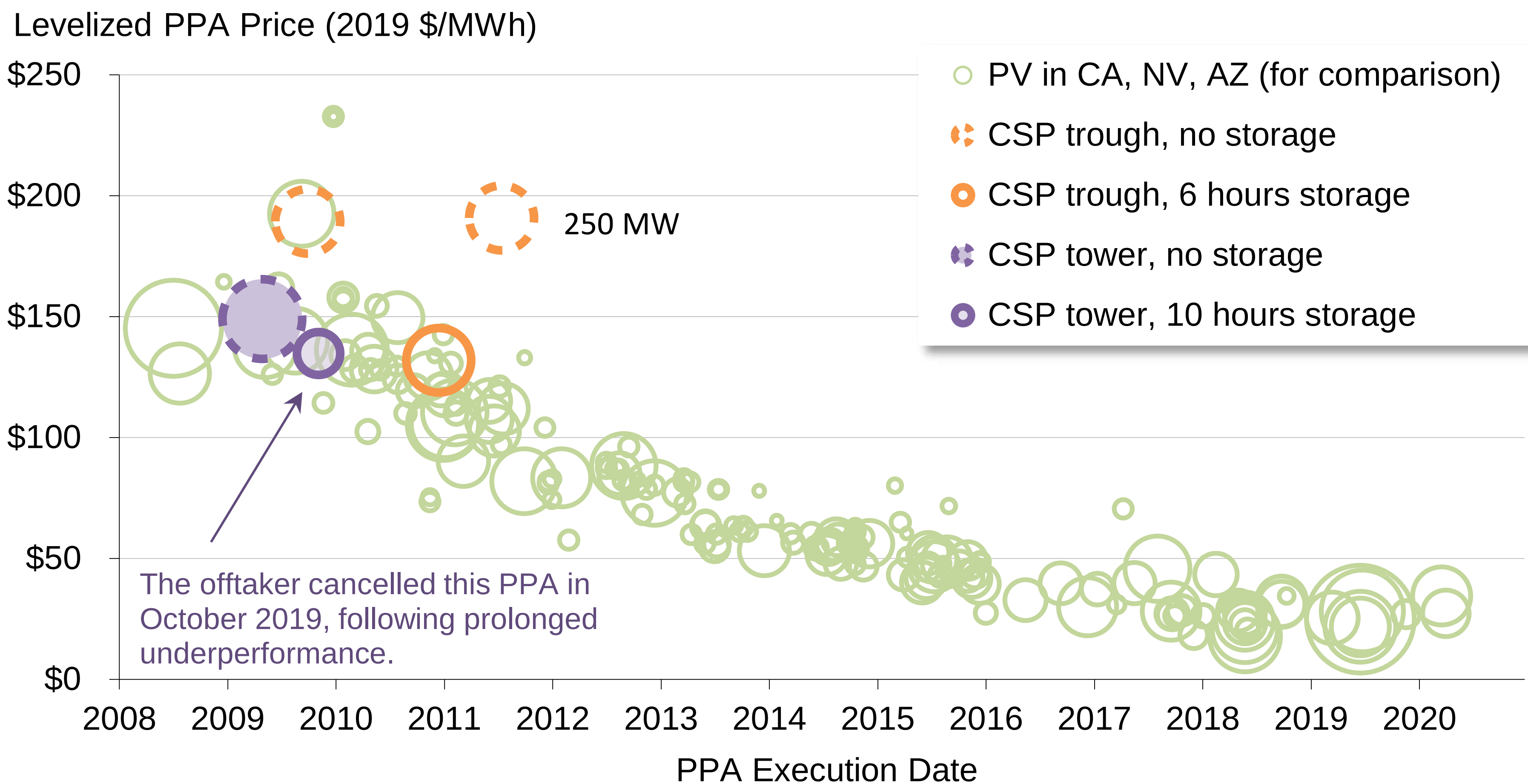
Sources: Berkeley Lab

Capacity factor of CSP projects (solar portion only) over time



Sources: Berkeley Lab, EIA, FERC

Levelized CSP and utility-scale PV PPA prices (in CA, NV, and AZ) by PPA execution date



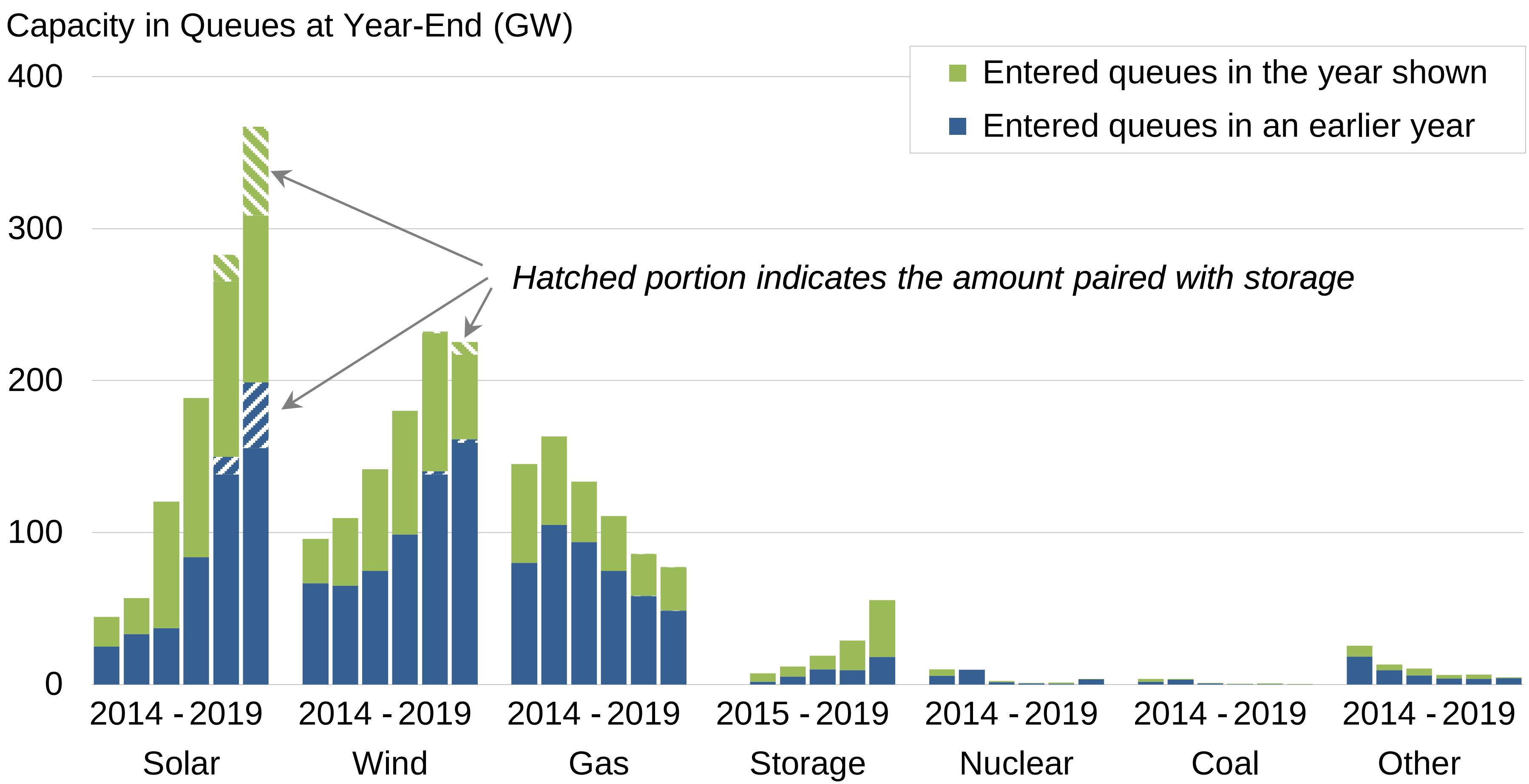
Sources: Berkeley Lab, FERC

Capacity in Interconnection Queues

Scope of generator interconnection queue data

- Data compiled from **interconnection queues** for 7 ISOs and 30 utilities, representing ~80% of all U.S. electricity load
  - Projects that connect to the bulk power system
  - Includes all projects in queues through the end of 2019
  - Filtered to include only “active” projects: removed those listed as “online,” “withdrawn,” or “suspended”
- Hybrid / co-located projects identified via either of these two methods:
  - “Generator Type” field includes **multiple types for a single queue entry** (row)
  - Two or more queue entries (of different generator types) that share the **same point of interconnection** and sponsor, queue date, ID number, and/or COD
    - Emphasis was placed on identification of PV+storage and wind+storage
    - Other hybrid configurations are likely undercounted
- **Note that being in an interconnection queue does not guarantee ultimate construction: majority of plants are not subsequently built**

Generation capacity in 37 selected interconnection queues from 2014 to 2019, by resource type

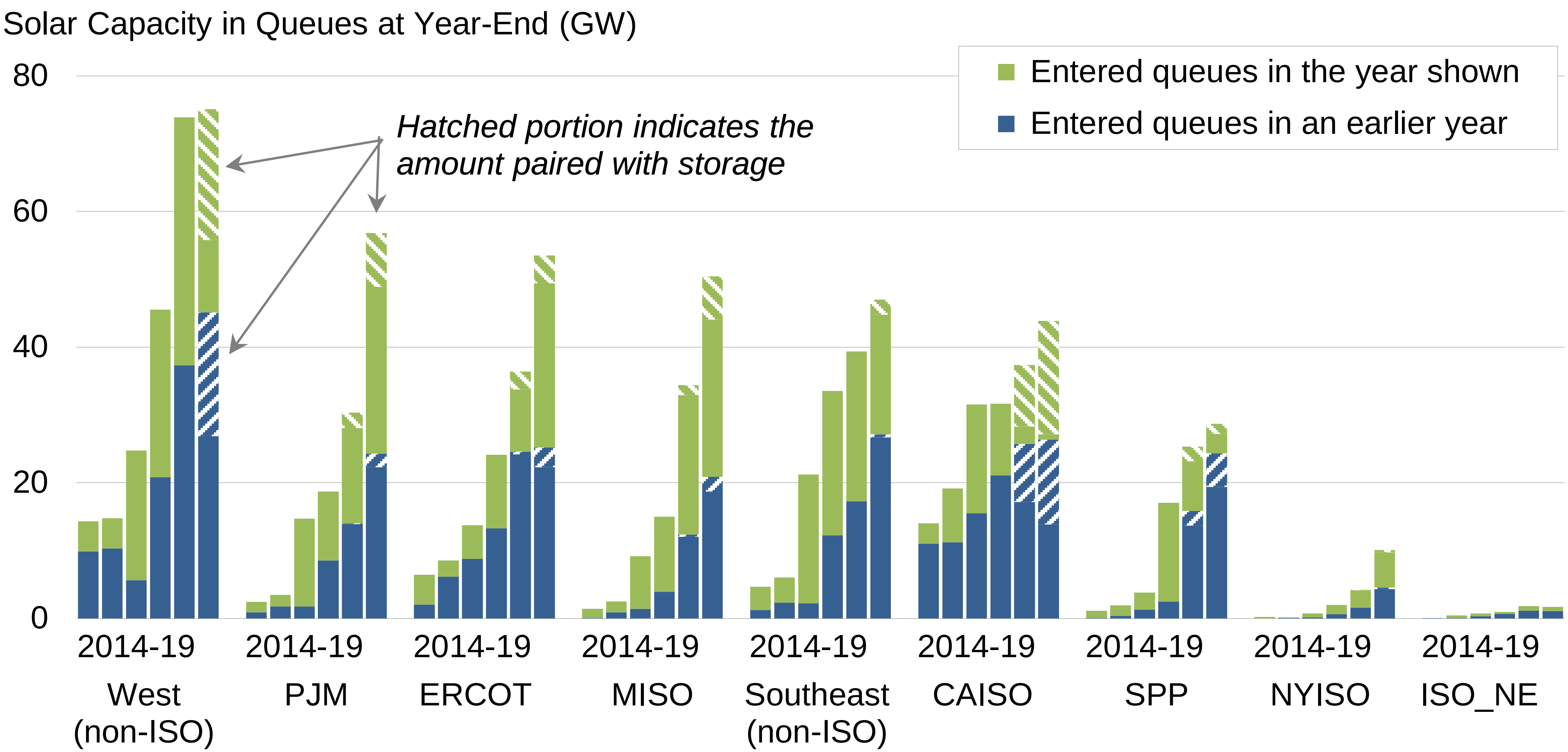


Source: Berkeley Lab review of interconnection queues

Note: Not all of this capacity will be built

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

Solar capacity in 37 selected interconnection queues from 2014 to 2019, by region

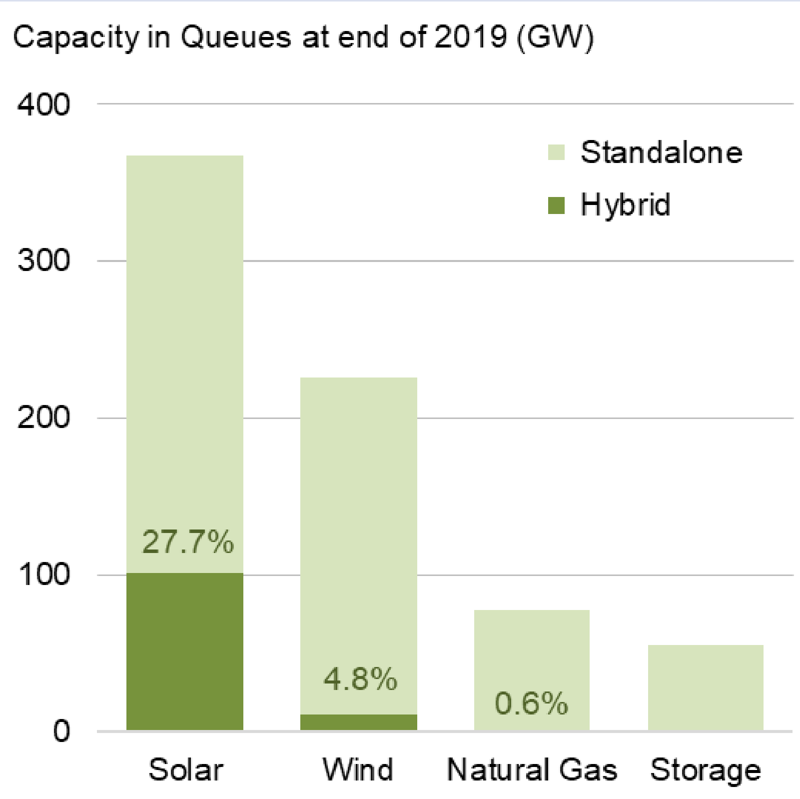


Source: Berkeley Lab review of interconnection queues

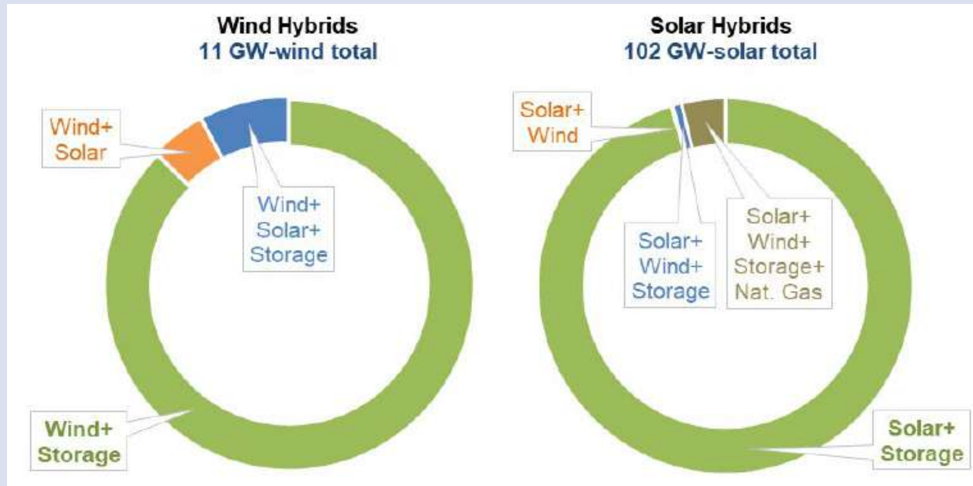
Note: Not all of this capacity will be built

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

Hybrid/co-located capacity within interconnection queues at end of 2019: 102 GW of solar proposed as hybrids, 11 GW of wind



Solar+Storage and Wind+Storage configurations are more common than other hybrid types[1]



Source: Berkeley Lab review of interconnection queues

[1] Emphasis was placed on identification of solar+storage and wind+storage: other hybrid configurations are likely undercounted.

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.

BERKELEY LAB

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

Location of hybrid/co-located capacity within interconnection queues at end of 2019

Region	Percentage of Proposed Generators Hybridizing in Each Region		
	Wind	Solar	Nat. Gas
CAISO	50%	67%	0%
ERCOT	3%	13%	0%
SPP	1%	22%	0%
MISO	2%	17%	0%
PJM	0%	17%	1%
NYISO	1%	5%	4%
ISO-NE	6%	0%	0%
West (non-ISO)	6%	50%	0%
Southeast (non-ISO)	0%	6%	0%
TOTAL	**4.8%**	**27.7%**	**0.6%**

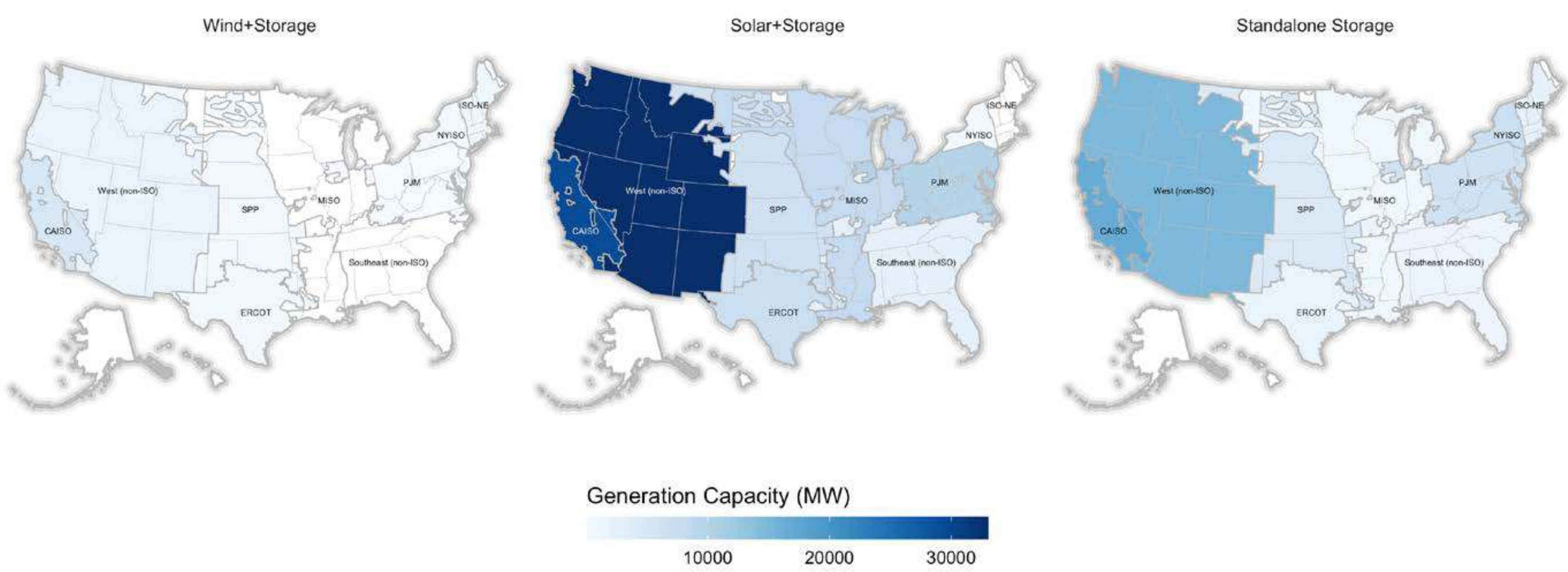
Source: Berkeley Lab review of interconnection queues

Solar hybridization is more evenly distributed across queues than wind hybridization

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) Emphasis was placed on identification of solar+storage and wind+storage in queues: other hybrid / co-located projects are likely undercounted.

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

Generator+storage hybrid/co-located projects and standalone storage in interconnection queues



For hybrid/co-located plants, the generation capacity is depicted. For standalone storage, the storage capacity is depicted.

In the subset of ISO queues shown here, solar hybrids plan to install more storage capacity relative to generation capacity than do wind hybrids

	Storage:Generation Capacity Ratio	
Region	**Wind+Storage**	**Solar+Storage**
CAISO	25%	78%
ERCOT	54%	38%
SPP	23%	38%
NYISO	7%	49%
Combined	**27%**	**66%**

Source: Berkeley Lab review of interconnection queues

Note: Not all of this capacity will be built

Data and Methods

Summary of Data and Methods (1)

Much of the analysis in this report is based on primary data, the sources of which are listed below (along with some general secondary sources) by data set. We collect data from a variety of unaffiliated and incongruous sources, often resulting in data of varying quality that must be synthesized and cleaned in multiple steps before becoming useful for analytic purposes. In some cases, we essentially create new and useful data by piecing together various snippets of information that are of less consequence on their own.

Technology Trends: Project-level metadata are sourced from a combination of Form EIA-860, FERC Form 556, state regulatory filings, interviews with project developers and owners, and trade press articles. We independently verify much of the metadata—such as project location, fixed-tilt vs. tracking, azimuth, module type—via satellite imagery. Other metadata are indirectly confirmed (or flagged, as the case may be) by examining project performance—e.g., if a project's capacity factor appears to be an outlier given what we think we know about its characteristics, then we dig deeper to revisit the veracity of the metadata.

Installed Prices: Project-level CapEx estimates are sourced from a combination of Form EIA-860, Section 1603 grant data from the U.S. Treasury, FERC Form 1, data from applicable state rebate and incentive programs, state regulatory filings, company financial filings, interviews with developers and owners, trade press articles, and data previously gathered by NREL. CapEx estimates for projects built from 2013-2018 have been cross-checked against confidential EIA-860 data obtained under a non-disclosure agreement (and we expect to receive similar data for 2019 projects and successive years going forward). The close agreement between the confidential EIA data and our other sources in most cases provides comfort that our normal data collection process (i.e., the process that we go through prior to receiving the confidential EIA data with a one-year lag) does, in fact, yield reputable CapEx estimates. That said, we do caution readers to focus more on the overall trends rather than on individual project-level data points.

Capacity Factors: We calculate project-level capacity factors using net generation data sourced from a combination of FERC Electric Quarterly Reports, FERC Form 1, Form EIA-923, and state regulatory filings. Because many projects file data with several of these sources, we are often able to cross-reference (and correct, if needed) odd-looking data across several sources, thereby providing higher confidence in the veracity of the data.

Summary of Data and Methods (2)

PPA Prices: We gather PPA price data from a combination of FERC Electric Quarterly Reports, FERC Form 1, Form EIA-923, state regulatory filings, company financial filings, and trade press articles. We only include a PPA within our sample if we have high confidence in all of the key variables such as execution date, starting date, starting price, escalation rate (if any), time-of-day factor (if any), and term. By this process of exclusion, there is very little chance for erroneous PPA price data to enter our sample. Instead, this winnowing process results in our PPA price sample being somewhat smaller than it might otherwise be—though we are typically able to add back in any "incomplete" PPAs in subsequent years, once more data have become available with the passage of time.

LCOE: Our project-level LCOE calculations draw upon the empirical project-level data presented throughout this report, including installed prices, O&M costs, and capacity factors, and are supplemented with assumptions about financing and other items, as described in more detail in earlier slides.

An accessible data file and multiple visualizations can be found at utilityscalesolar.lbl.gov

To contact the corresponding authors:

- Mark Bolinger, Lawrence Berkeley National Laboratory 603-795-4937, MABolinger@lbl.gov
- Joachim Seel, Lawrence Berkeley National Laboratory 510-486-5087, jseel@lbl.gov

Berkeley Lab's contributions to this work were funded by the Solar Energy Technologies Office, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors are solely responsible for any omissions or errors contained herein.