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Tracking the Sun VII

An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013

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— Report Summary —
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SunShot U.S. Department of Energy

Project overview

Objective: Using project-level data, describe and analyze trends in the installed price of grid-connected PV systems in the United States

- Total installed price over time
  - Decomposed into module and non-module costs
  - Relationship to changes in PV incentive levels over time
- Comparisons to other major international PV markets
- Differences in installed price by system size and across states
- Differences in installed price by customer type, application, and technology
  - customer-owned vs. third party-owned systems
  - micro-inverter vs. central inverter
  - module efficiency level
  - Chinese vs. non-Chinese PV modules
  - residential vs. commercial vs. tax-exempt
  - residential new construction vs. residential retrofit
  - building-integrated vs. rack-mounted
  - rooftop vs. ground-mounted
  - tracking vs. fixed-tilt

- Each of the listed items is covered for **residential and commercial PV**
- A smaller set of trends is presented for **utility-scale PV**, given limitations of data and sample size

Associated National Lab PV Cost Tracking and Analysis Activities

- **NREL's *OpenPV* project**: Online data visualization tool, with data collection undertaken in conjunction with Tracking the Sun
- **Joint NREL-LBNL briefing, *Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections***: Excerpts from Tracking the Sun and from NREL-led modeling of PV installed prices and synthesis of industry pricing projections
- **LBNL's annual report series, *Utility-Scale Solar***: Focuses on utility-scale solar (PV and CSP) projects, describing trends related to installed prices, operating costs, capacity factors, and PPA pricing
- **LBNL and Academic Partners PV cost "deep-dive" projects:** Parallel analyses recently completed or underway, which analyze installed price data using more-sophisticated statistical techniques

Outline of presentation

- **Data Summary**
- Installed Price Trends: Residential and Commercial PV
- Installed Price Trends: Utility-Scale PV
- Conclusions and Policy Implications

Terminology and data sources

Key Terminology

- ***Installed price:*** the purchase price paid to the installer/integrator, prior to receipt of incentives, tax credits, etc.
- ***Residential and Commercial PV:*** Roof-mounted systems and ground-mounted systems <5 MW
- ***Utility-Scale PV:*** Ground-mounted systems ≥5 MW

Sources for Installed Price Data

- ***Residential & Commercial PV:*** state and utility PV incentive programs (60 programs in total), supplemented with data from other public sources
- ***Utility-Scale PV:*** FERC Form 1 filings, the U.S. Treasury Department's Section 1603 Grant Program database, SEC filings, company presentations, and trade press articles

Methodological details

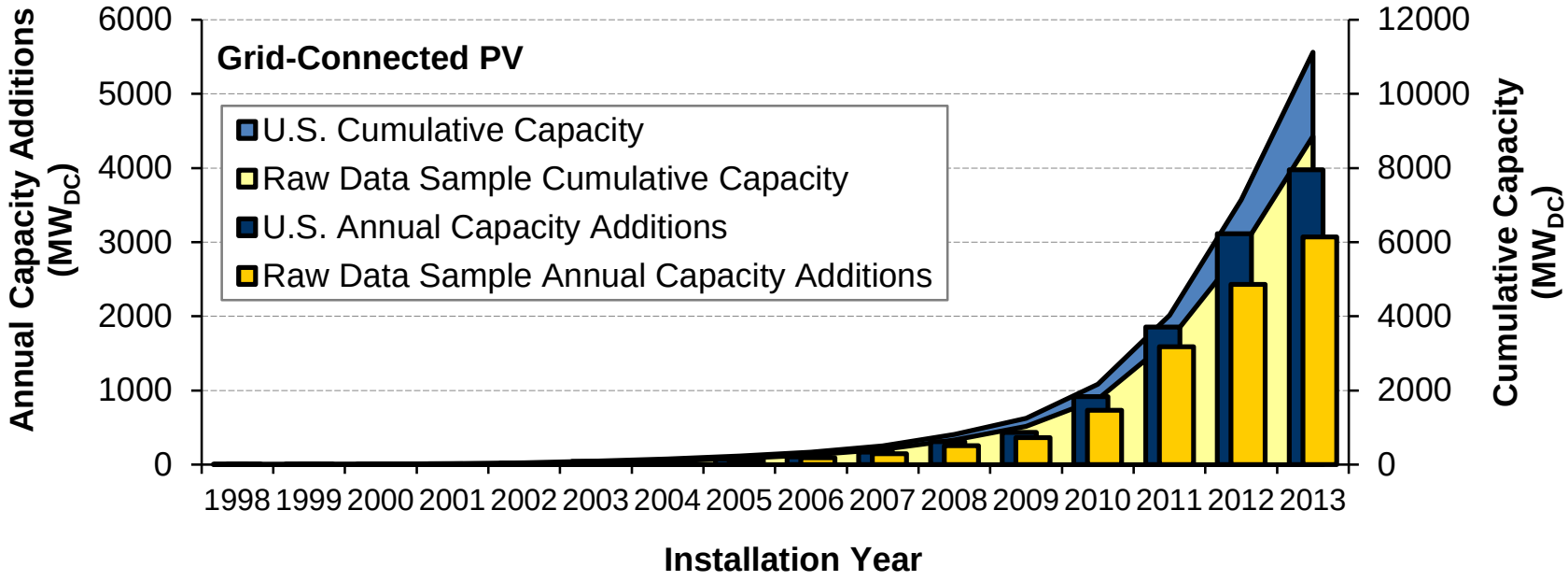
- Price and incentive data expressed in real 2013$
- System size and capacity data refer to rated module direct current (DC) power output at standard test conditions
- Data cleaned to remove systems with missing or clearly erroneous data for installed price, system size, or installation date
- All third party owned (TPO) residential & commercial systems for which reported installed prices were deemed likely to represent an *appraised value* were eliminated from the sample (see report appendix for details)
- Module and inverter manufacturer and model names standardized, and used to identify module efficiency and categorize projects as building integrated vs. rack-mounted, Chinese-brand vs. non-Chinese-brand module, and microinverter vs. central inverter
- Utility-scale PV sample consists of only fully operational projects for which all individual phases are in operation; separate project phases are not treated as individual projects

Caveats to installed price data

- **The data are historical**, focusing primarily on projects installed through 2013 (with some limited data for the first half of 2014), and therefore do not reflect the price of more-recently installed projects or prices currently being quoted for prospective projects
- **The data may differ from current installed price benchmarks** for a variety of reasons, including differences in timing, definitions, system size, location, project characteristics, and developer/owner profit margins
- **The data focus on the up-front purchase price** rather the levelized cost of electricity (LCOE) and therefore do not reflect improvements in performance over time or differences in performance among projects

The sample represents a large fraction of all U.S. PV capacity through 2013

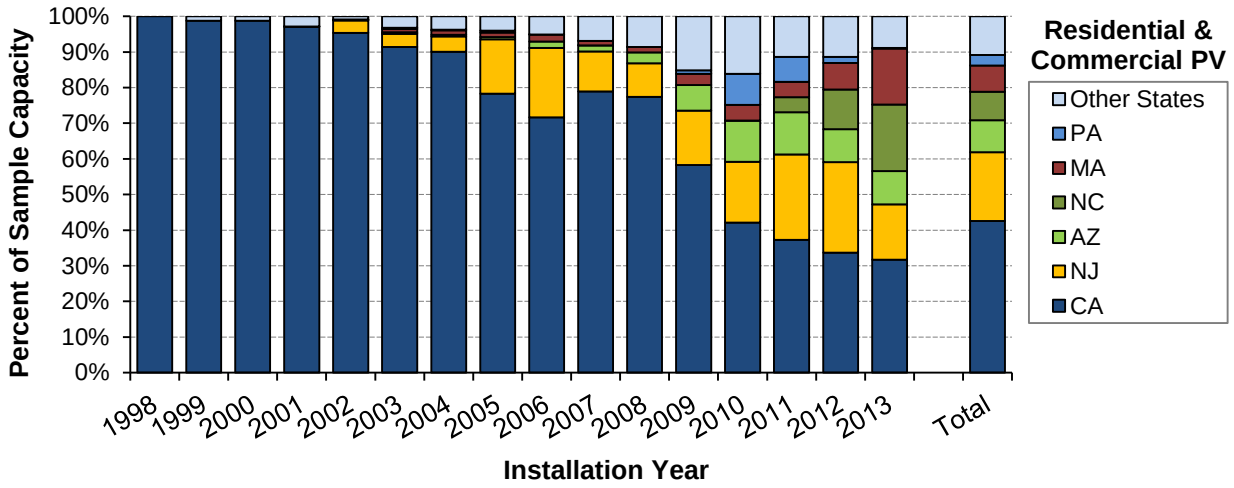
- The raw data sample consists of >300,000 PV systems installed through 2013, representing 80% of U.S. grid-connected PV capacity
- Removal of appraised-value and other excluded systems reduced the residential and commercial PV sample capacity by roughly 18% overall and by 33% among systems installed in 2013



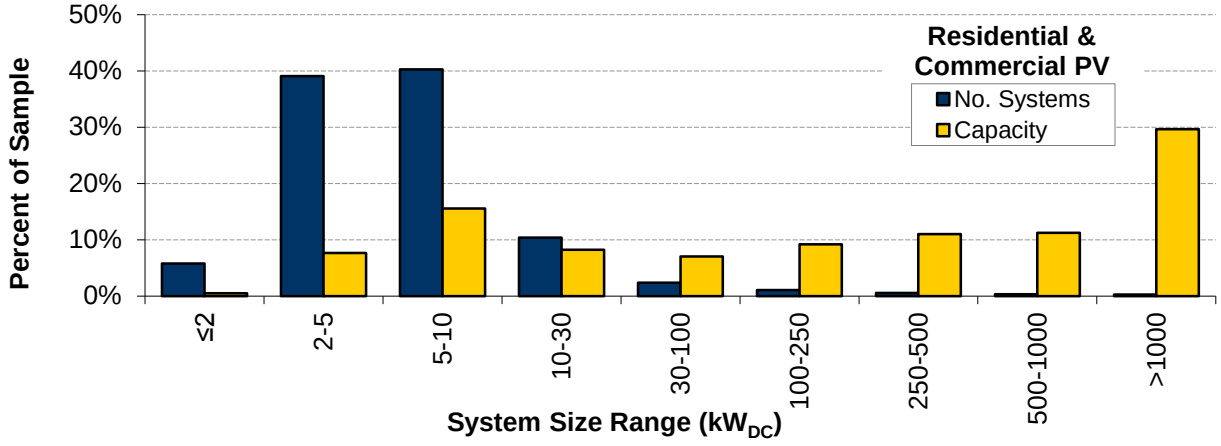
Data source for U.S. total grid-connected PV capacity additions: Sherwood (2014) and SEIA/GTM (2014a). LBNL modified those values by re-assigning the capacity associated with individual phases of large, multi-phase utility-scale projects to the year in which the final project phase was (or is scheduled to be) completed.

Residential & commercial PV data sample:
Distribution across states and by system size

Distribution of Capacity Across States



Sample Distribution by System Size

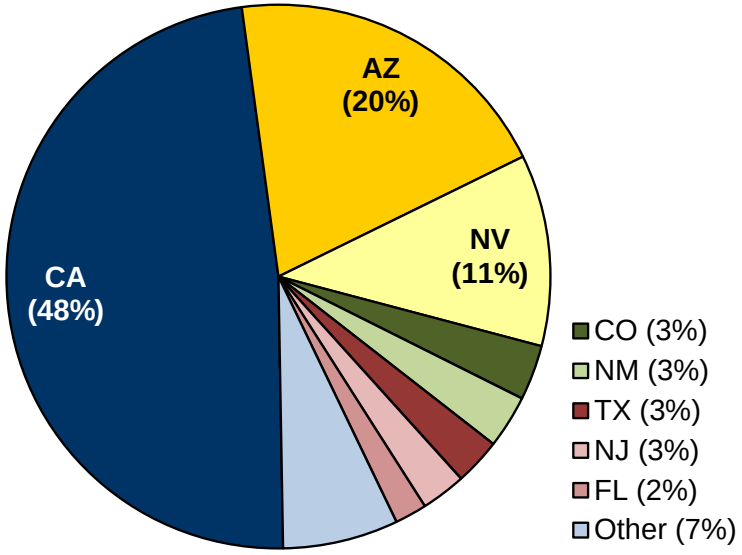


- Sample spans 33 states
- Heavily weighted towards CA, though sample (like broader market) has diversified over time
- 2013 systems primarily in 5 states (CA , NC, MA, NJ, AZ)
- Vast majority of systems are ≤10 kW
- Sample capacity is more evenly distributed by size, with one-third of capacity consisting of systems >1 MW (not counting utility-scale)

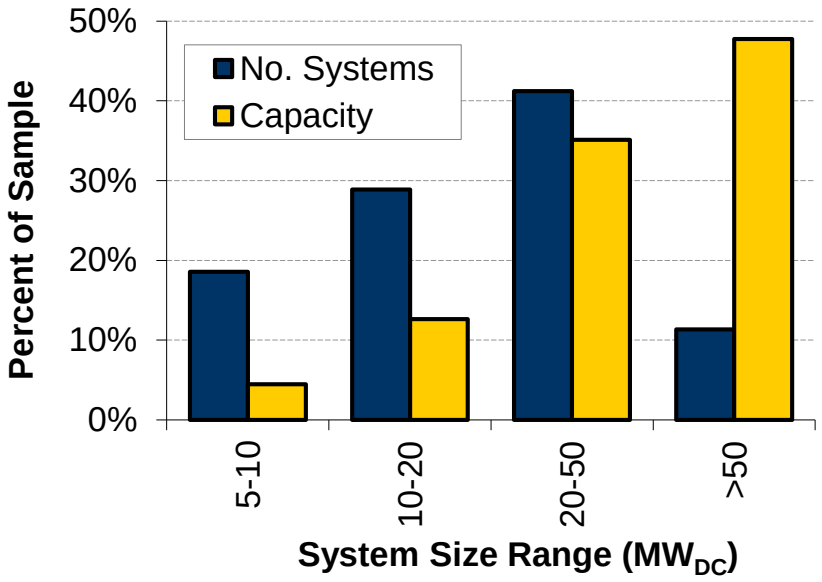
Utility-scale PV data sample:
Distribution across states and by system size

- The 100 utility-scale PV systems in the data sample are located across 17 states, with more than 80% of that capacity in CA, AZ, NV (where projects are relatively large)
- Systems range in size from 5 MW (by definition) to 320 MW; most systems are 10-50 MW, but almost half of the sample capacity consists of projects >50 MW

Distribution of Capacity Across States



Sample Distribution by System Size



Outline of presentation

- Data Summary
- **Installed Price Trends: Residential and Commercial PV**
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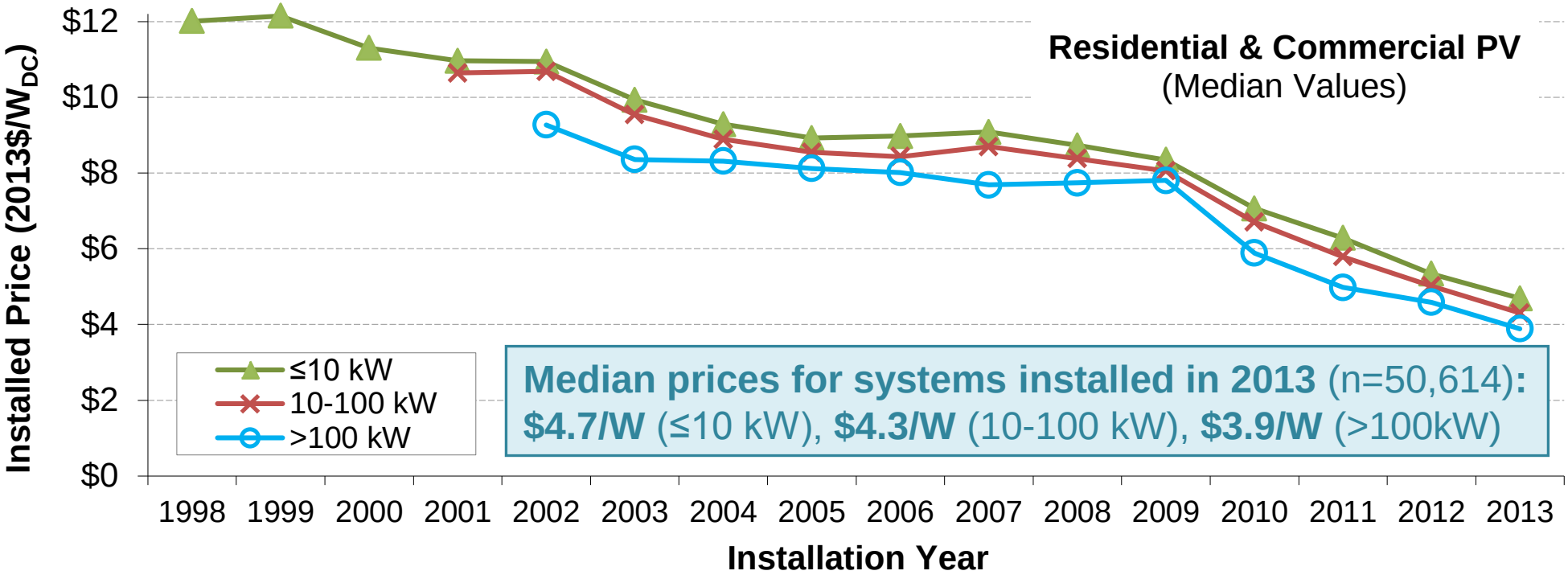
Installed prices continued their precipitous decline in 2013

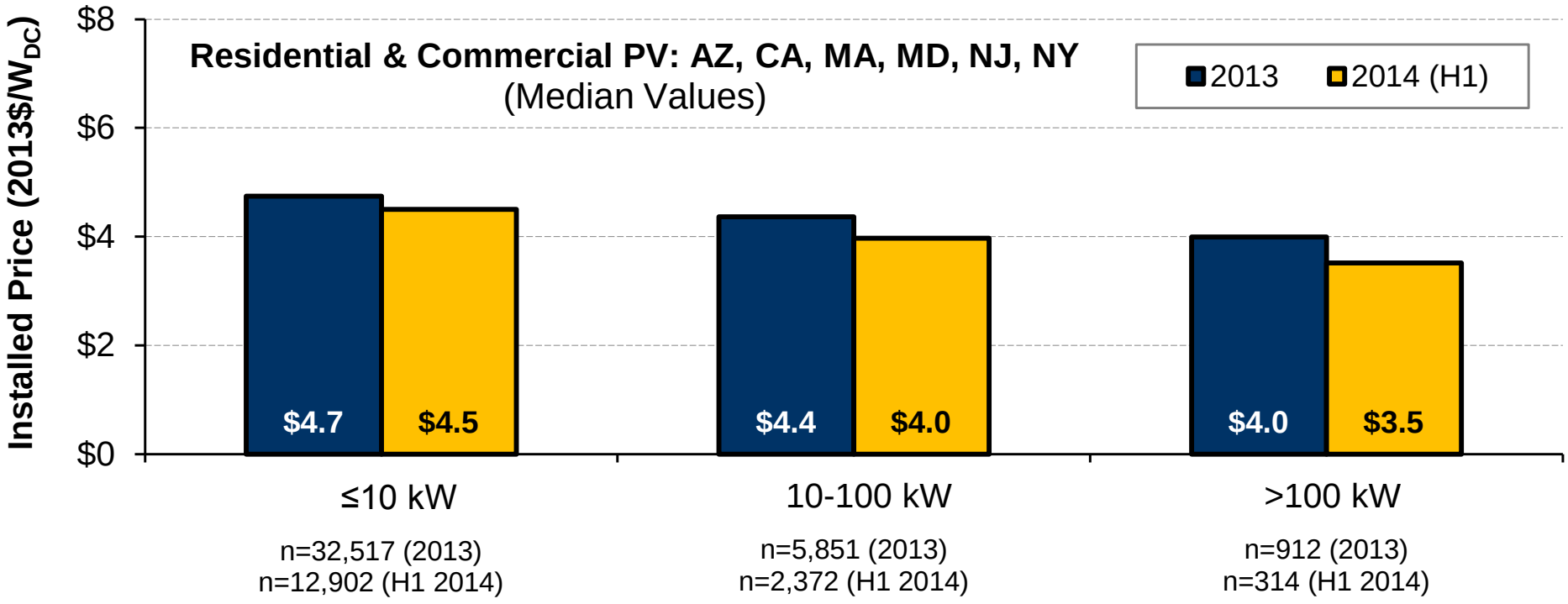
Median installed prices fell by $0.7/W (12-15%) from 2012-2013, across the three size ranges shown, and have fallen by an average of $0.5/W (6-8%) annually over the full historical period



Note: Median installed prices are shown only if 15 or more observations are available for the individual size range

Data for H1 2014 show installed price declines keeping pace with recent trends

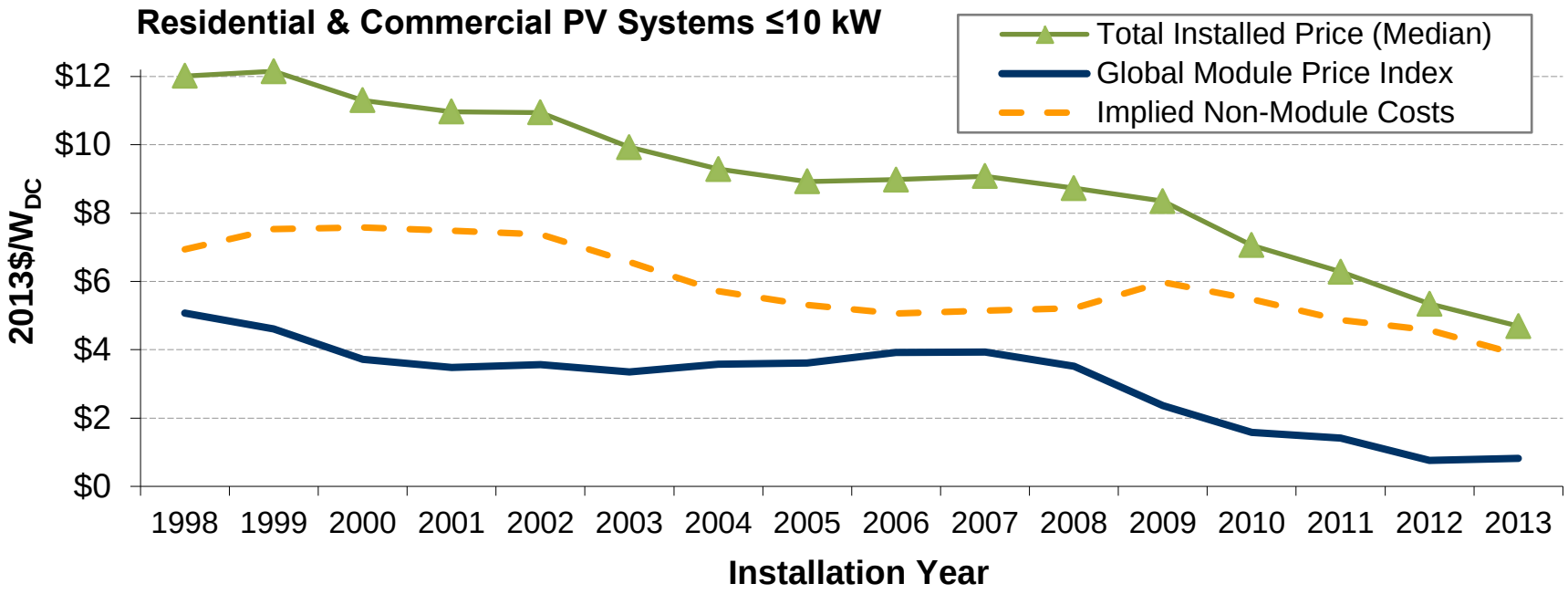
Median installed prices in many of the larger state markets fell by $0.2-0.5/W (5-12%) during the first half of 2014, relative to 2013, across the three size ranges shown



Note: Given the reduced sample of PV incentive programs and states represented within the figure, the 2013 median installed prices shown here differ from national median values cited elsewhere.

Installed price reductions in 2013 occurred despite flattening of module prices

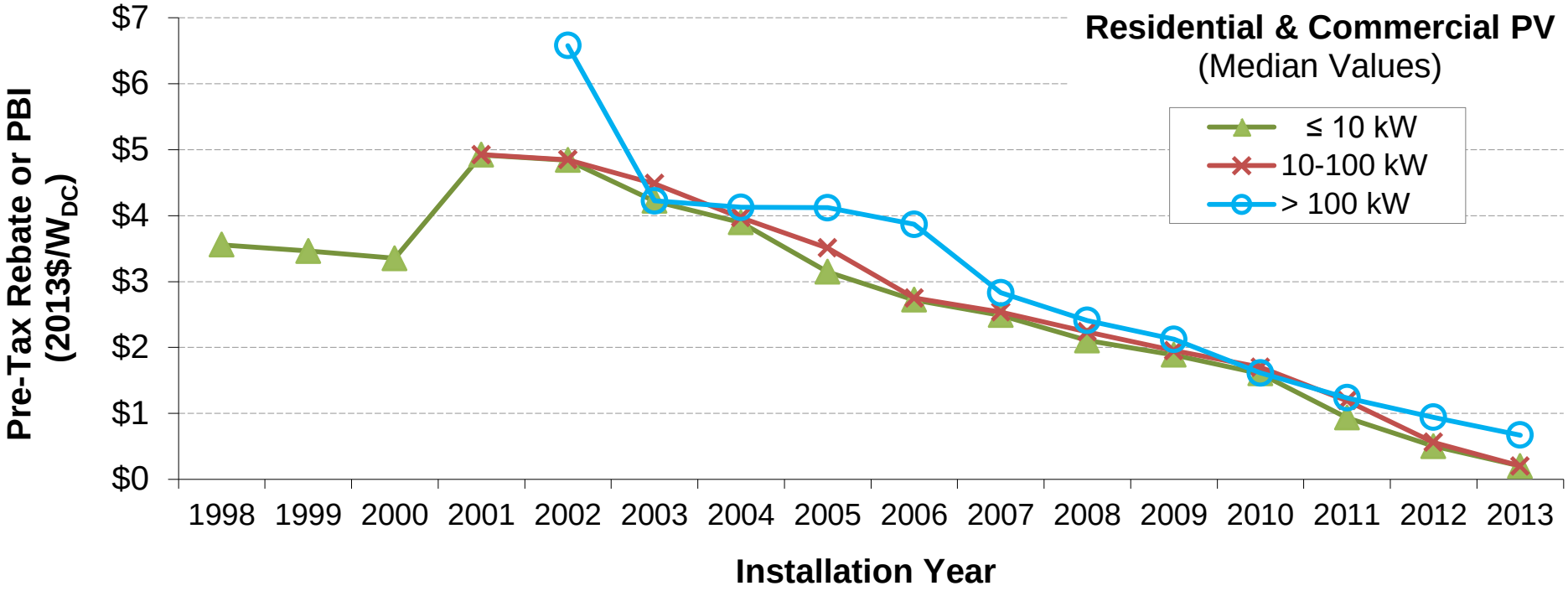
- Module price reductions were the driving force behind much of the installed price decline since 2008, but module prices remained relatively flat from 2012-2013
- Continued reductions in installed system prices suggest possible growing contributions from reductions in soft costs and other non-module costs (though may also reflect lagged effect of module price decline in preceding years)



Notes: The Global Module Price Index is the SPV Market Research index for large-quantity buyers (Mints 2014). "Implied Non-Module Costs" are calculated as the Total Installed Price minus the Global Module Price Index.

Installed price declines have occurred in concert with falling state/utility cash incentives for PV

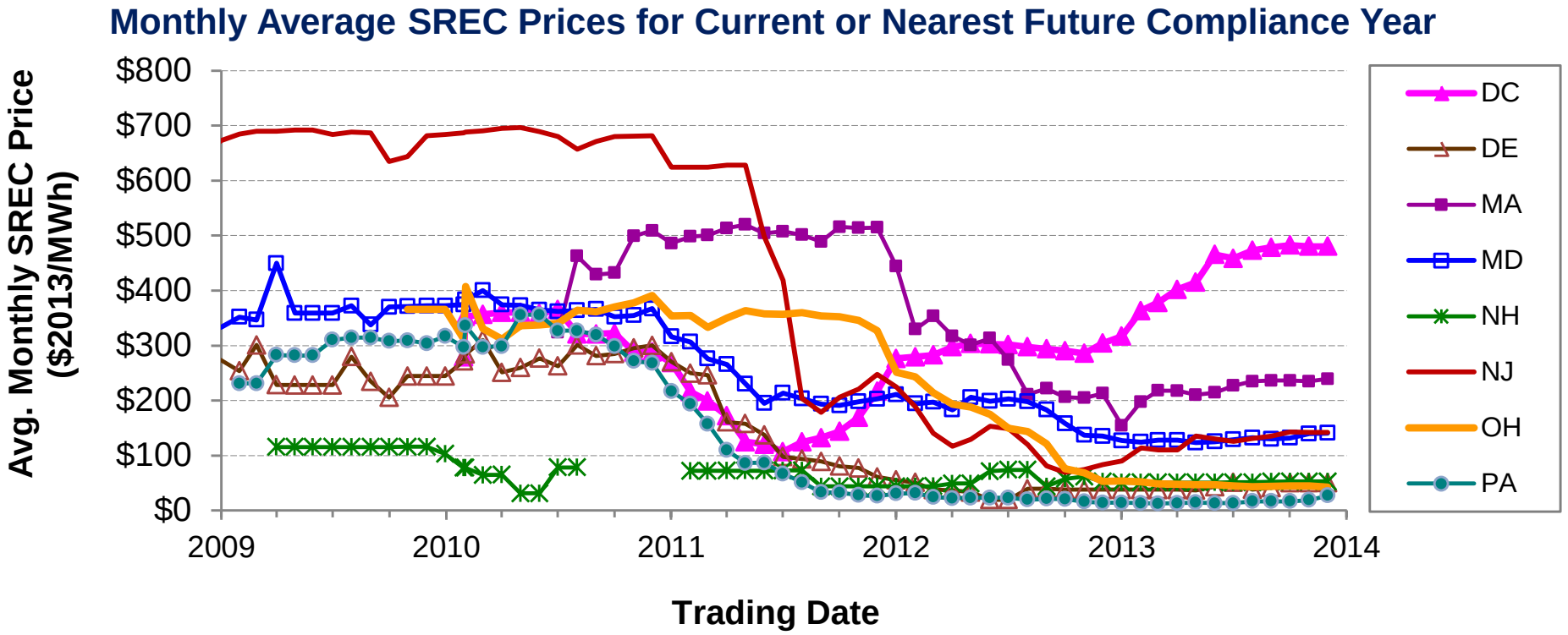
Cash incentives (rebates and performance-based incentives) have fallen by 85-95% from their historical peak in 2001/02, and incentive reductions from 2012-2013 equal 40-50% of the drop in installed prices



Notes: The figure depicts the pre-tax value of rebates and performance-based incentives provided through state/utility PV incentive programs, excluding systems that received incentives solely in the form of ongoing SREC payments over time. Results are excluded if fewer than 15 observations are available. The high median incentive for >100 kW systems in 2002 reflects the large percentage of systems that received an incentive through LADWP's PV incentive program, which provided especially lucrative incentives in that year.

SREC prices in many RPS solar set-aside markets have also declined significantly

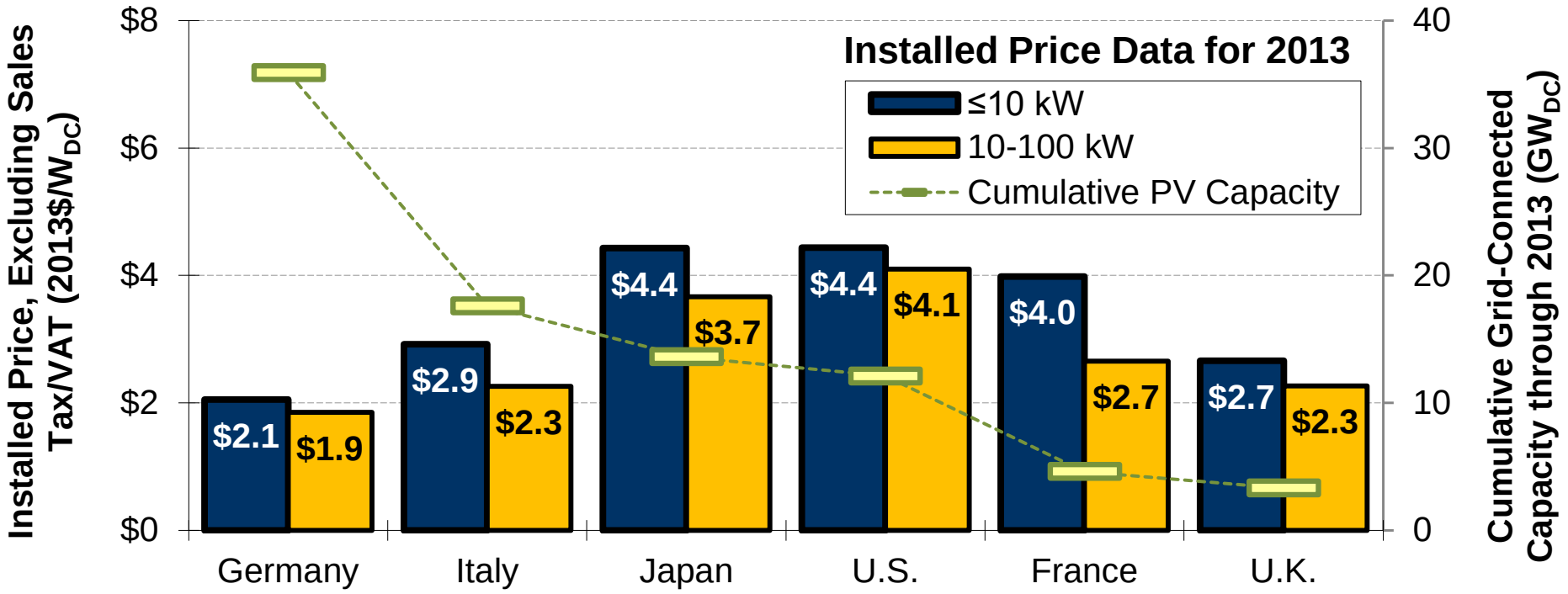
Solar renewable energy certificate (SREC) prices fell precipitously in many states during 2011 and 2012, and remained below $150/MWh in most major markets through 2013



Notes: Data sourced from Spectron, SRECTrade, and Flett Exchange (data averaged across available sources). Plotted values represent SREC prices for the current or nearest future compliance year traded in each month. Data for Ohio are for in-state SRECs.

Installed prices in the U.S. are higher than in many other major international PV markets

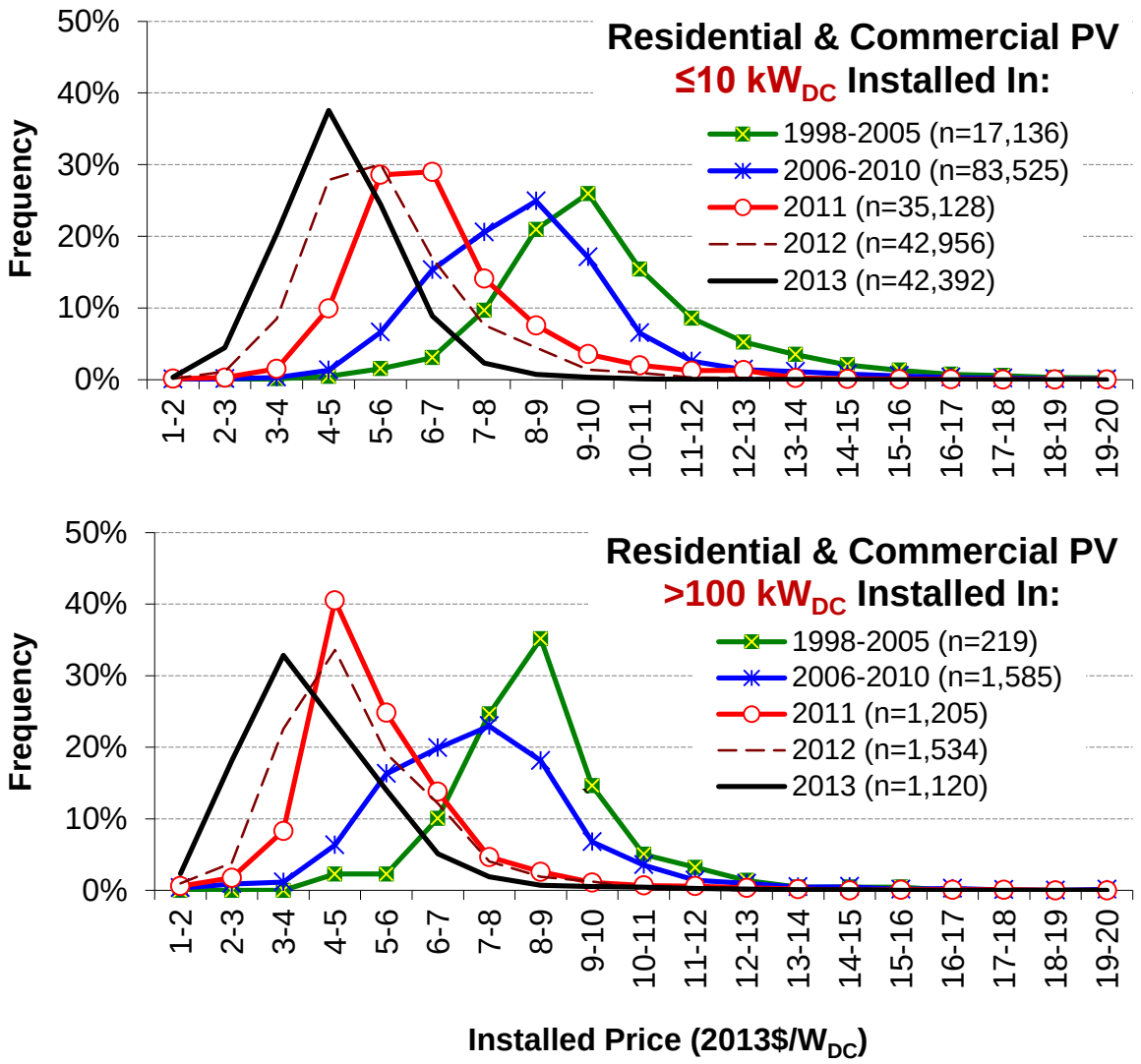
Lower installed prices in other countries largely reflects differences in "soft costs", which may be driven partly by differing levels of deployment scale, though other factors are also clearly important



Notes: Installed price data for Germany are based on price quotes issued for individual systems throughout 2013 (EuPD 2014). Installed prices for all other countries (with the exception of the U.S.) are based on data reported by individual country members to the IEA Photovoltaic Power Systems Programme (IEA-PVPS 2014). Data for cumulative grid-connected PV capacity through 2013 are from REN21 (2014).

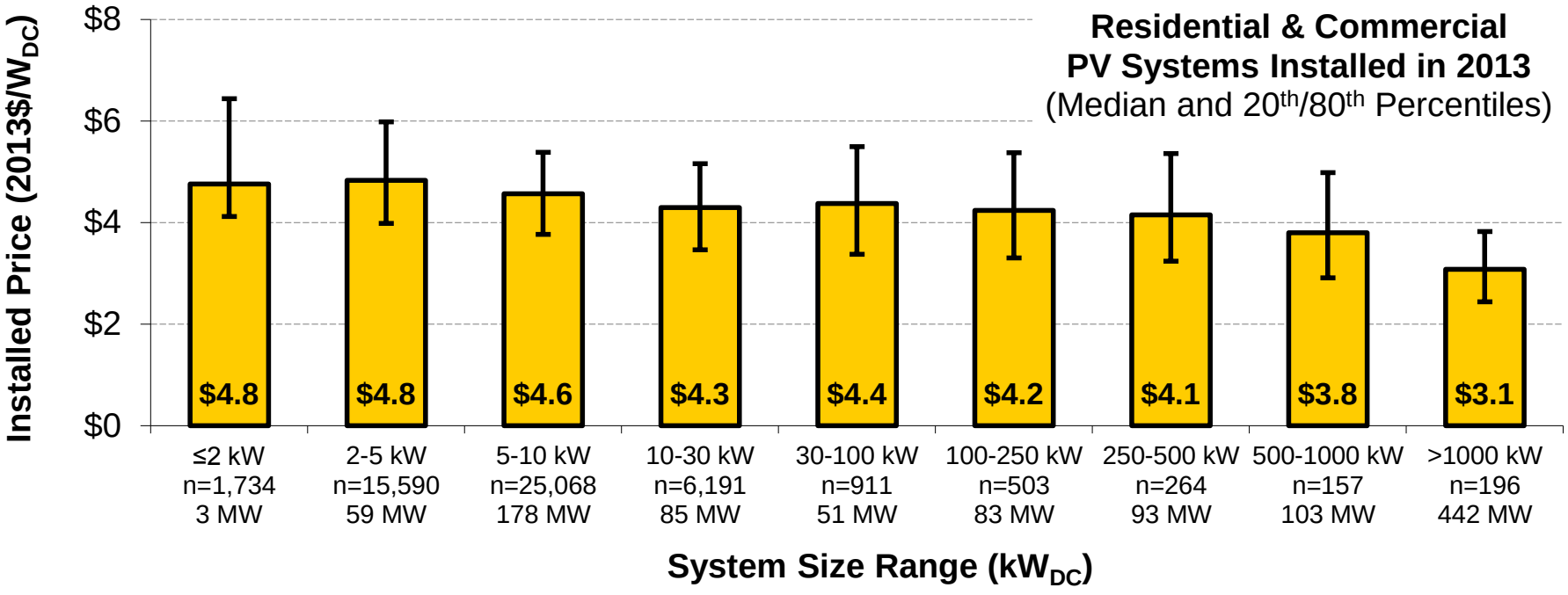
Installed prices vary widely across individual projects

- Installed price distributions have shifted and narrowed over time, suggestive of a maturing market, though substantial variability persists
- Among ≤10 kW systems installed in 2013, 20% of systems were priced <$3.9/W while a similar percentage was >$5.6/W
- Pricing variability reflects differences in project characteristics, installer attributes, regional/local market and regulatory conditions, etc.



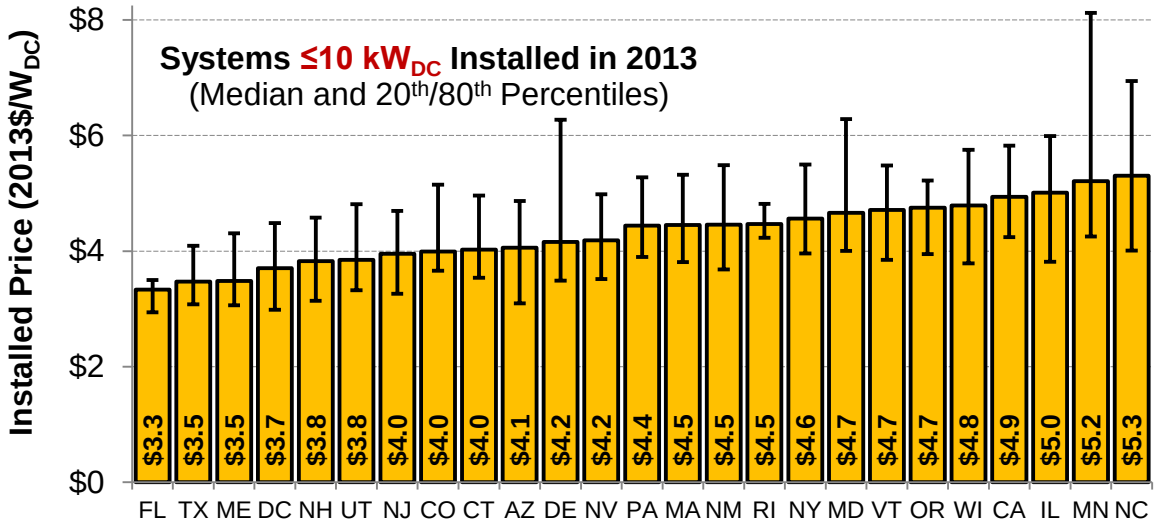
Installed prices exhibit clear economies of scale

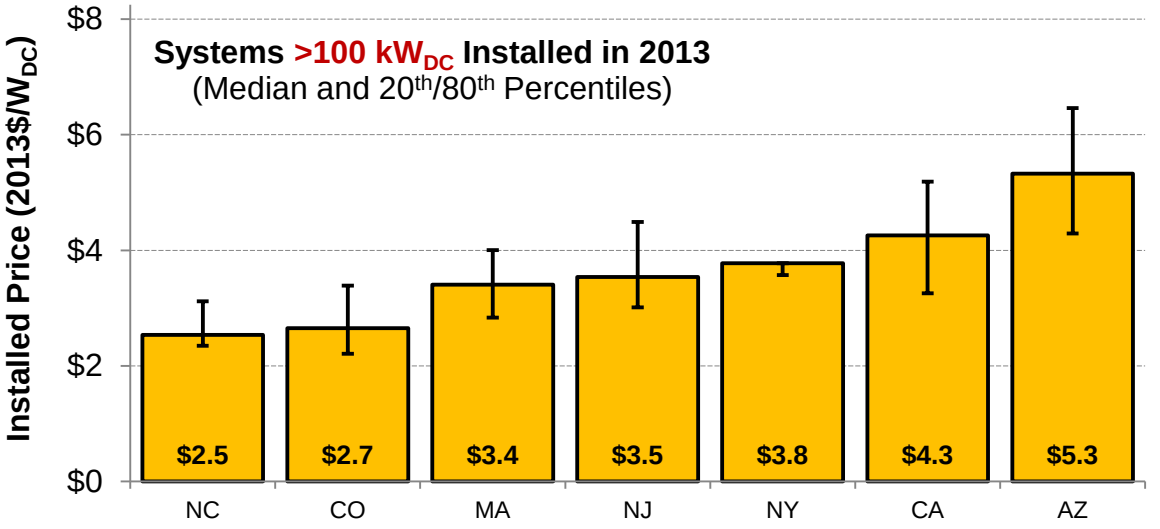
- Economies of scale reflect the spreading of fixed costs over a larger number of installed watts and, in some cases, price reductions on volume purchases of materials
- The median installed price for large commercial systems >1,000 kW is 35% lower than for systems ≤2 kW and 27% below the median price of systems in the 100-250 kW range



Installed prices differ significantly across states

- California is a relatively high-priced state, pulling U.S. median upward by virtue of its large fractional share
- Although larger market size may facilitate lower prices, strong correlation not always apparent
- Cross-state variation may also reflect differences in labor costs, installer competition, incentives and electricity rates, permitting costs, sales taxes
- For >100 kW systems, samples are relatively small; state-level medians strongly impacted by project characteristics





Note: Results shown only if 15 or more observations are available for the state

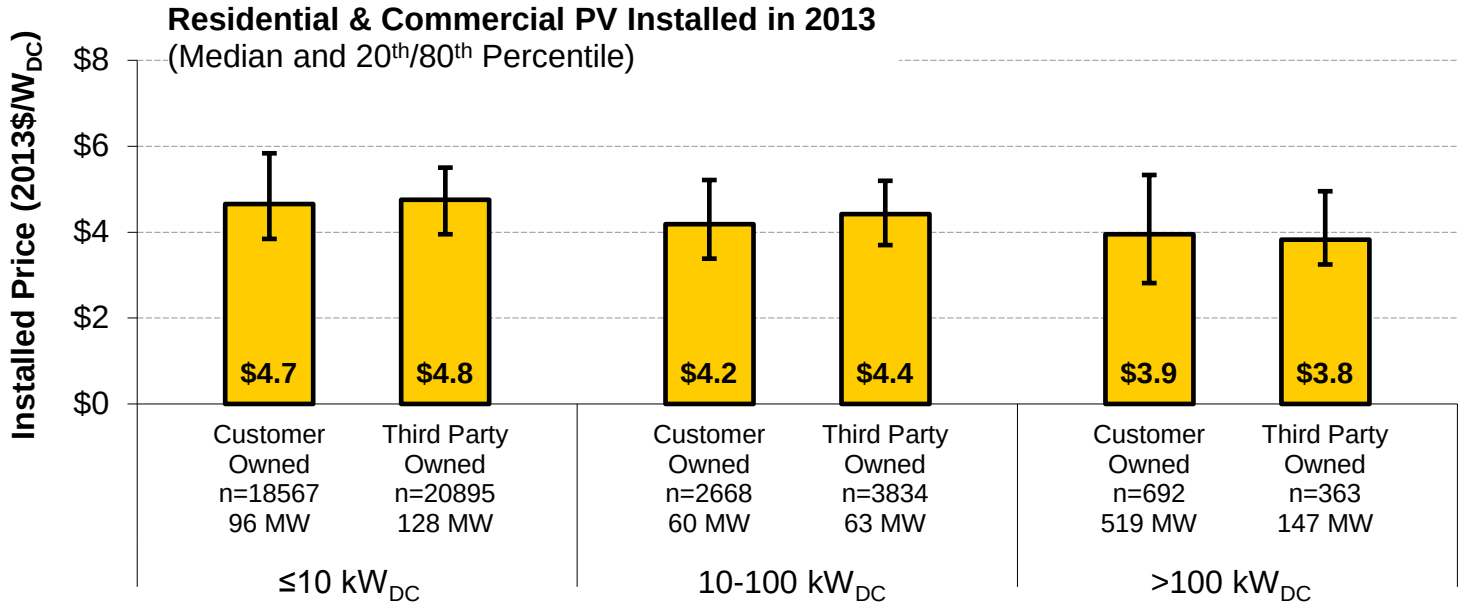
Installed price reporting for third-party owned systems complicates the analysis of price trends

Installed price reporting for third party owned (TPO) systems depends on the type of customer finance provider

- For TPO systems financed by *integrated* companies that provide both installation and customer financing:
  - Installed price data reported to PV incentive program administrators typically represent an appraised value (in some cases, an assessed "fair market value")
  - To the extent identifiable, these systems were removed from the sample
- For TPO systems financed by *non-integrated* companies that provide customer financing but purchase systems from EPC contractors/installers:
  - Installed price data reported to PV incentive programs generally represent the actual purchase price paid to the EPC contractor
  - These systems were retained in the data sample

TPO systems retained in the sample have similar installed prices to customer-owned systems

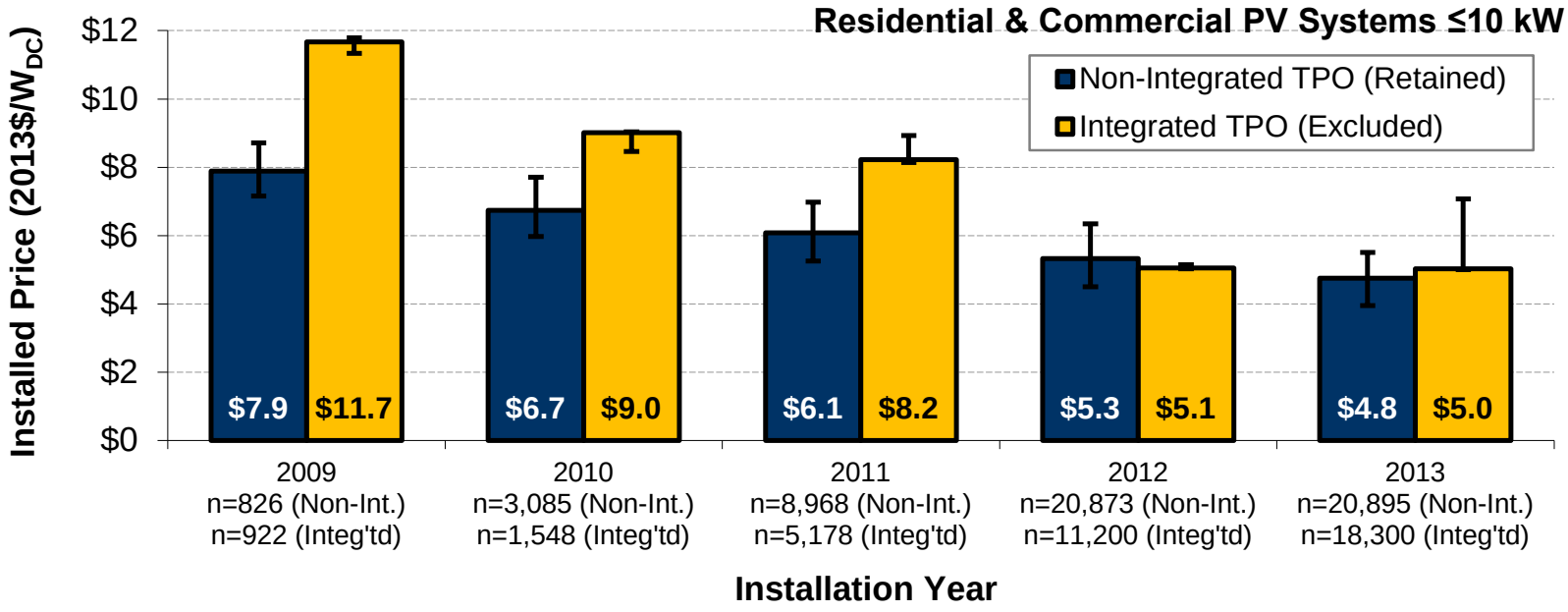
- Growing prominence of TPO systems thus has not had a material impact on overall installed price trends (given the exclusion of appraised value TPO systems)
- TPO systems do have somewhat narrower variability than customer-owned systems, as customer finance providers often purchase groups of systems and are relatively well-informed buyers



Notes: As is the case throughout the report, data from TPO systems for which reported installed prices were deemed likely to represent an appraised value were excluded from the sample. The values shown here for TPO systems are based only on systems for which the installed prices reported to state/utility PV incentive programs were deemed likely to represent an actual transaction price between an EPC contractor and a customer finance provider.

In contrast, TPO systems excluded from the data sample historically have had much higher prices

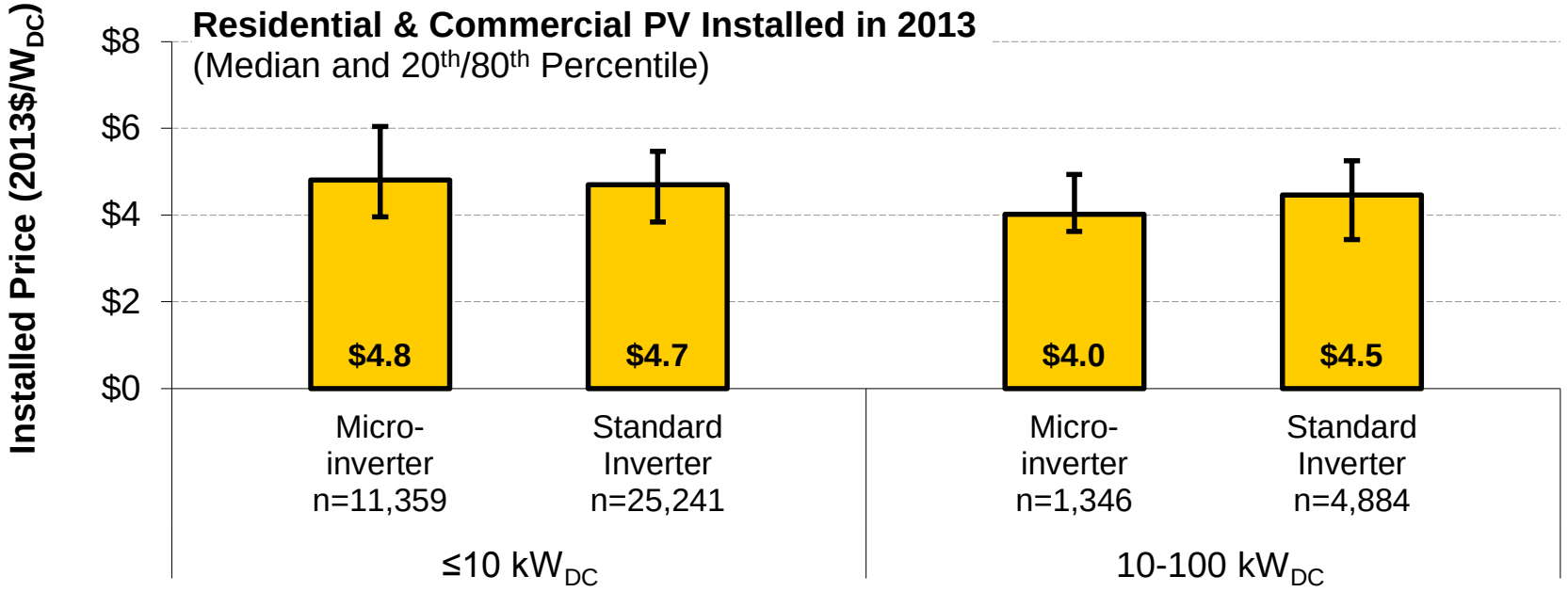
- Through 2011, installed prices reported for TPO systems installed by integrated finance providers (often reflecting an assessed "fair market value") were dramatically higher than for non-integrated TPO systems
- Starting in 2012, one major integrated TPO provider altered its methodology for reporting installed prices to PV incentive programs



Notes: The data for integrated TPO systems are included in this figure but excluded throughout all other elements of this report. The data presented here for both types of TPO systems represent installed prices reported to state and utility PV incentive programs, which may differ from those reported to other entities (e.g., to the U.S. Treasury Dept. or the IRS, for the purposes of the 1603 Grant or federal ITC).

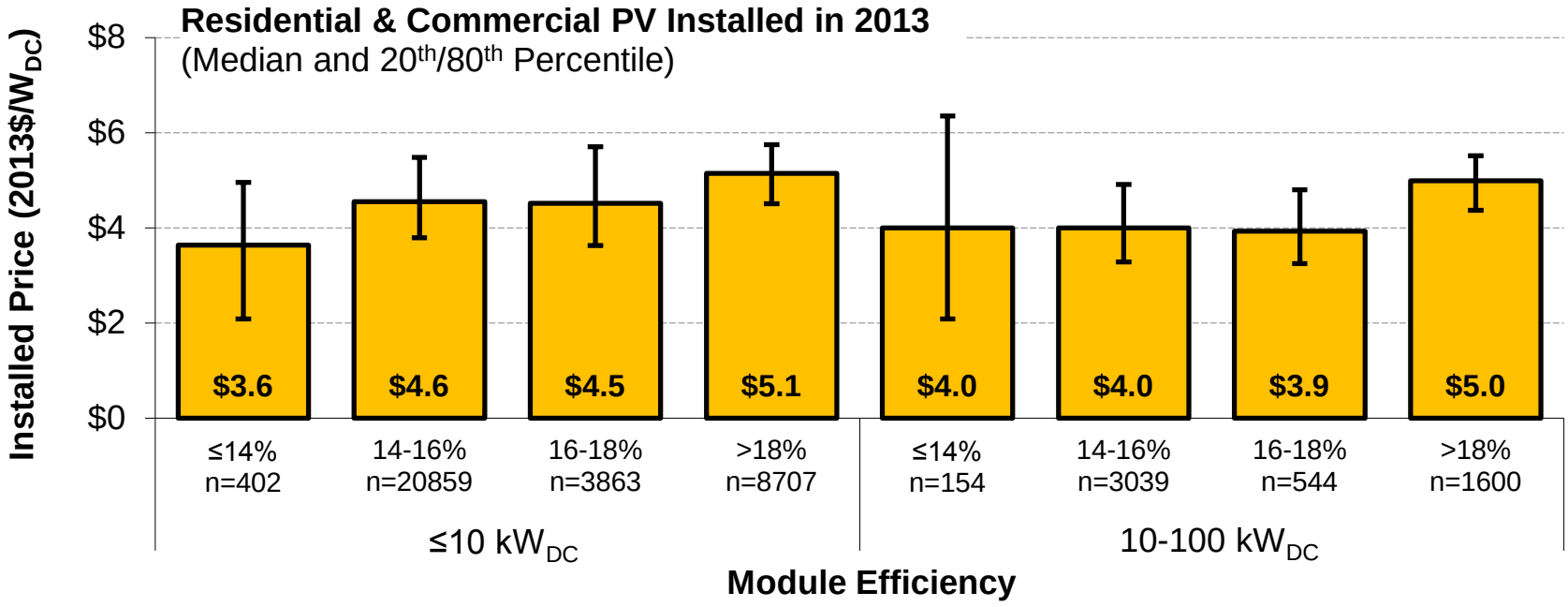
Installed price differentials for systems with microinverters depend on project size

- Penetration of microinverters has increased substantially, comprising 31% of ≤10 kW systems and 22% of 10-100 kW systems installed in 2013 in the data sample
- Microinverters offer higher performance than standard inverters, but cost more (though that premium may potentially be offset by BOS/soft cost savings)
- On net, the median installed price of systems with microinverters was $0.1/W higher for ≤10 kW systems, but was $0.5/W lower for 10-100 kW systems, compared to those with standard inverters



Installed prices are higher for systems with premium module efficiencies

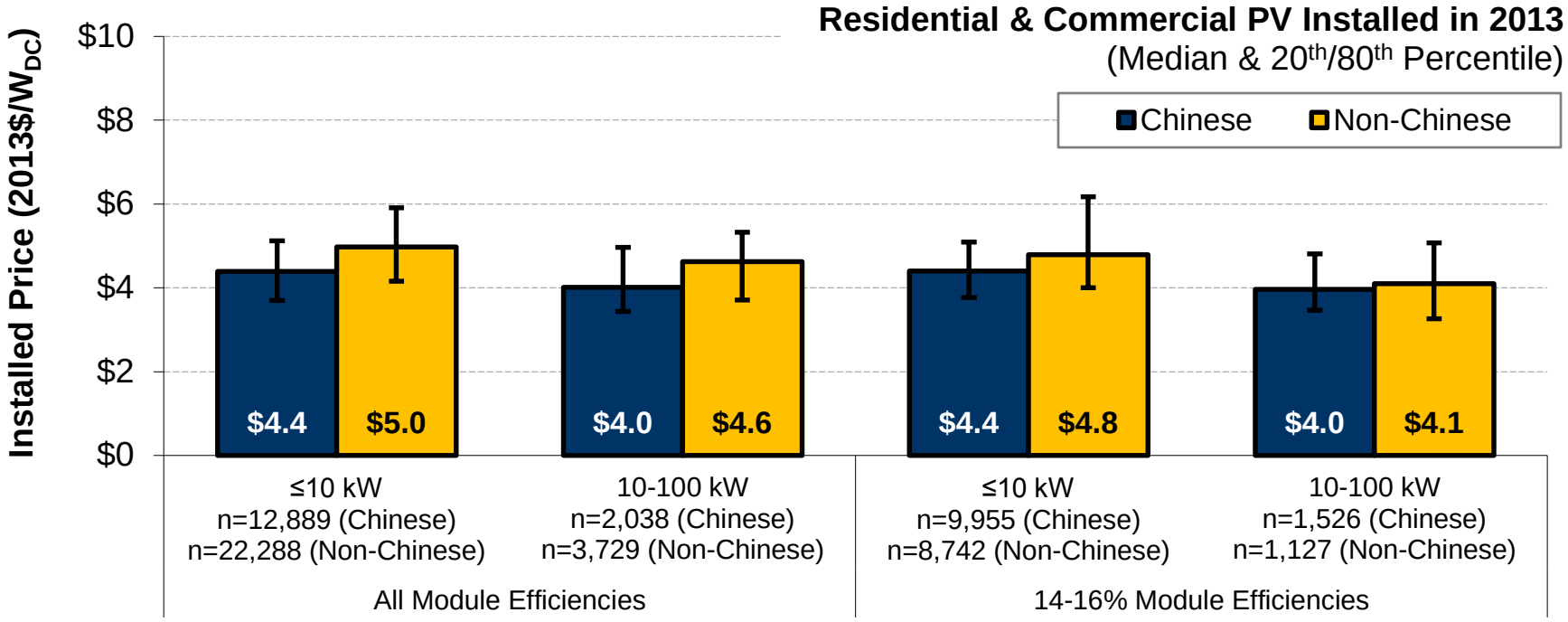
- Systems with premium-efficiency (>18%) modules installed in 2013 had a median installed price $0.5/W to $1.0/W higher than that of systems with 14-16% module efficiencies (typical of standard polysilicon modules)
- Suggests that the cost premium for high-efficiency modules has, thus far at least, generally outweighed associated reduction in balance of systems costs



Notes: The figure excludes building-integrated PV (BIPV) systems, in order to avoid any bias associated with a higher incidence of BIPV systems with particular module efficiency levels.

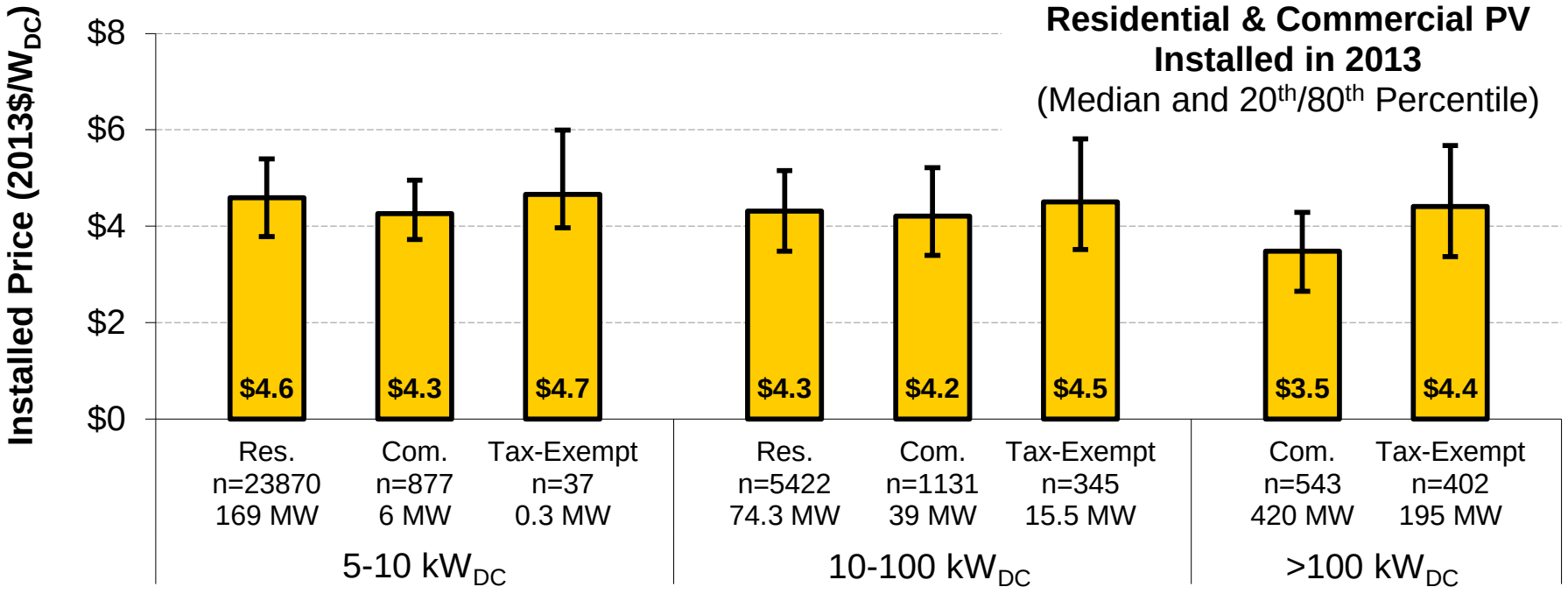
Systems with Chinese-brand modules generally have lower installed prices

- Across all module efficiencies, the median installed price of systems with Chinese-brand modules was $0.6/W lower than those with non-Chinese-brand modules, though that partly reflects premium efficiency non-Chinese brands
- Focusing more narrowly on systems with module efficiencies of 14-16% (the range within which most Chinese-brand modules fall), the installed price differential between systems was considerably smaller ($0.1/W to $0.4/W)



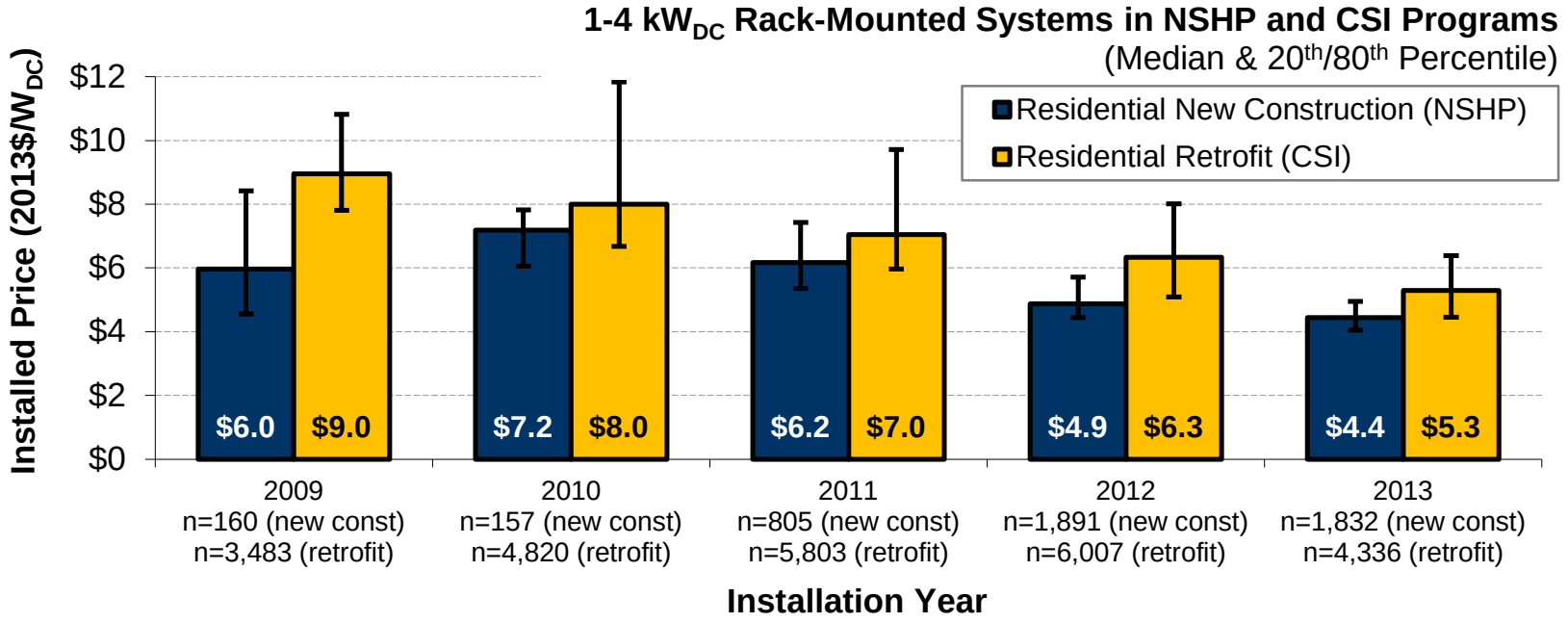
Installed prices for tax-exempt customers are higher than for other customer segments

- The median installed price of systems hosted by tax-exempt customers was $0.1/W to $0.9/W higher than for residential- and commercial-hosted systems
- Higher price of tax-exempt customer systems may reflect: prevailing wage/union labor requirements, a high incidence of shade and parking structure PV arrays, preferences for domestically manufactured components, additional permitting requirements, and more complex government procurement processes



The new construction market offers installed price advantages for small residential PV

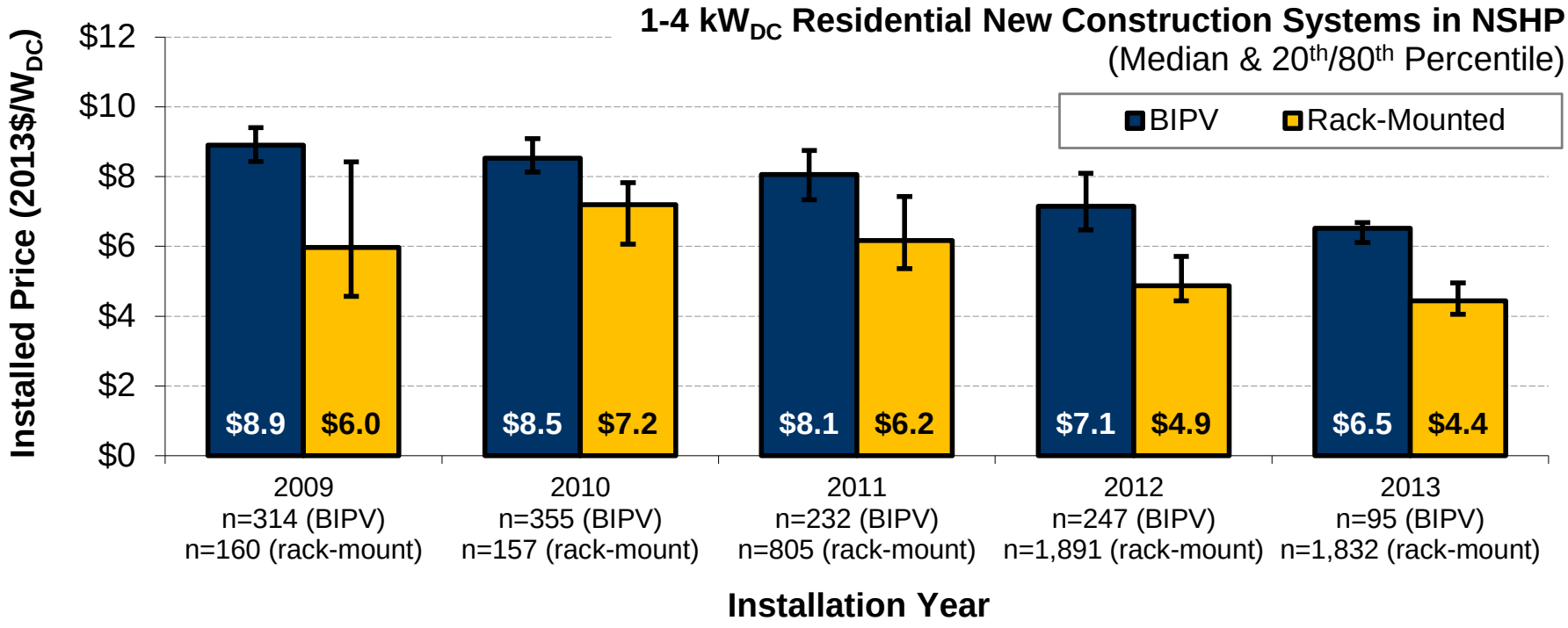
- New construction applications offer potential economies of scope (contractors and materials already on site) and economies of scale (large housing developments)
- Among 1-4 kW systems (typical of new construction), median installed prices for rack-mounted systems have been consistently lower in residential new construction (by $0.9/W in 2013) than for similarly-sized retrofit systems



Notes: The data for retrofits are based on systems installed through the California Solar Initiative (CSI), and data for residential new construction are based on systems installed through California's New Solar Homes Partnership (NSHP) program. The comparison focuses on 2-4 kW systems, the most common size range for residential new construction systems.

BIPV systems have shown substantially higher installed prices than rack-mounted systems in new construction

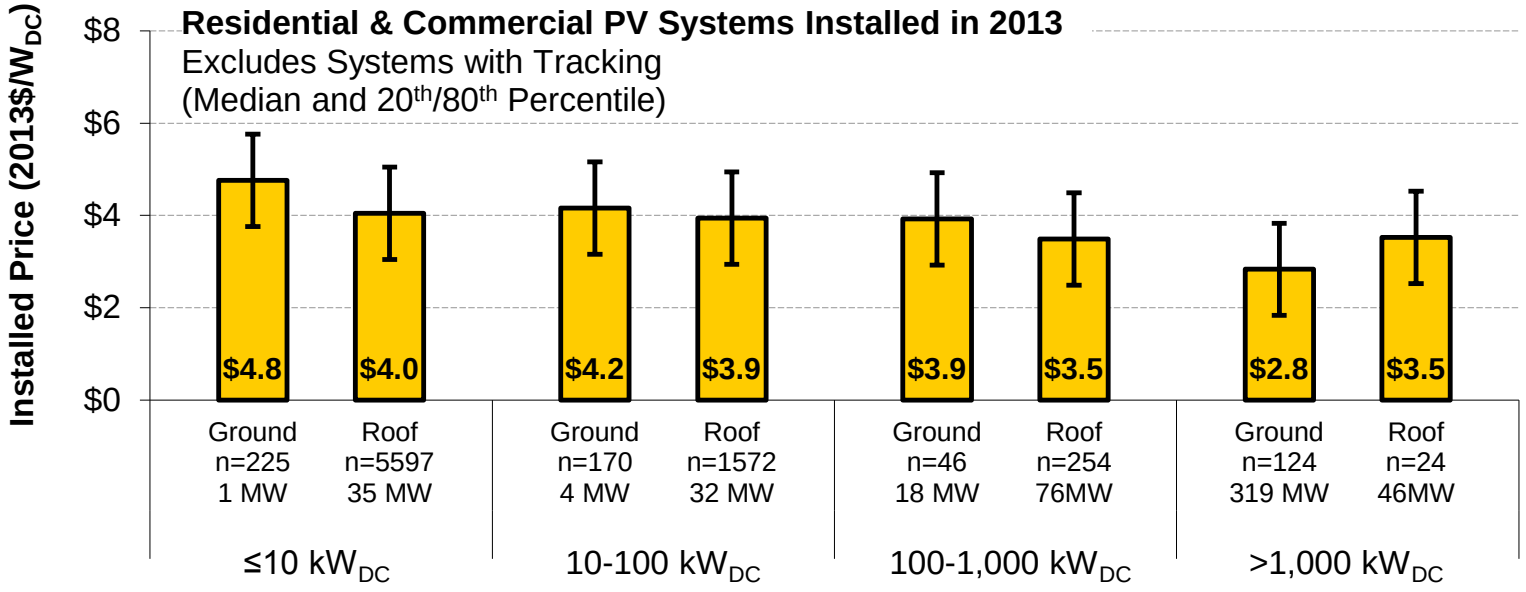
- BIPV systems installed in residential new construction have consistently been substantially higher priced (by $2.1/W in 2013) than rack-mounted systems
- That comparison does not account for avoided roofing materials cost associated with BIPV or performance differences, both of which also impact LCOE



Notes: Data are based on systems installed through California's New Solar Homes Partnership (NSHP) program. The comparison focuses on 2-4 kW systems, the most common size range for residential new construction systems.

The relative installed price of ground-mounted to roof-mounted systems depends on system size

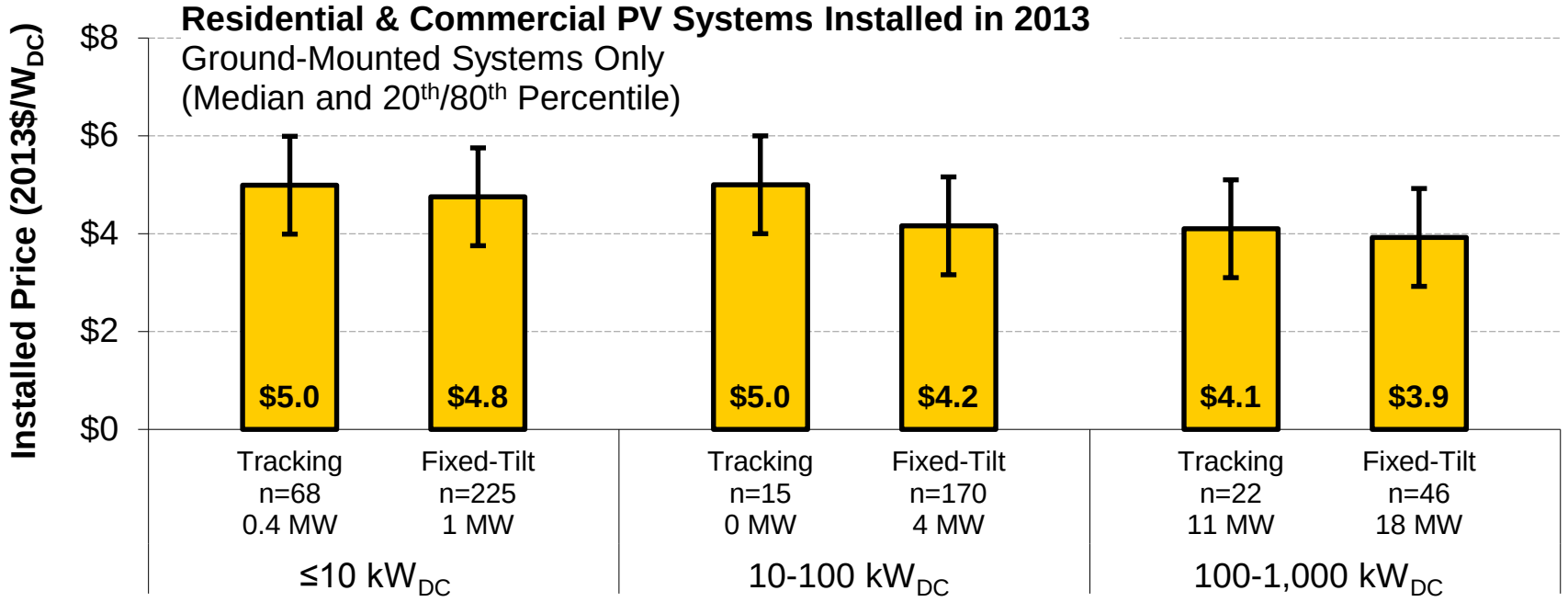
- Among small (≤10 kW) systems, ground-mounted systems in 2013 were $0.7/W higher priced than roof-mounted systems, owing to additional structural costs (including, in some cases, carport/parking structures)
- Among large commercial systems >1,000 kW, however, ground-mounted systems were $0.7/W *lower* priced than roof-mounted systems, suggesting greater scale economies for ground-mounted applications



Notes: The figure is derived from the relatively small subsample of systems for which data were available indicating whether the system is roof- or ground-mounted, and excludes systems with tracking or BIPV.

Systems with tracking have higher installed prices than fixed-tilt systems

- Among residential and commercial systems installed in 2013, the installed price premium for systems with tracking ranged from $0.2/W to $0.8/W (4-20%), depending on system size
- This differential is less than in previous years (typically $0.5/W to $1.5/W), suggestive of a potential decline in the incremental cost of tracking equipment



Notes: The figure is derived from the relatively small subsample of systems for which data were available indicating whether the system is roof- or ground-mounted.

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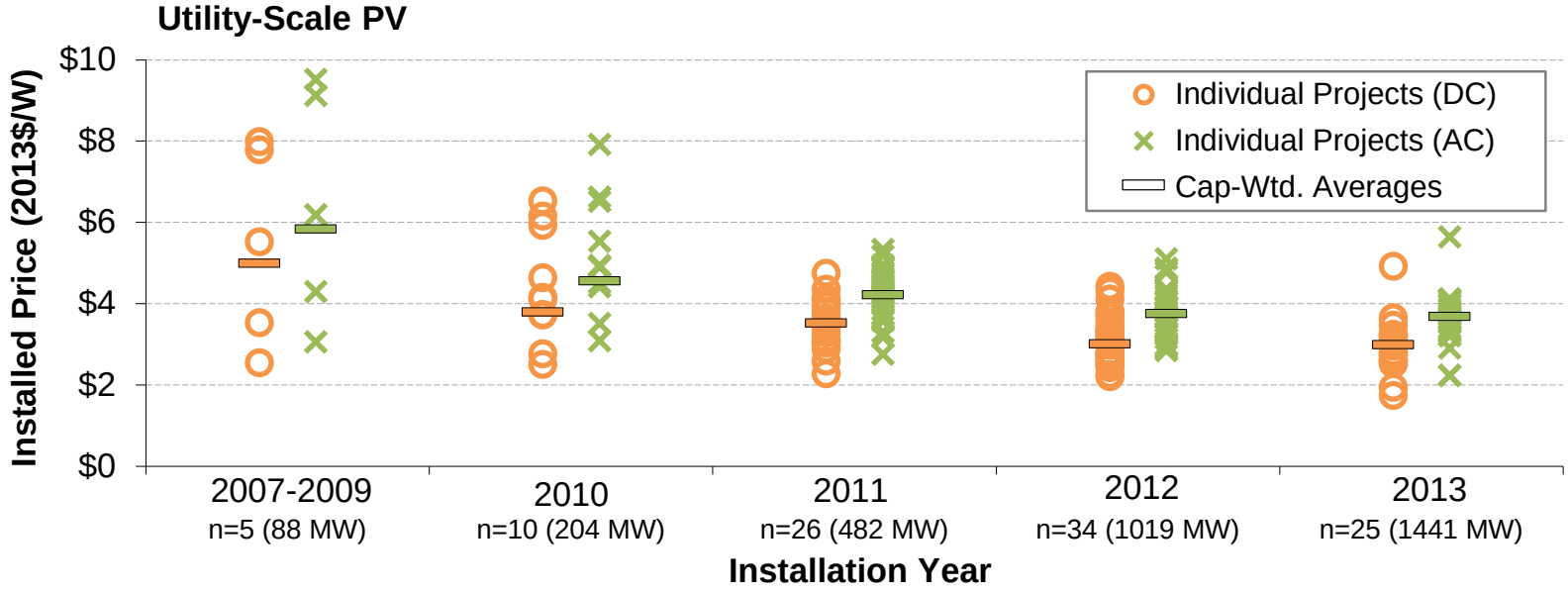
Utility-scale PV: A few points on the underlying installed price data

- **Lag in component pricing and market conditions:** The installed price of some projects may reflect component pricing (and/or the market conditions) at the time that power sales agreements and EPC contracts were signed, which may have occurred several years prior to project completion
- **Reliability of data sources:** Installed price data for utility-scale PV projects are derived from varied sources and, in some instances, may be less reliable or consistently defined than the data presented for residential and commercial systems
- **DC versus AC capacity ratings:** For consistency with residential and commercial data, we report system sizes and installed prices for utility-scale PV systems in DC units; however, AC units may be more appropriate in many contexts, given that other forms of utility-scale generation are typically described in AC terms. (See LBNL's *Utility Scale Solar* report for data reported in AC terms)
- **Focus on installed price rather than levelized cost:** Focusing on installed price ignores performance-related differences and other factors that influence LCOE, a more comprehensive cost metric for utility-scale PV

The installed price of utility-scale PV has fallen over time but varies considerably

- Capacity-weighted average installed prices fell by 40% from the 2007-2009 period (5 projects) to 2013 (25 projects)
- Virtually no change in average price from 2012 to 2013, though that may partially be an artifact of particular projects in the data sample
- Installed prices for projects completed in 2013 generally ranged from \$2.6/W_{DC} to \$3.5/W_{DC} (20^{th} and 80^{th} percentiles), with a capacity-weighted average of \$3.0/W_{DC}

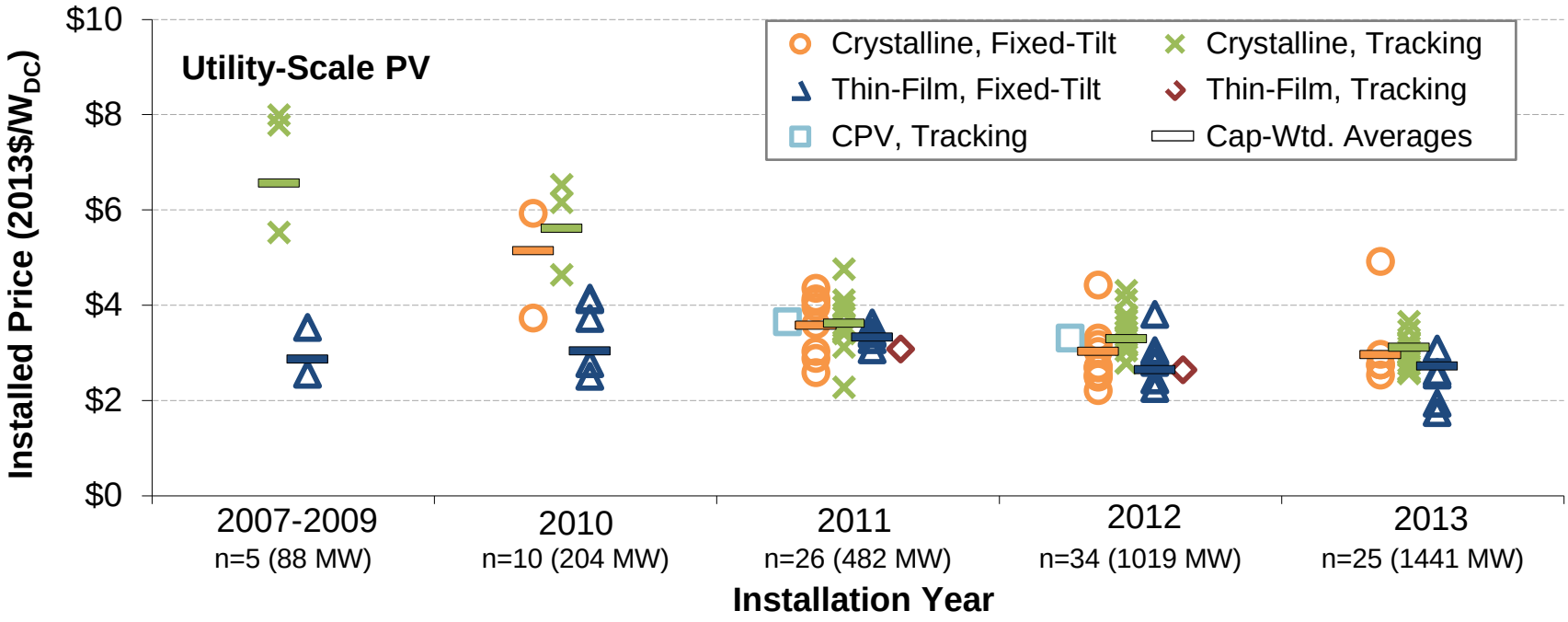


Notes: This figure deviates from the normal convention in this report by presenting installed price in both DC and AC units, the latter included for comparison to other forms of utility-scale generation; all other figures revert to the normal convention of DC units.

Installed prices depend partly on system configuration

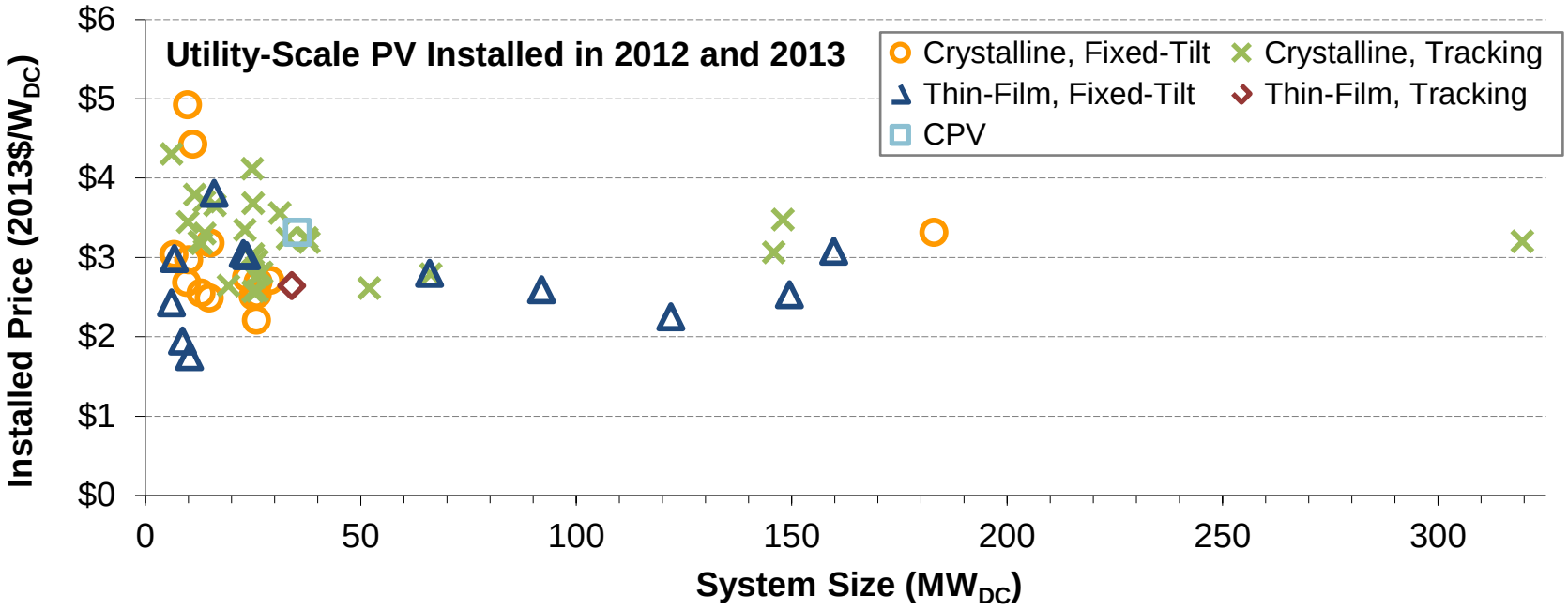
Among 2013 projects, the cap-weighted average price was $3.1/W for systems with crystalline silicon (c-Si) modules and tracking, $3.0/W for c-Si systems with fixed-tilt, and $2.7/W for thin-film, fixed-tilt systems

- Differing temporal trends for c-Si and thin-film projects have led to a convergence in pricing between those two technology classes



Larger utility-scale projects exhibit more uniform pricing

- Economies of scale are not readily apparent in the utility-scale data; may be obscured by a longer temporal lag in pricing data for large projects (and by the many other unobserved drivers introducing noise into the sample frame)
- However, pricing appears more uniform for larger projects: systems >50 MW ranged from $2.6/W to $3.2/W, while distribution for projects <50 MW has a somewhat longer tail and a number of projects priced above $4.0/W



Outline of presentation

- Data Summary
- Installed Price Trends: Residential and Commercial PV
- Installed Price Trends: Utility-Scale PV
- **Conclusions and Policy Implications**

Conclusions and policy implications

- PV installed prices declined substantially from 1998 through 2013 (and into 2014), but the pace and source of those reductions have varied over time
- Dramatic declines in module prices since 2008 have been the driving force behind reductions in installed system prices over that period, though module prices remained relatively flat from 2012 to 2013
- The fact that installed prices fell substantially in 2013 and continued to fall through the first half of 2014 suggests that recent efforts and initiatives aimed at reducing soft costs have started to bear fruit
- Lower installed prices in other major international PV markets and within some U.S. states, as well as the high degree of variability in U.S. system pricing, suggests that additional deep reductions in soft costs are possible in the near term
- Achieving dramatic reductions in soft cost may accompany market scale, but also likely requires some combination of incentive policy designs that provide a stable and straightforward value proposition, targeted policies aimed at specific soft costs, and basic and applied research and development

For more information

Download the full report along with the companion briefing and data file:

http://emp.lbl.gov/publications/tracking-sun-vii-historical-summary-installed-price-photovoltaics-united-states-1998-20

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