

Tracking the Sun V

An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2011

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- Report Summary -

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Environmental Energy Technologies Division

Project Overview

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

- Changes in total system installed price over time
- Variation in installed price by system size
- Differences in installed price across U.S. states and countries
- Differences in installed price by customer type, application, and technology
 - customer-owned vs. third party-owned systems
 - residential vs. commercial vs. tax-exempt
 - building-integrated vs. rack-mounted
 - residential new construction vs. residential retrofit
 - thin-film vs. crystalline silicon systems
 - module efficiency level
 - rooftop vs. ground-mounted
 - tracking vs. fixed-tilt
- Changes in PV incentives over time

- *Each of the listed items covered for residential and commercial PV*
- *Smaller set of trends described for utility-scale PV, given limitations in data and sample size*



Data Sources and Methodology

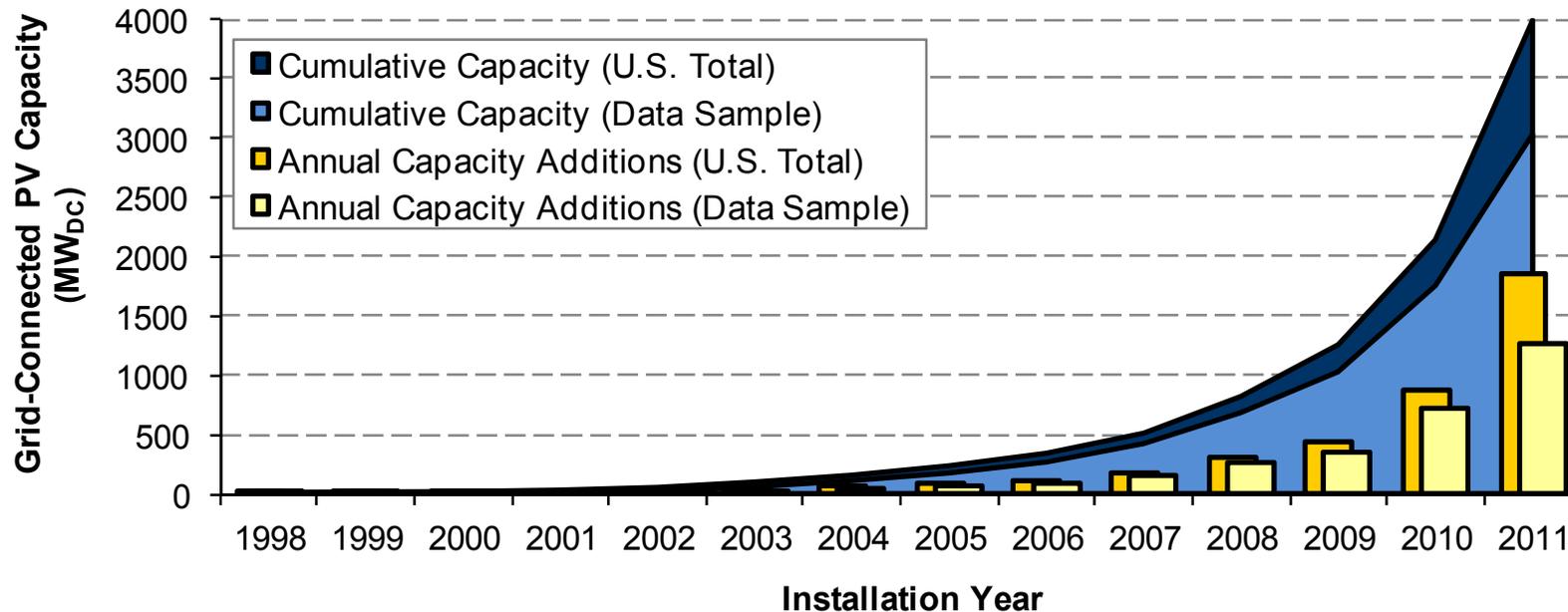
- Focus of report is on *installed price* (i.e., the purchase price paid to the installer, prior to receipt of incentives, tax credits, etc.)
- Installed price data for residential & commercial PV projects sourced primarily from state and utility PV incentive programs (42 programs in total), supplemented with data from other public sources
- Installed price data for utility-scale PV projects sourced from the U.S. Treasury Department's Section 1603 Grant Program database, FERC Form 1 filings, SEC filings, company presentations, and trade press articles
- Price and incentive data are expressed in real 2011\$, and size data are converted to direct current watts at standard test conditions (W_{DC})
- All third party owned projects for which reported installed prices were deemed likely to represent an *appraised value*, rather than a purchase price paid to an installer, were eliminated from the sample (see report appendix for details)
- Data were cleaned further to remove systems with missing or clearly erroneous data for installed price, system size, or installation date

Important Limitations in the Data Presented within This Report

- ***The installed price data are historical***, focusing primarily on projects installed through 2011, and therefore do not reflect the price of more-recently installed projects or prices currently being quoted for prospective projects
- ***The installed price data differ from current benchmarks for a variety of reasons*** (e.g., differences in timing, definitions, system size, location, project characteristics, and developer/owner profit margins)
- ***The report focuses on the up-front purchase price rather the levelized cost of electricity*** and therefore does not consider improvements in performance over time or differences in performance between projects
- ***The utility-scale PV data are based on a small sample size and include a number of relatively small projects and “one-off” projects***, and therefore are not necessarily representative of prototypical, large utility-scale PV projects
- ***Installed price reporting for third party-owned projects can be ambiguous***, in some cases representing an appraised value; efforts were made to eliminate projects for which reported prices likely represent appraised values, but the screening process is imperfect

The Sample Represents a Large Fraction of All U.S. PV Capacity through 2011

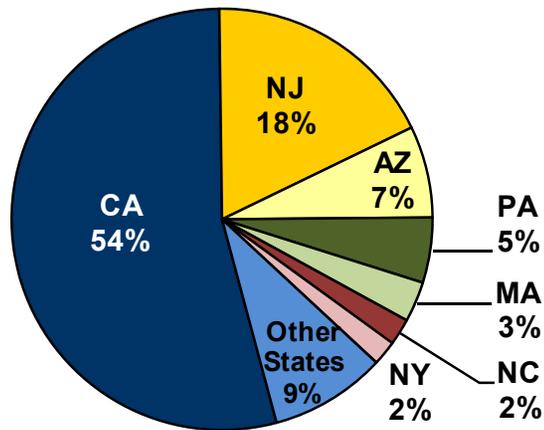
- The final dataset, after all data cleaning was completed, consists of 152,311 PV systems totaling 3,022 MW, including 2,224 MW of residential and commercial PV and 798 MW of utility-scale PV
- The sample represents approximately 76% of cumulative grid-connected PV capacity installed in the United States through 2011, and 69% of annual capacity additions in 2011



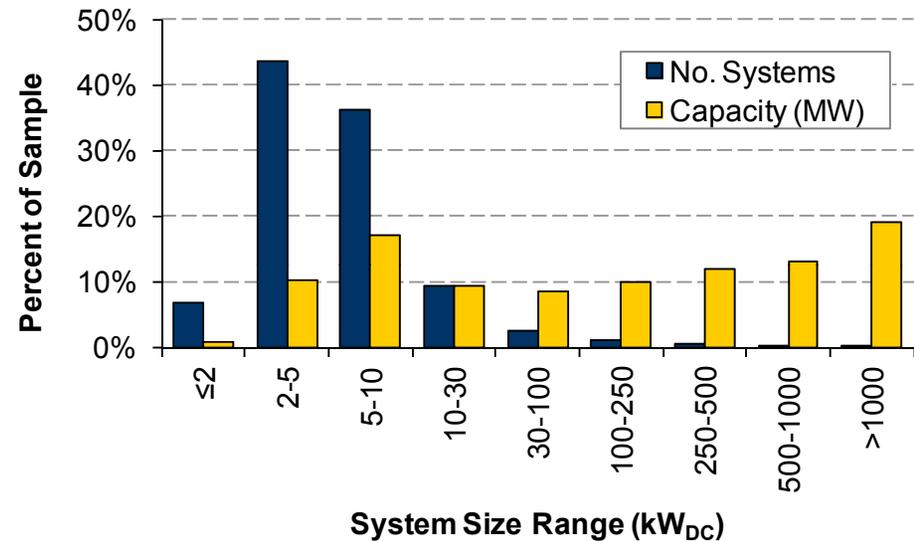
Data source for U.S. grid-connected PV capacity additions: Larry Sherwood (Interstate Renewable Energy Council)

Residential & Commercial PV Data Sample: Distribution Across States and by System Size

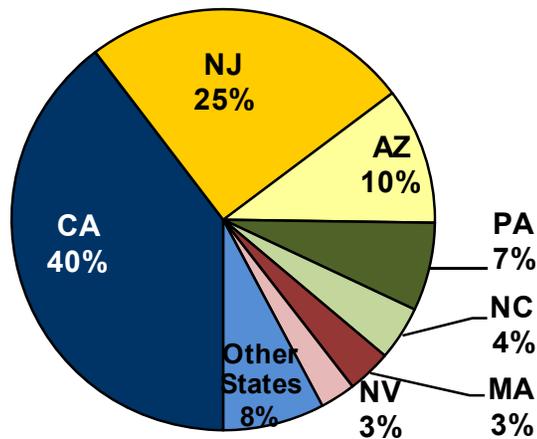
Distribution of Capacity Across States (1998-2011)



Sample Distribution by System Size



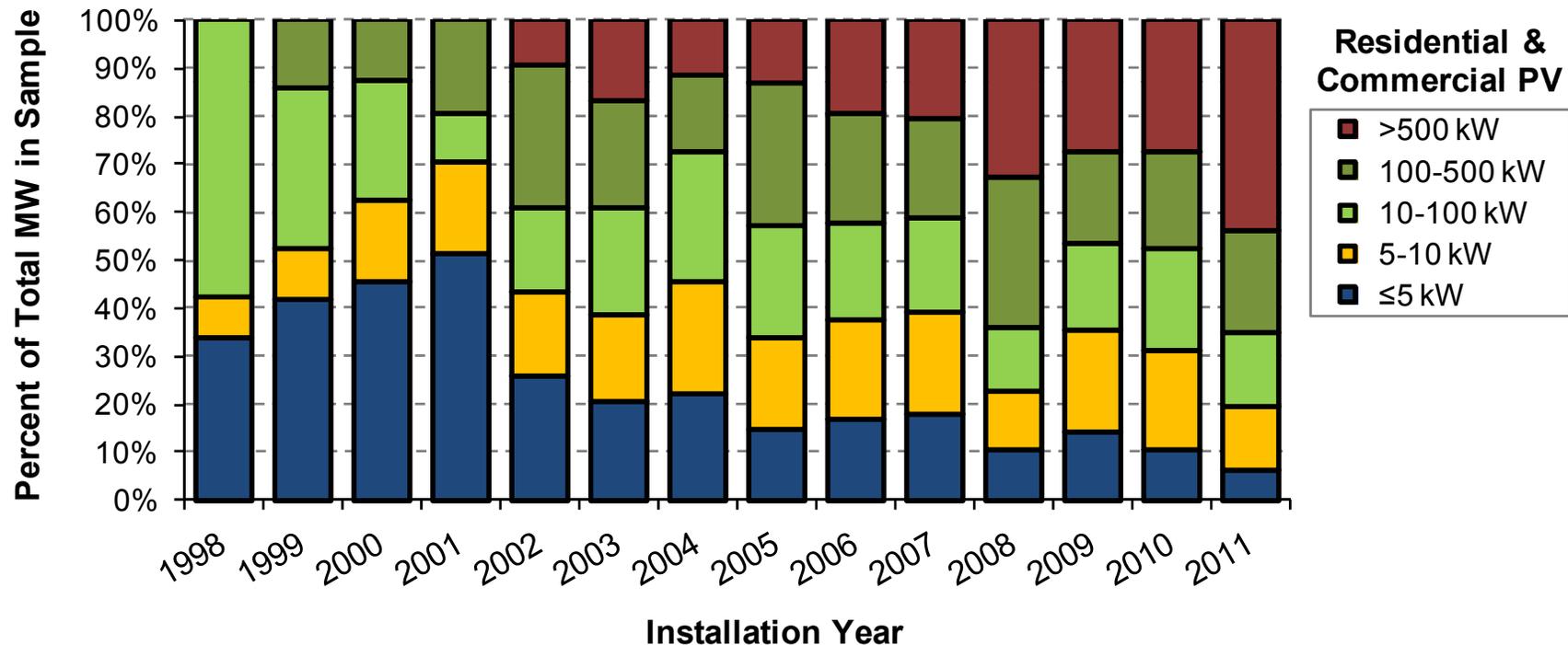
Distribution of Capacity Across States (2011 only)



- CA represents the majority of cumulative installed capacity in the data sample, though 2011 capacity additions are more evenly distributed across states
- The vast majority of systems are relatively small (<10 kW), though the sample capacity is evenly distributed across system sizes

Residential & Commercial PV Data Sample: System Size Trend over Time

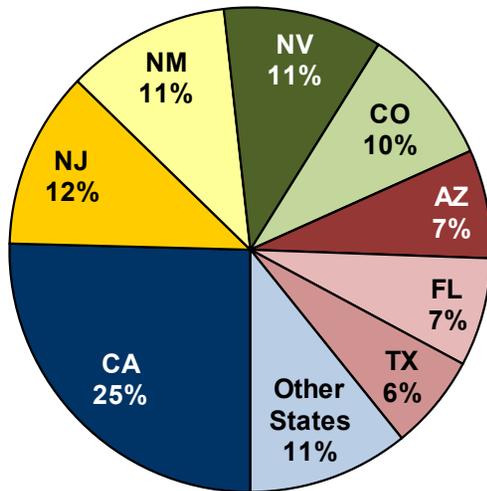
Over time, an increasing portion of residential and commercial PV capacity has consisted of relatively large systems



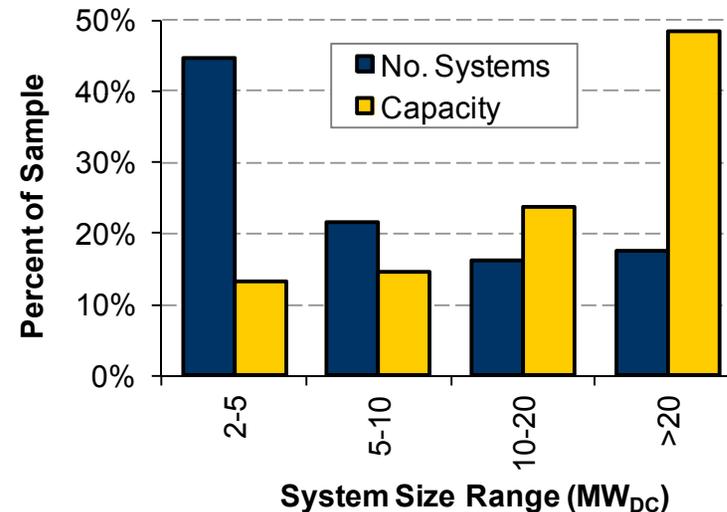
Utility-Scale PV Data Sample: Distribution Across States and by System Size

For the purpose of this report, *utility-scale PV* is defined to consist of ground-mounted systems with nameplate capacity of at least 2 MW

Distribution of Capacity Across States



Sample Distribution by System Size



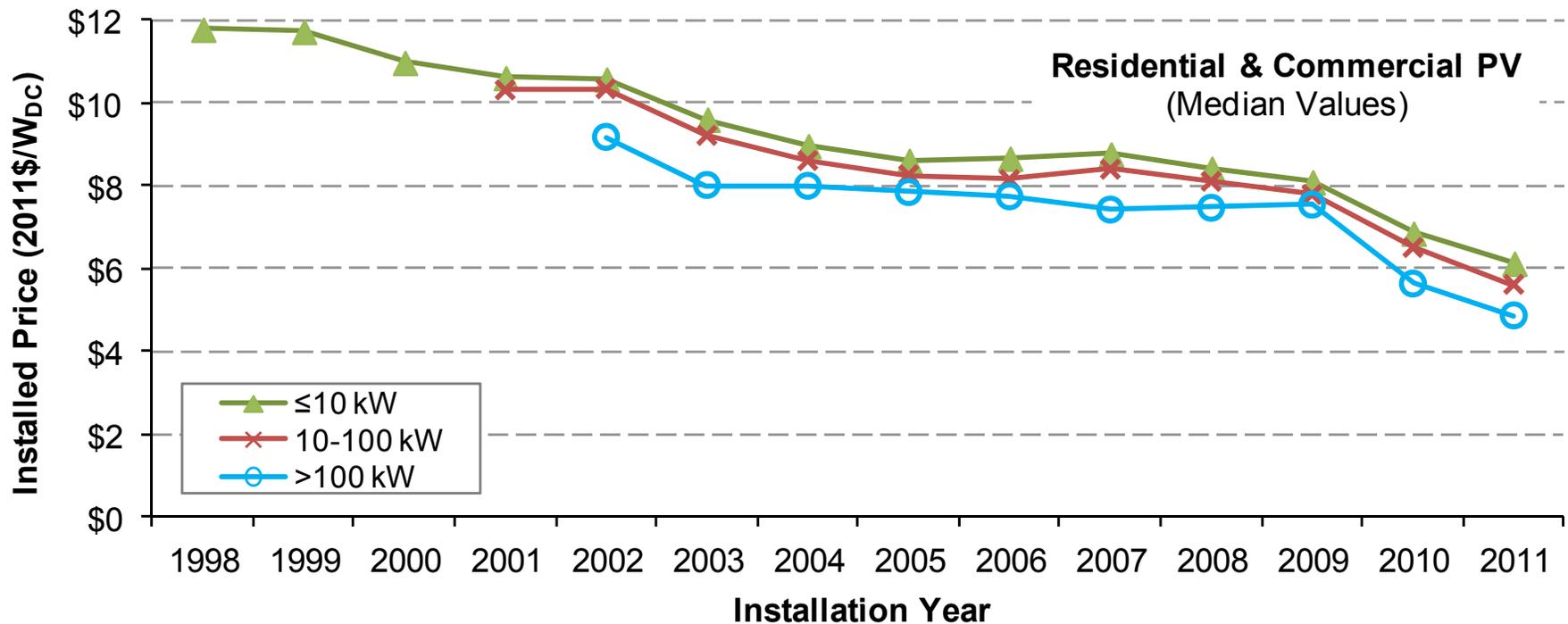
- The 80 utility-scale PV systems in the data sample are located in a total of 17 states, with 90% of that capacity distributed across 8 of those states (California, New Jersey, New Mexico, Nevada, Colorado, Arizona, Florida, and Texas)
- Systems range in size from 2 MW to 58 MW, a large fraction of which are <10 MW

Installed Price Trends for Residential & Commercial PV



Installed Prices Continued Their Precipitous Decline in 2011

Median installed prices fell by **\$0.7-0.9/W (11-14%)** from 2010 to 2011, across the three size ranges shown, and have fallen by an average of **5-7%** annually since 1998

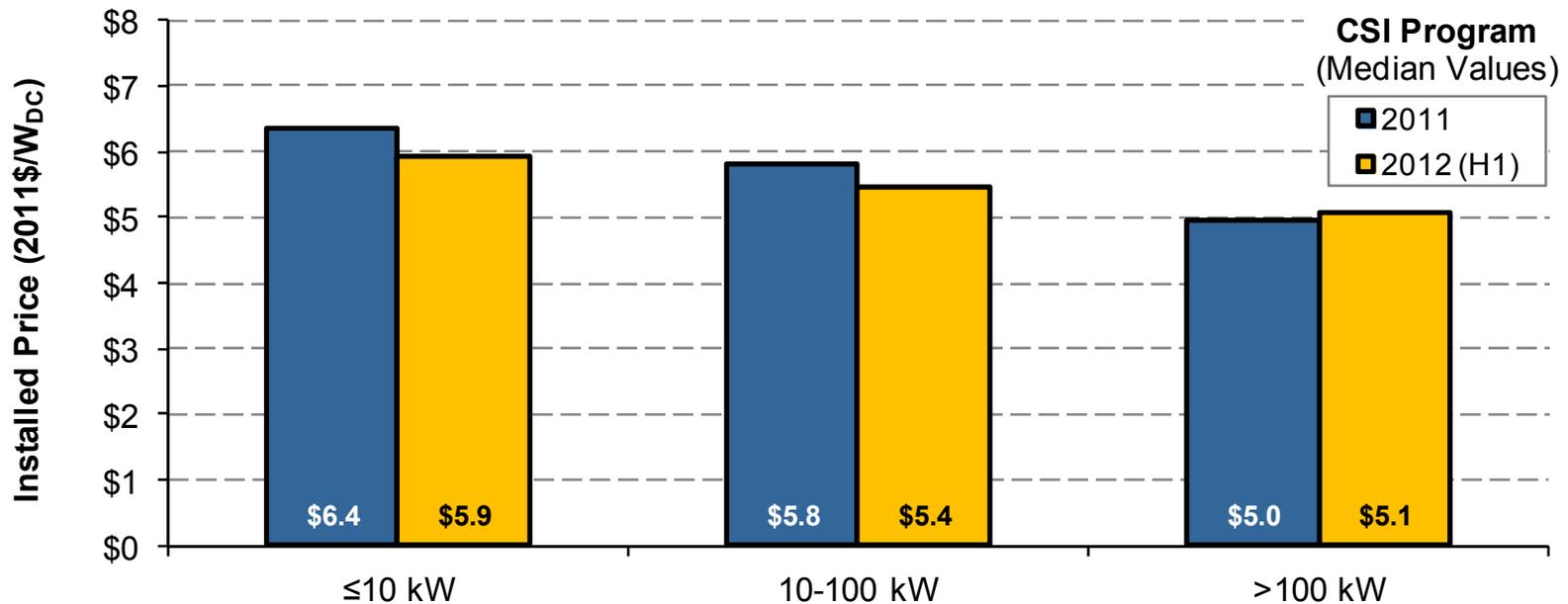


Note: Median installed prices are shown only if 15 or more observations are available for the individual size range

Preliminary Data for California Show That Installed Prices Continued to Fall into 2012

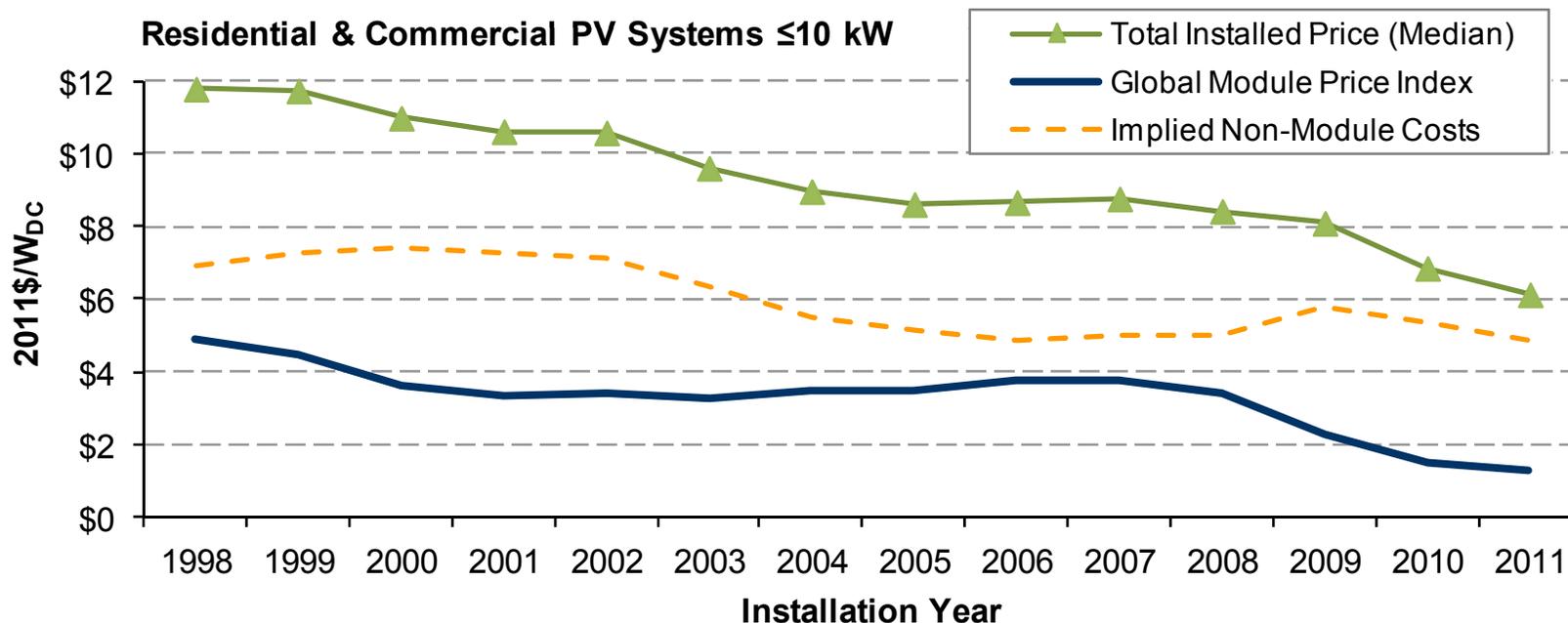
Median installed prices for ≤ 10 kW and 10-100 kW systems fell by roughly **\$0.4/W** (6-7%) in the CSI program during the first half of 2012, relative to 2011 (the slight increase for >100 kW systems is due to shift towards smaller systems within that size range from 2011 to H1 2012)

Median Installed Prices For Residential & Commercial Systems in the California Solar Initiative (CSI) Program: 2011 vs. the First-Half of 2012



Recent Installed Price Declines Primarily Reflect Falling Module Prices

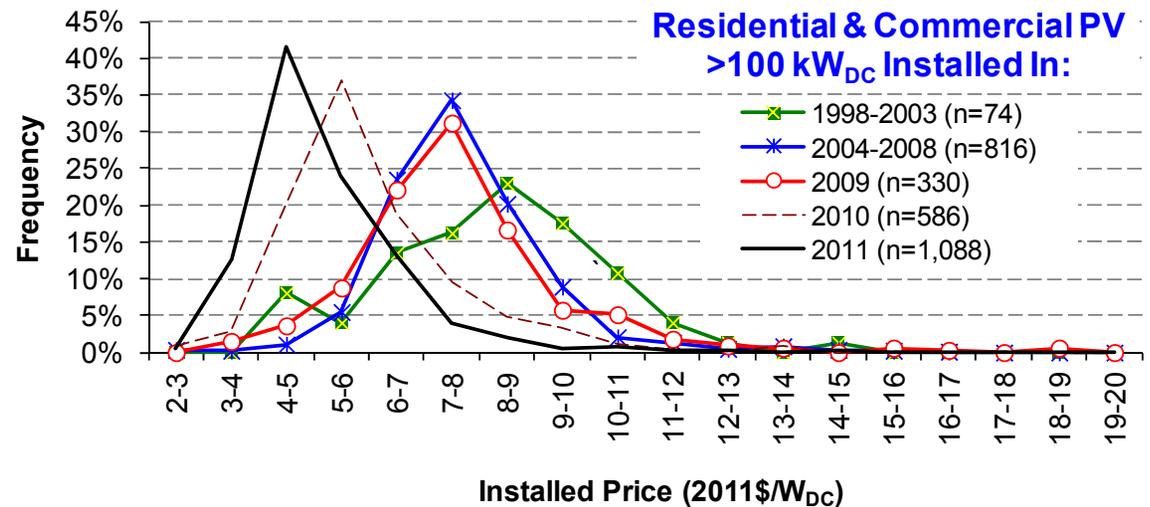
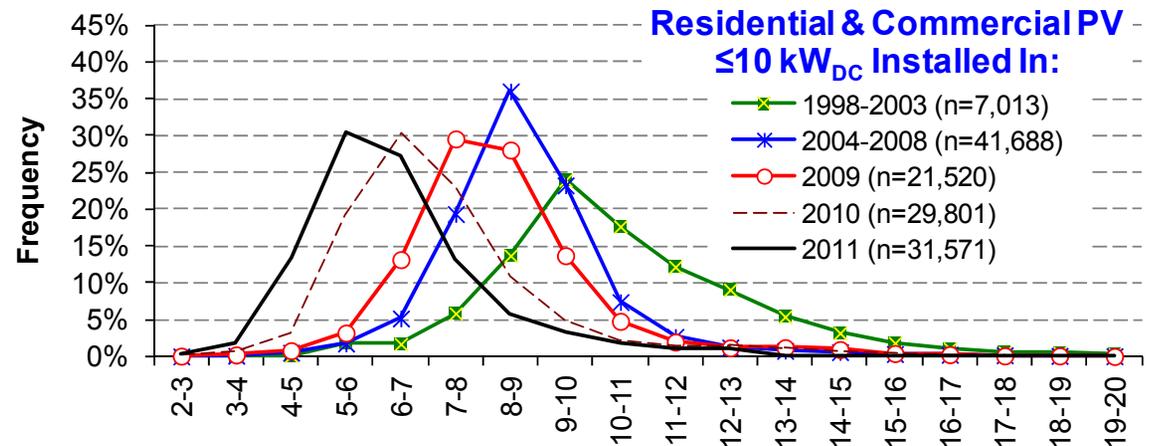
Global average module prices began a steep decline in 2008, falling by **\$2.1/W** from 2008-2011, with movements in total installed price appearing to lag behind; implied non-module costs have fallen by **\$2.0/W** since 1998, but have remained relatively flat in recent years



Notes: The Global Module Price Index is Navigant Consulting's module price index for large-quantity buyers (Mints, 2012). "Implied Non-Module Costs" are simply a residual term, equal to the Total Installed Price minus the Global Module Price Index.

Installed Prices Vary Widely Across Individual Projects

- Over time, installed price distributions have both shifted to the left and narrowed
- Narrowing is suggestive of a maturing market with greater competition and better informed consumers
- However, narrowing trends have ceased in recent years, and high degree of variability in pricing persists
- Among ≤ 10 kW systems installed in 2011, 15% of systems were priced $< \$5/W$ while a similar percentage was $> \$8/W$



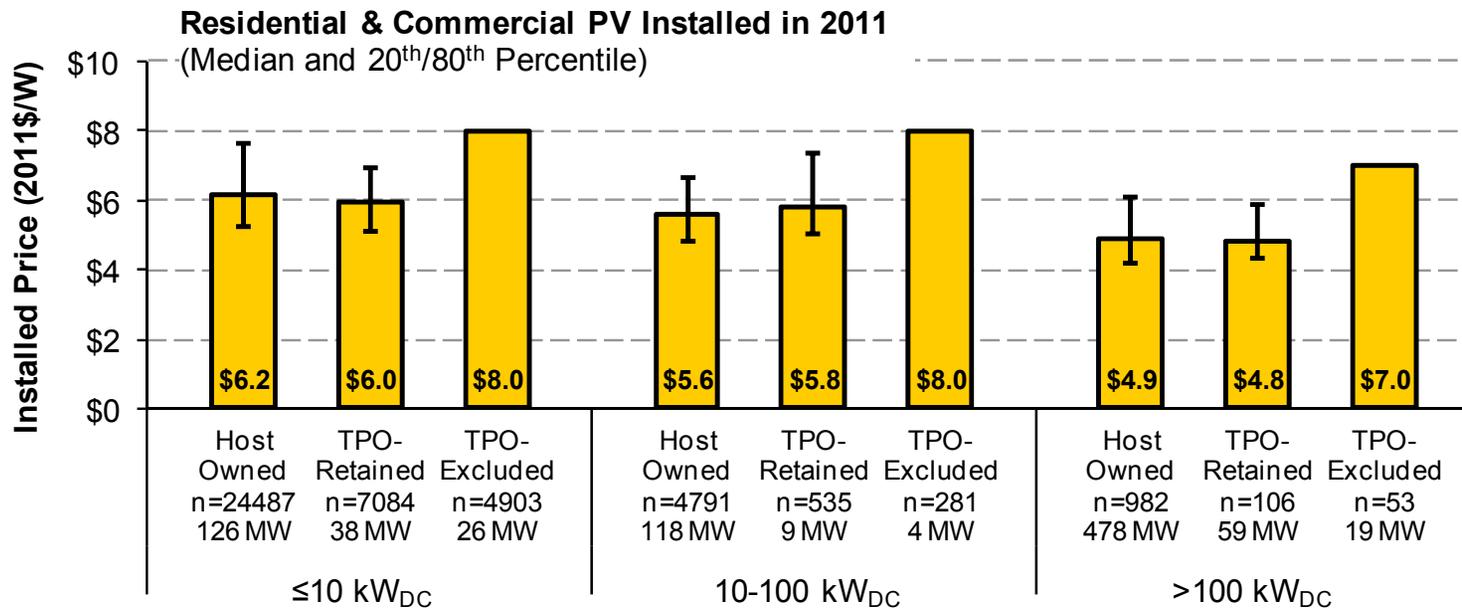
Installed Price Reporting for Third Party Owned Systems Complicates The Analysis of Price Trends

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 possible, 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

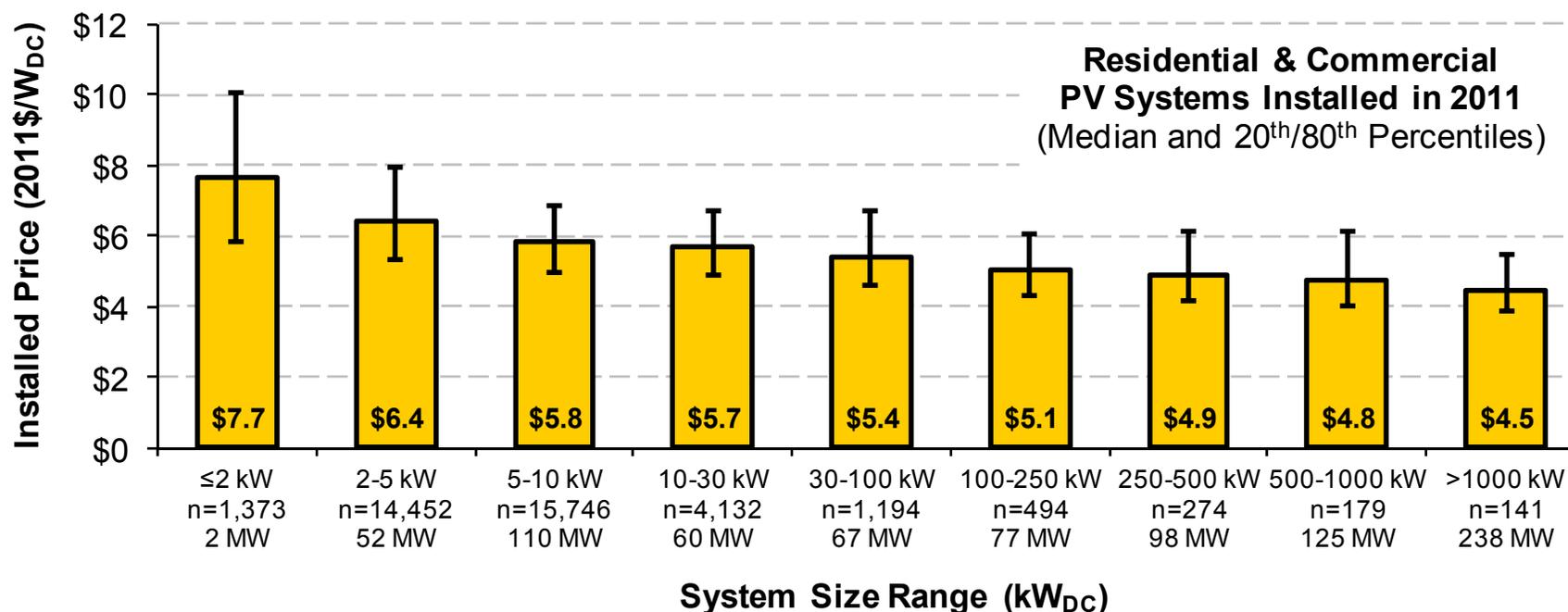
- In contrast, TPO systems excluded from the sample (i.e., appraised value systems) have much higher installed prices than customer owned systems (e.g., \$8.0/W vs. \$6.2/W among ≤ 10 kW systems installed in 2011)



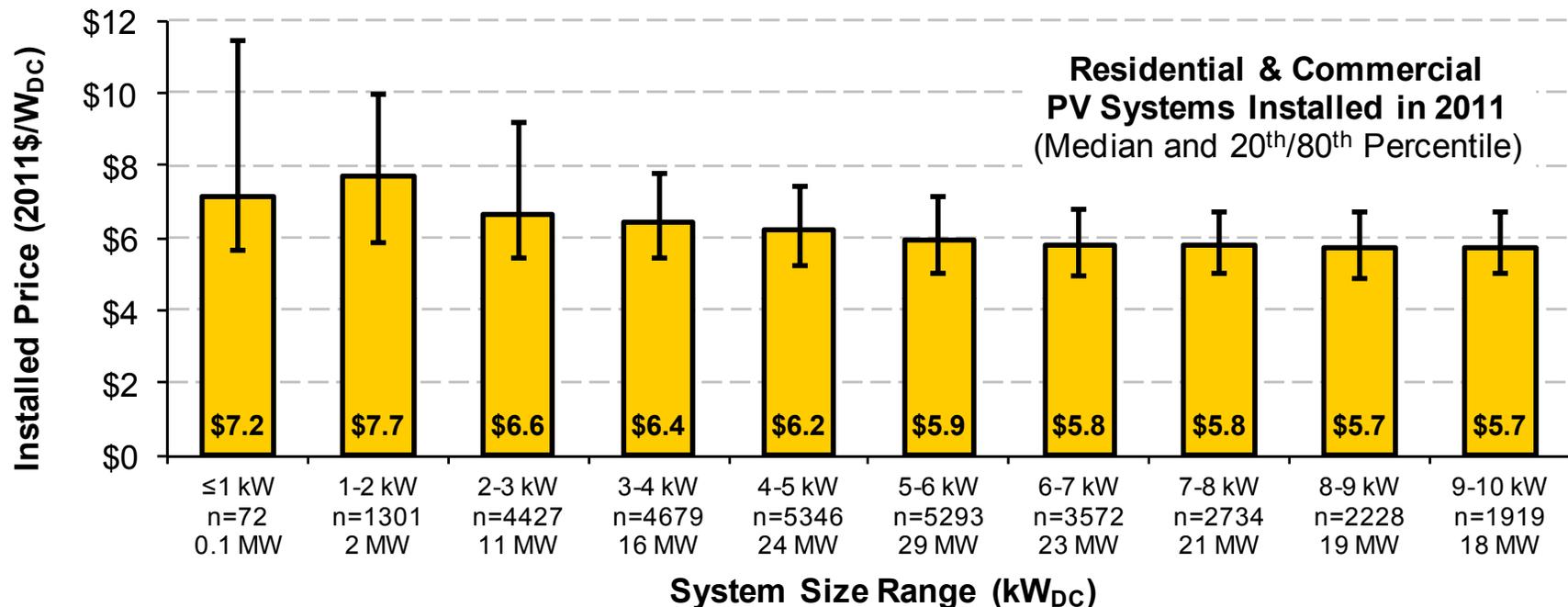
Notes: TPO-Retained refers to third party owned systems that were retained in the data sample. TPO-Excluded refers to third party owned systems for which reported installed prices were deemed likely to represent an appraised value; those systems are excluded from all other figures in the report. No percentile bands are shown for TPO-Excluded systems, as the percentile values and median values are identical within each size range.

Installed Prices Exhibit Economies of Scale

The median installed price of >1,000 kW systems installed in 2011 (excluding utility-scale, analyzed separately) was **42%** lower than for ≤ 2 kW systems (**\$4.5/W** vs. **\$7.7/W**), though reductions in installed price with system size show diminishing returns to scale



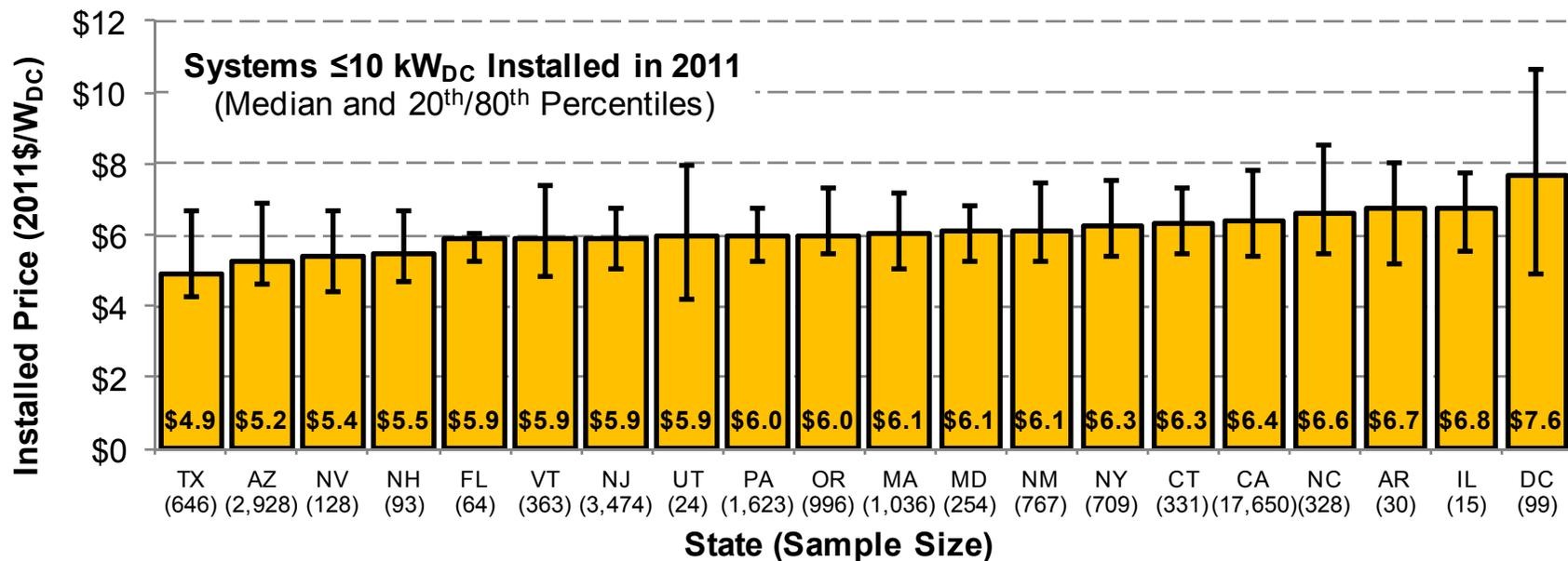
Economies of Scale Are Particularly Pronounced up to a 5-6 kW System Size



- The median price of 5-6 kW systems installed in 2011 was **23%** lower than for 1-2 kW systems (\$5.9/W vs. \$7.7/W), and price variability also lower
- The median size of ≤10 kW systems has grown from 2.3 kW in 1998 to 5.0 kW in 2011, partly contributing to the long-term decline in median prices for this class of systems

Installed Prices Differ Significantly Across States

- Across the 20 states for which sufficient data was available, median installed prices ranged from **\$4.9/W** to **\$7.6/W** among ≤ 10 kW systems installed in 2011, reflecting a range of potential state and local drivers
- California is a relatively expensive state and comprises a large share of the data sample, pulling the overall sample median upward

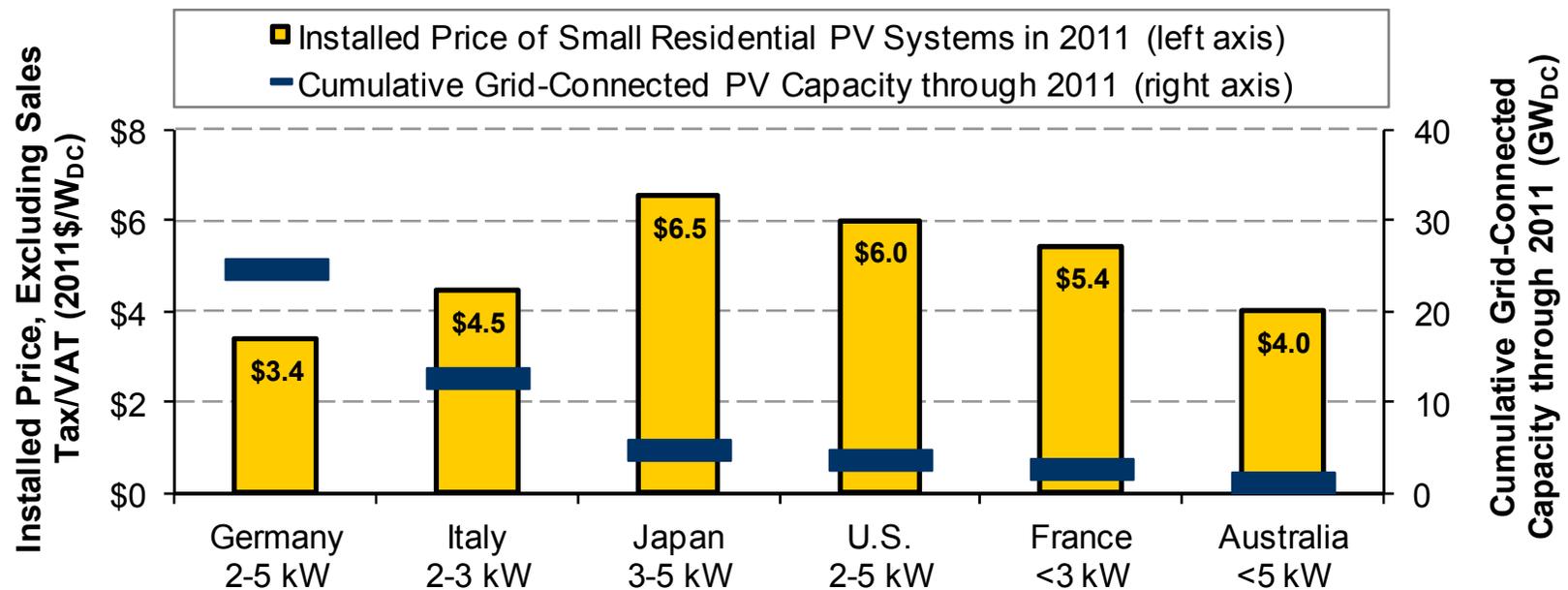


Notes: Median installed prices are shown only if 15 or more observations were available for a given state.



The Installed Price of Small Residential PV in the United States Is Higher than in Other Countries

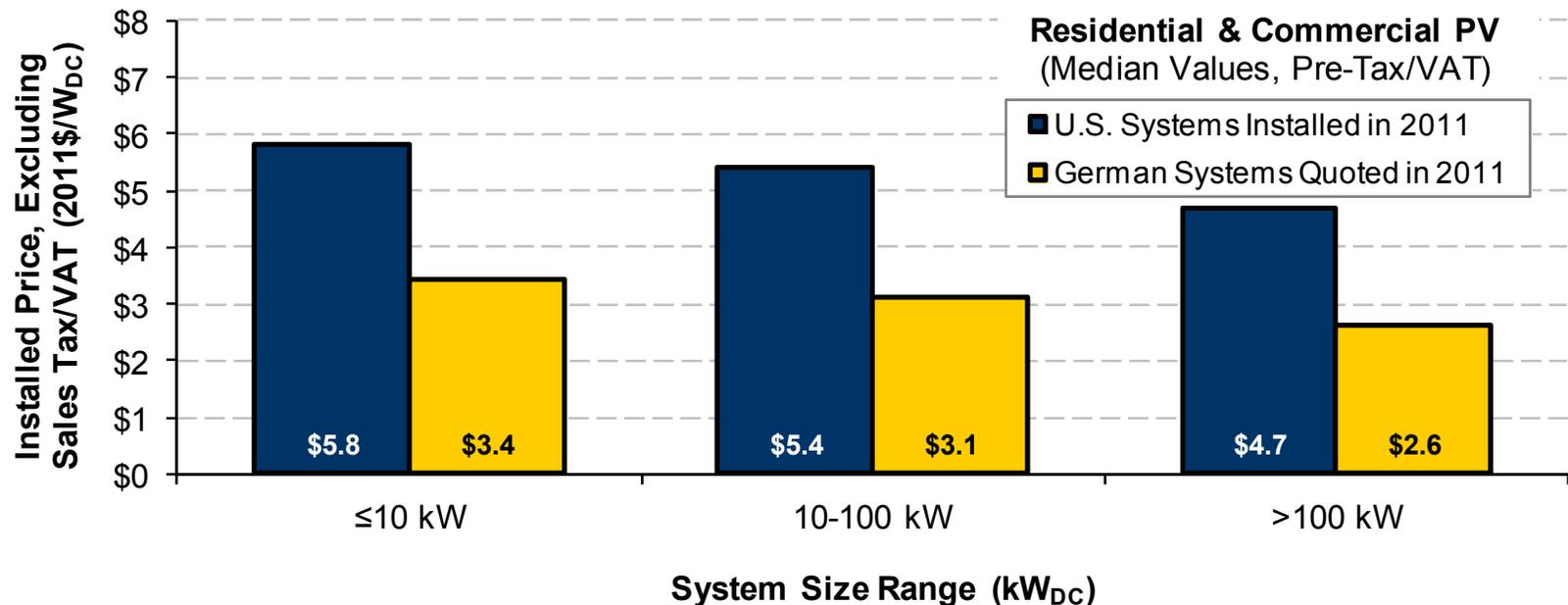
The lower prices in other countries largely reflects differences in “soft costs,” which may be driven partly by differing levels of deployment scale, though other factors are also likely at play



Notes: The U.S. data point represents the median price of 2-5 kW residential systems installed in 2011, and unlike other figures presented in this report, excludes sales tax. All other installed price data represent the “turnkey price of typical PV applications” reported in each country’s IEA PVPS Country Report, for the particular size range shown. For Germany, the reported price in each year’s country report represents the year-end price, and the value plotted in the figure is the average of the year-end 2010 and year-end 2011 values, in order to provide greater comparability to the other values, which represent annual averages for 2011. Cumulative installed capacity data for each country derive from REN21 (2012).

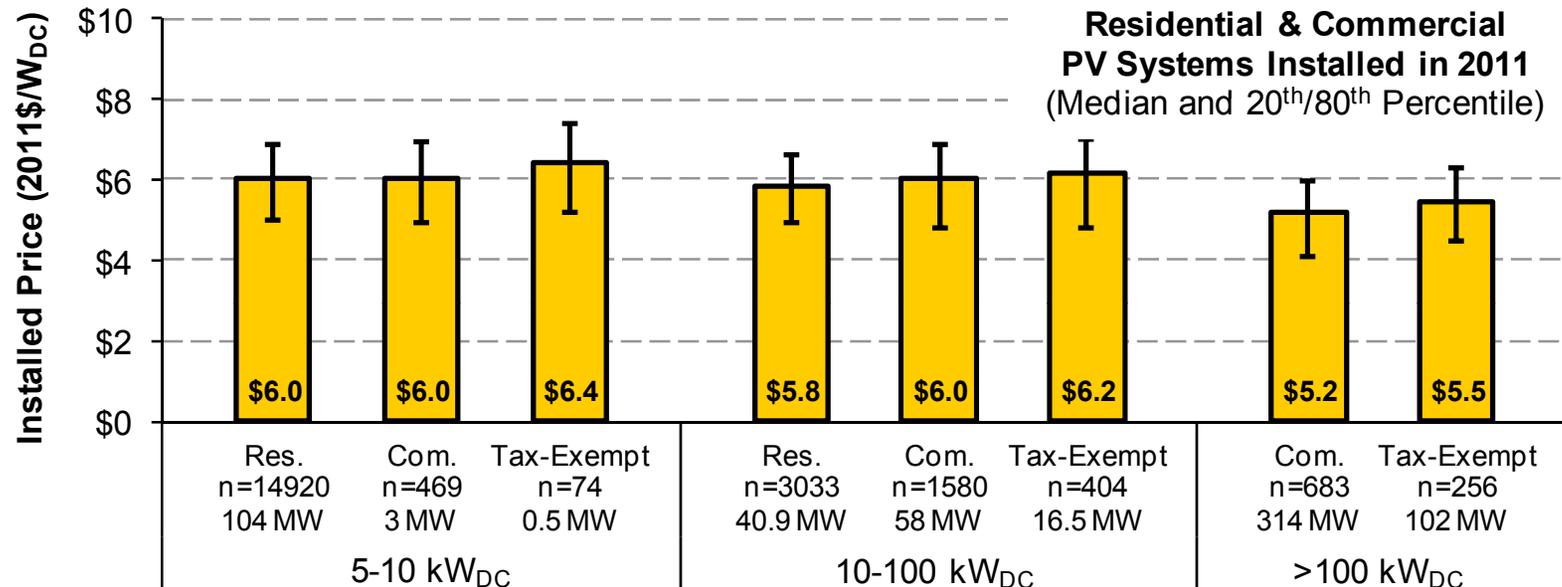
Installed Prices in Germany Are Lower Than in the U.S. across a Wide Range of System Sizes

The pricing disparity between the United States and other major international PV markets is greatest in comparison to Germany, where installed prices are **44-46% lower** across the three size ranges shown



Notes: This figure relies upon price quotes for 5,729 individual German PV systems, obtained by EuPD through its quarterly survey of German installers and provided to LBNL (EuPD 2012).

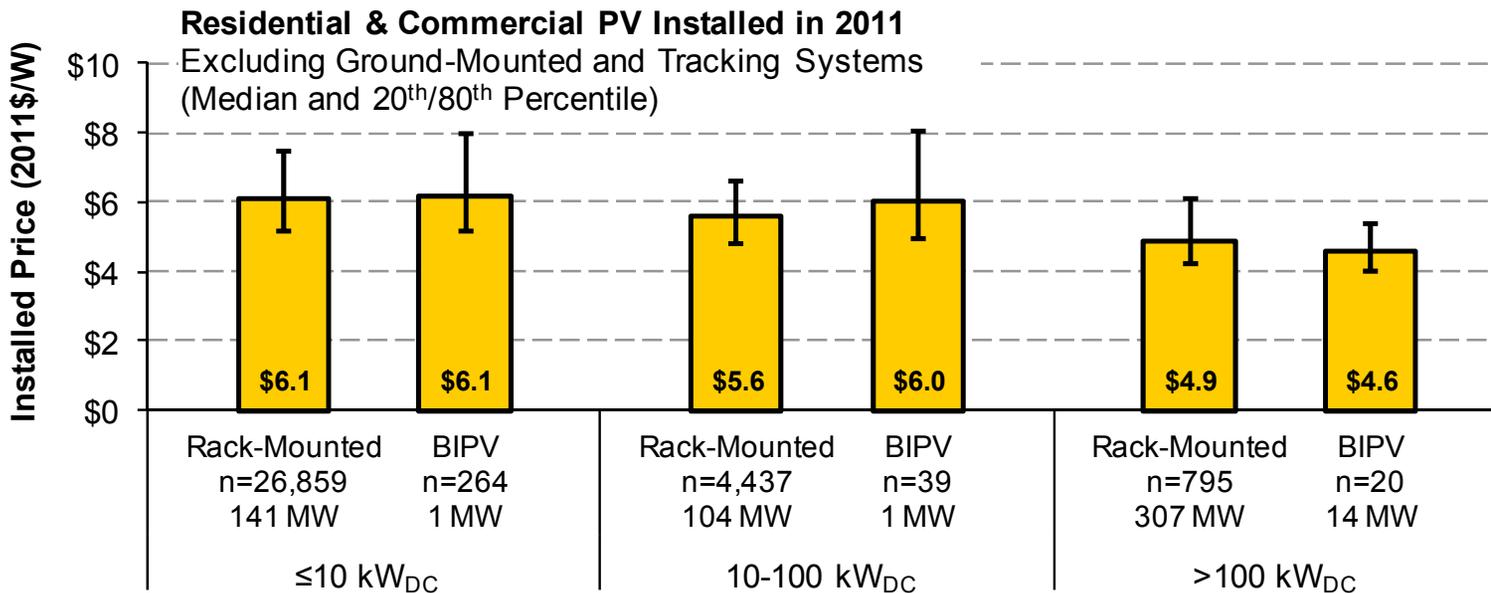
Installed Prices for Tax-Exempt Customers Are Moderately Higher Than Other Customer Segments



- The median price of systems installed at tax-exempt customer sites was \$0.2/W to \$0.5/W higher than residential and commercial systems within each size range, potentially reflecting higher transaction costs for public sector entities (though the gap has shrunk over time)
- In prior years, installed prices for residential systems were generally lower than for similarly sized commercial systems, though that trend largely abated in 2011

Installed Prices Have Historically Been Higher for BIPV than for Rack-Mounted PV (for small systems)

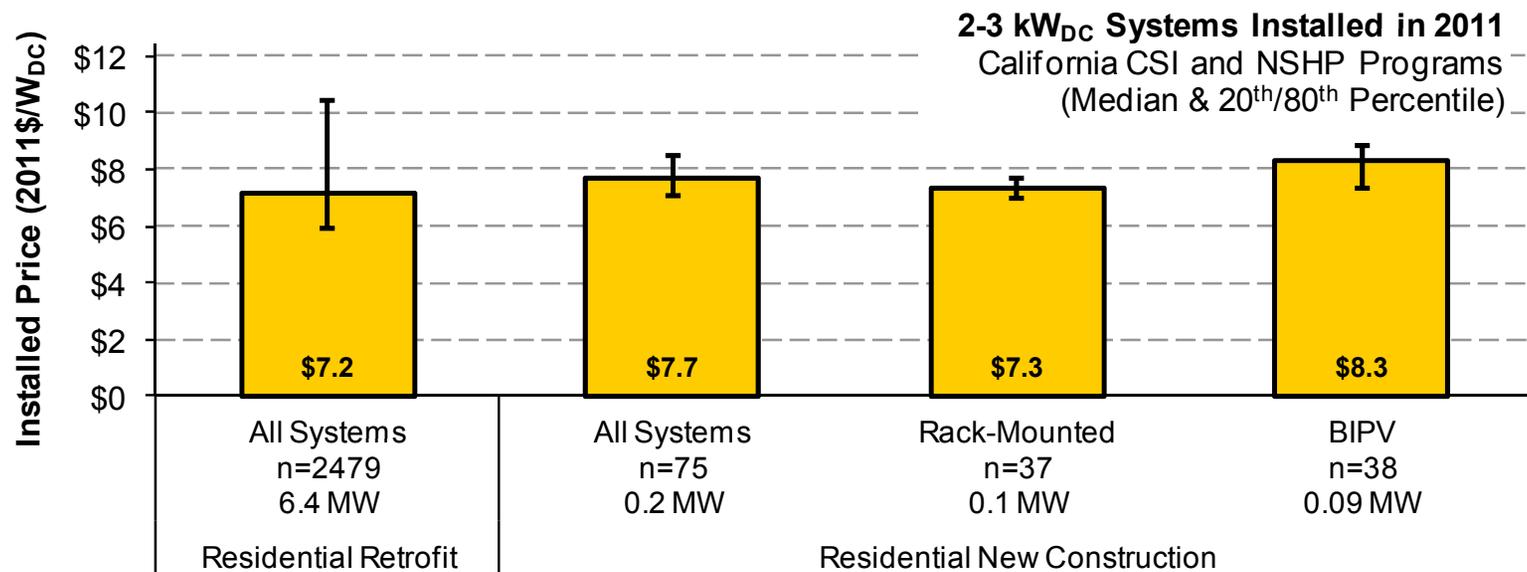
- Among systems ≤ 10 kW, median installed prices were \$0.3-\$0.9/W higher for BIPV than for rack-mounted systems during 2007-2010, but were roughly equivalent in 2011
- For larger systems, no consistent trend is evident in either 2011 or prior years, potentially as a result of small sample sizes



Notes: The data sample used for this comparison excludes all identifiable ground-mounted and tracking systems in order to eliminate any biases associated with a higher incidence among rack-mounted systems

The New Construction Market Has Historically Offered Price Advantages for Small Residential PV

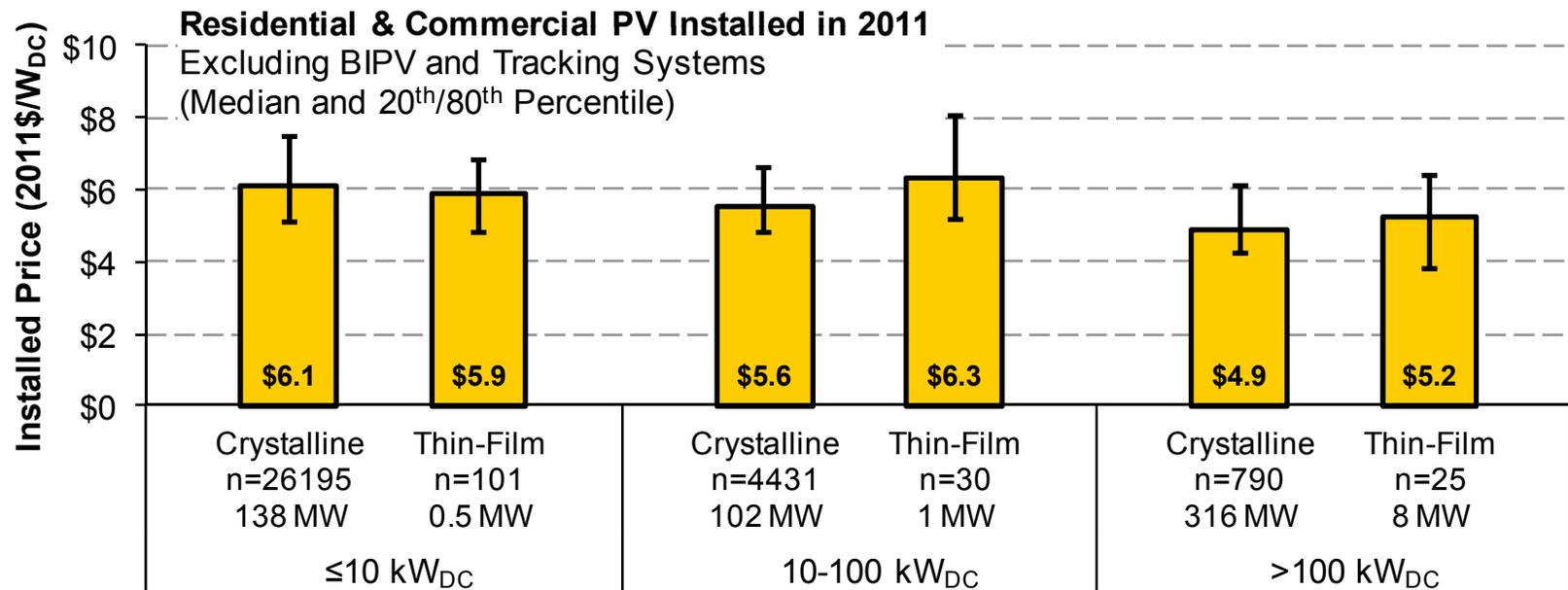
Prior years have shown lower prices for small residential PV in new construction than in retrofits (**\$0.3-\$0.5/W** less overall, and **\$0.8-\$1.2/W** less for rack-mounted systems); these trends did not persist in 2010/2011, which may be an artifact of the slowdown in the new construction market



Notes: Values shown for retrofits are based residential PV systems installed through the California Solar Initiative (CSI), and values shown for residential new construction are based on systems funded through California's New Solar Homes Partnership (NSHP) program. The comparison is focused on systems in the 2-3 kW size range, as that is the most common size range for residential new construction systems.

No Consistent Differential Is Evident between Thin-Film and Crystalline System Prices

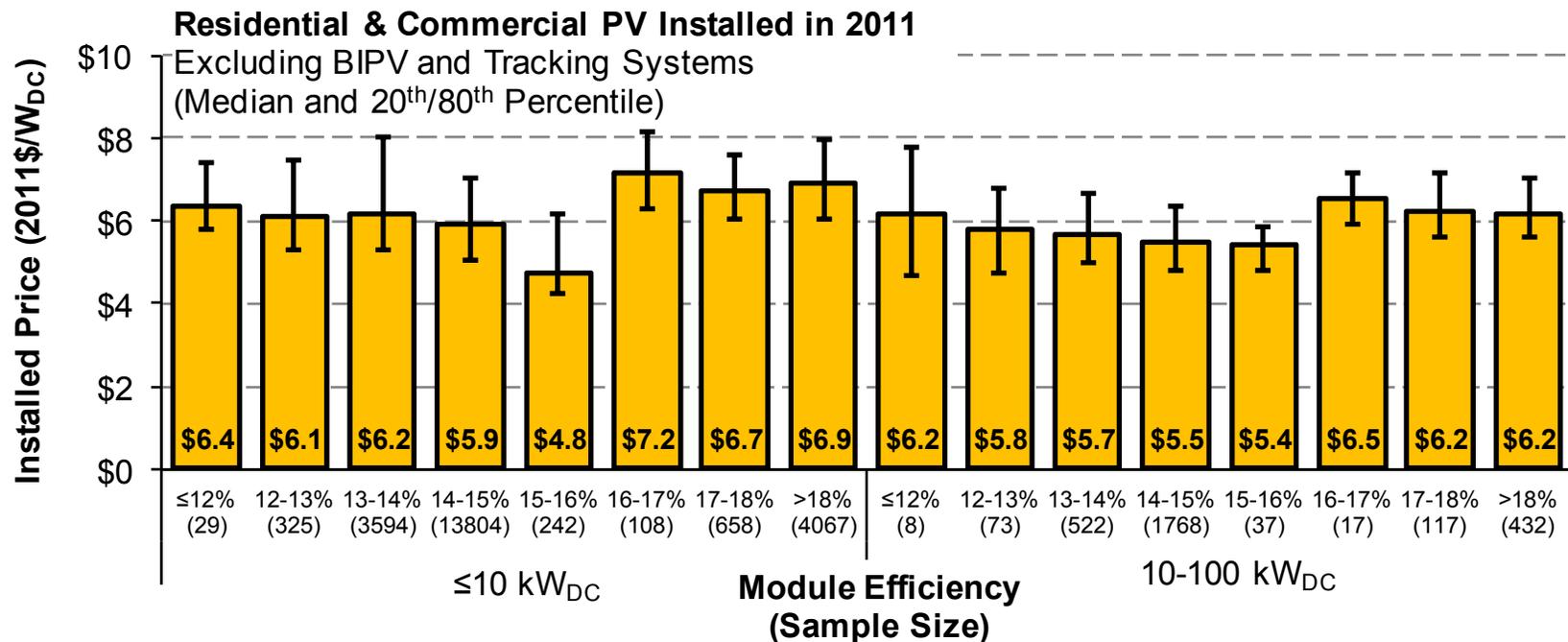
In 2011, as well as in prior years, neither those systems with crystalline modules nor those with thin-film modules exhibited any consistent price advantage across system sizes (though small sample size of thin-film systems may obscure underlying trends)



Notes: The data sample used for this comparison excludes all identifiable BIPV and tracking systems in order to eliminate any biases associated with a higher incidence of BIPV among thin-film systems and/or a higher incidence of tracking equipment among crystalline systems.

Installed Prices Are Lowest for Systems Using Modules with Mid-Range Efficiencies

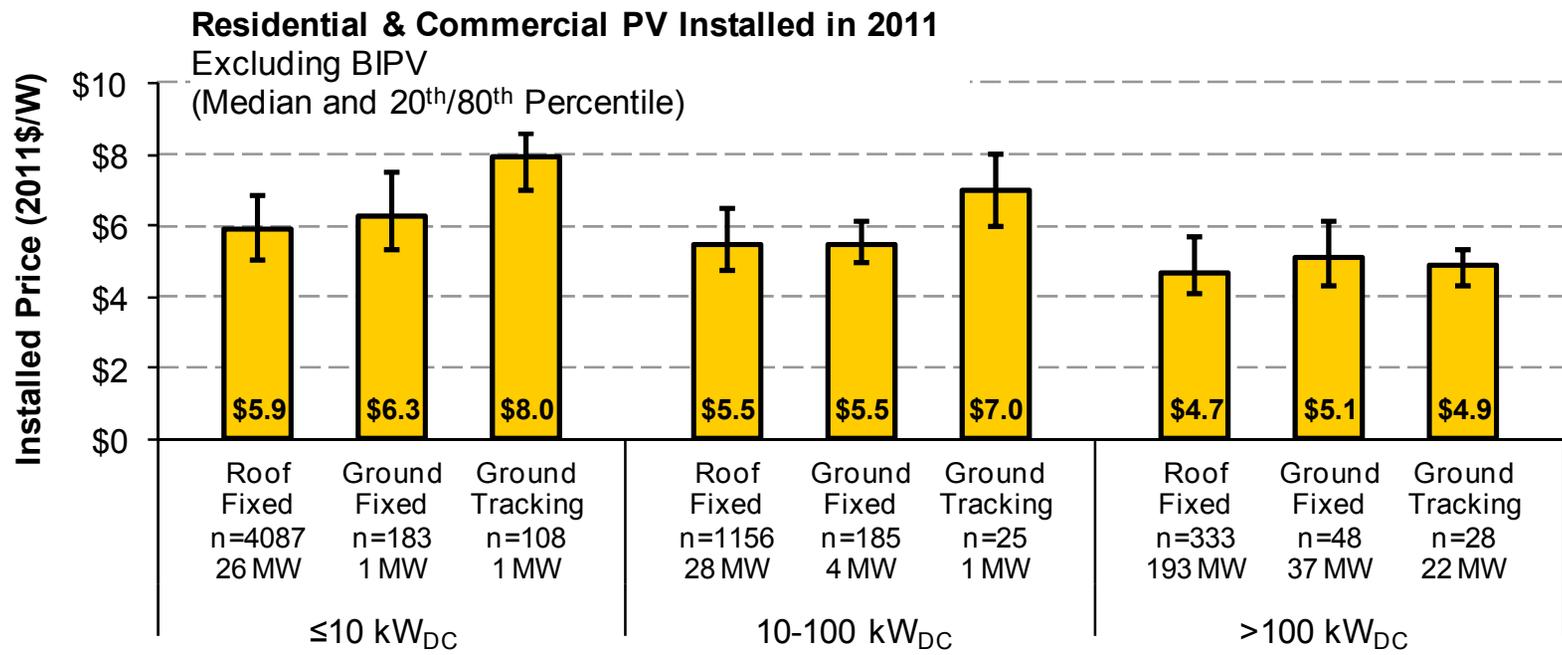
- Within both size ranges shown, systems with module efficiencies of 14-16% had the lowest installed price in 2011 (and in earlier years as well)



Notes: The data sample used for this comparison excludes all identifiable BIPV and tracking systems in order to eliminate any biases associated with correlations between BIPV or tracking equipment and module efficiency.

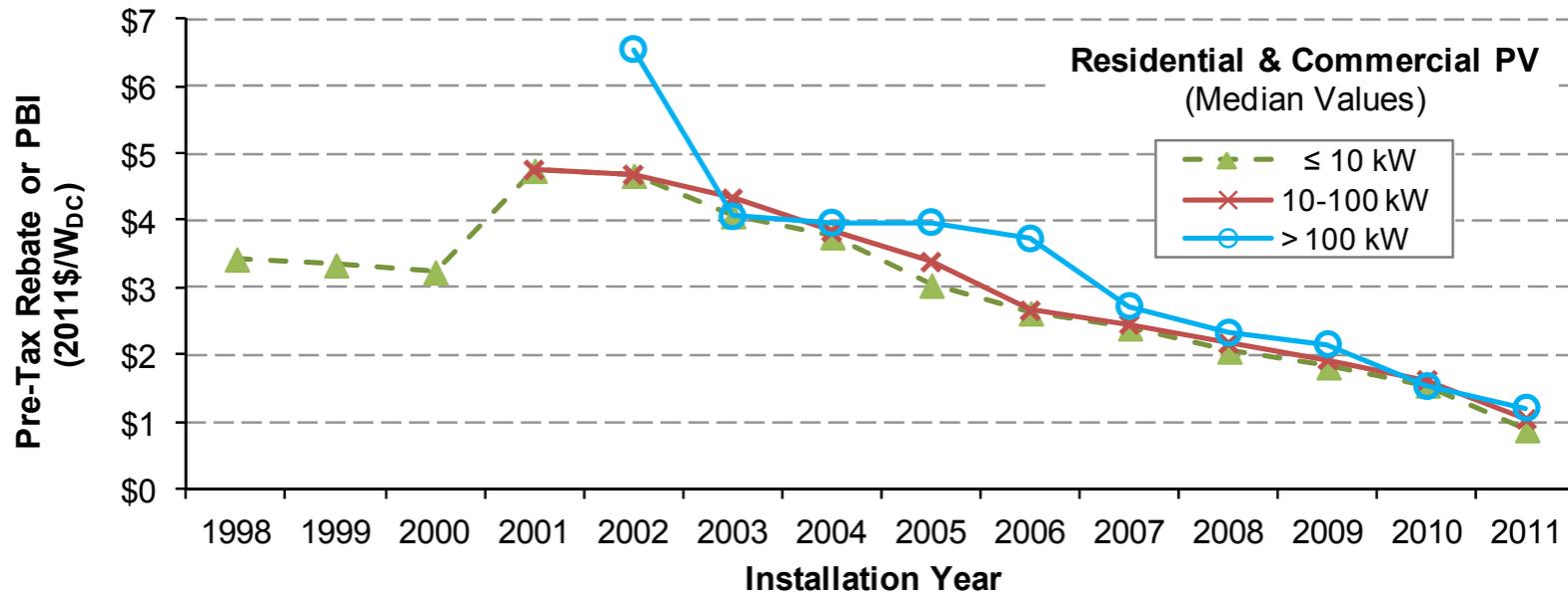
Installed Prices Are Typically Higher for Ground-Mounted Systems and for Systems with Tracking

- The median installed price of rooftop systems was \$0.4/W less than fixed-tilt ground-mounted systems, within both the ≤ 10 kW and the >100 kW size range (though no pricing difference is apparent in the 10-100 kW range).
- Ground-mounted systems with tracking had median installed prices \$1.7/W greater than fixed-tilt ground-mounted systems within the ≤ 10 kW size range and \$1.5/W greater within the 10-100 kW size range



State/Utility Cash Incentives Continued Their Steady Decline in 2011

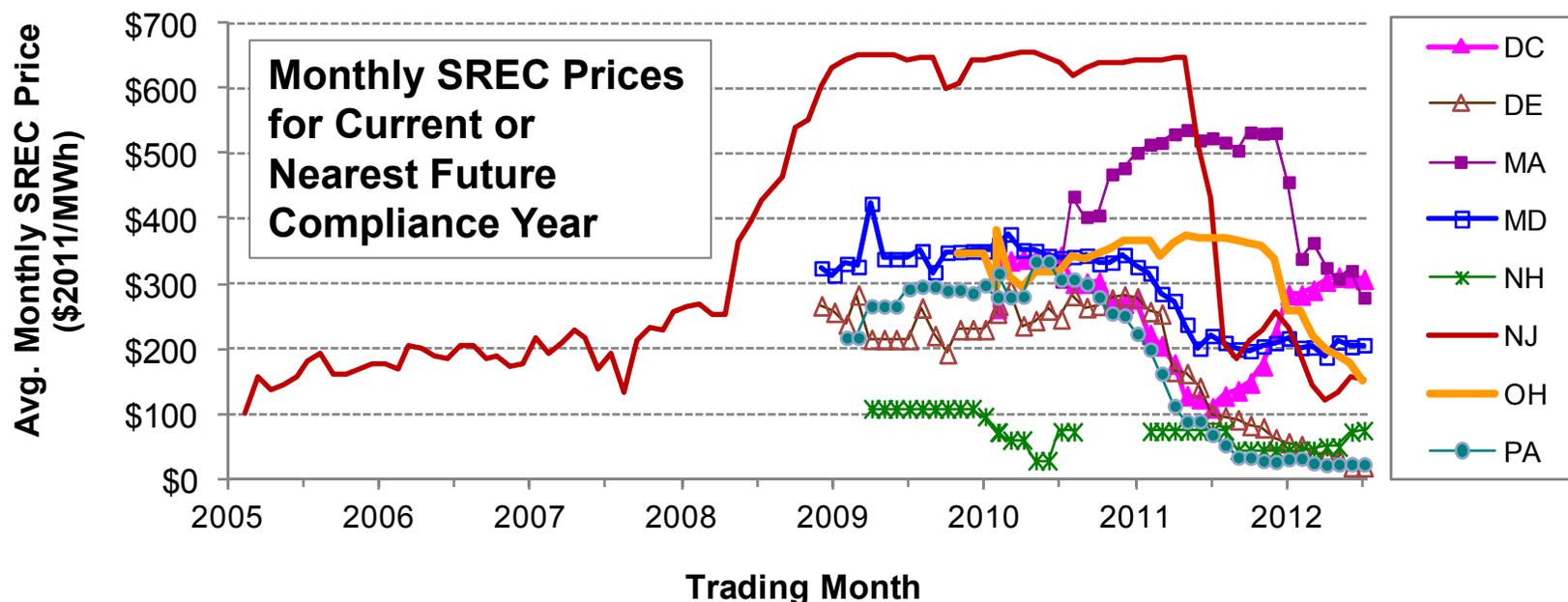
Median cash incentives from state/utility incentive programs in 2011 ranged from \$0.9-\$1.2/W across the three system size categories shown, falling by 21-43% relative to 2010 and by 80% relative to the historical peak



Notes: The figure focuses solely on the pre-tax value of rebates and PBI payments provided through the state/utility PV incentive programs in the data sample. As such, it ignores state or federal tax credits, the Section 1603 treasury grant, accelerated depreciation, and potential revenues from ongoing SREC payments. When calculating median values, systems in the data sample that received incentives solely in the form of ongoing SREC payments over time were excluded from the calculation. The high median incentive for >100 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. Results are omitted from the figure if fewer than 15 observations are available.

SREC Prices in Many Markets Have Also Declined Significantly

Solar renewable energy certificate (SREC) prices fell precipitously in most markets during 2011 and into 2012 as a result of oversupply in states with RPS solar set-asides, with spot prices and long-term contract prices in several major markets dropping to \$100-\$200/MWh (or lower)



Sources: Spectron, SRETrade, 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. Long-term contract prices, if available, may be either higher or lower than contemporaneous spot-market prices, depending on the particular state.

Installed Price Trends for Utility-Scale PV

(Ground-Mounted PV >2 MW)



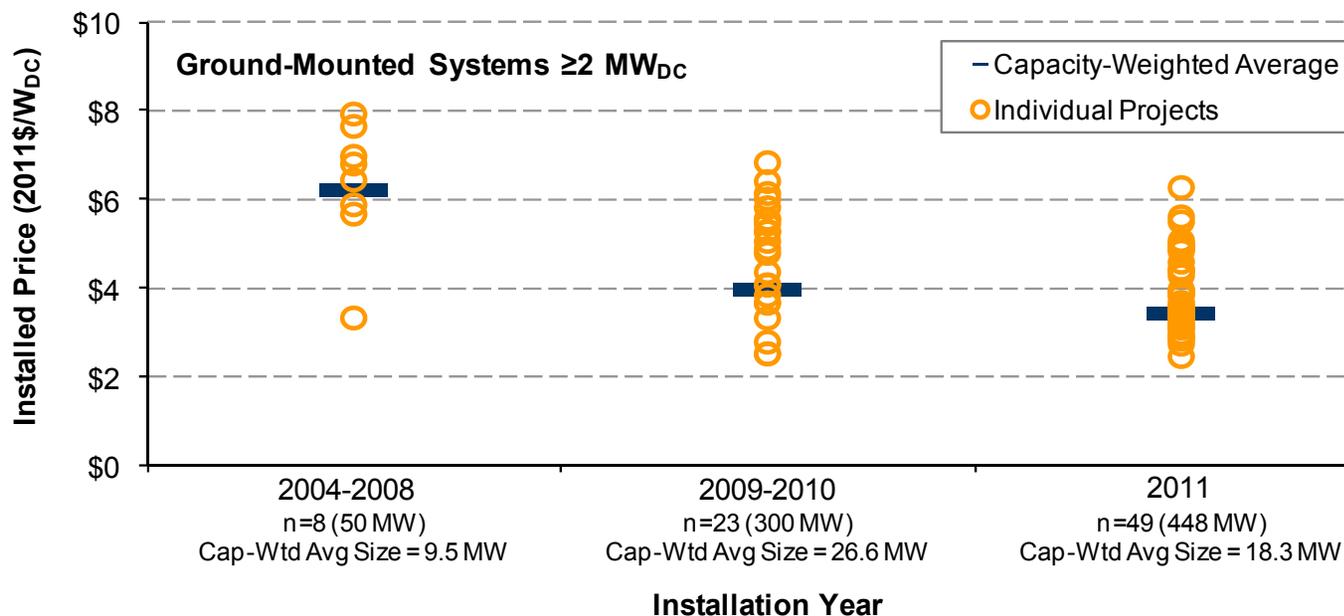
Important Caveats for Utility-Scale PV Installed Price Data

The utility-scale installed price data presented here must be interpreted with a certain degree of caution, for several reasons:

- ***Small sample size including atypical utility-scale PV projects:*** The sample is relatively small (80 systems) and includes a number of relatively small projects as well as a number of “one-off” projects with atypical project characteristics
- ***Lag in component pricing and market conditions:*** The installed price of some projects may reflect component pricing (and/or the market conditions under which power sales agreements were signed) one or two years prior to project completion, and therefore the data sample may not fully capture the recent decline in component prices or other changes in market conditions
- ***Reliability of data sources:*** The data are derived from varied sources and, in some instances (e.g., trade press articles and press releases), are arguably less reliable than the installed price data presented earlier for residential & commercial systems
- ***Focus on installed price rather than levelized cost:*** The focus on installed price ignores performance-related differences and other factors that influence the levelized cost of electricity, a more comprehensive cost metric for utility-scale PV

The Installed Price of Utility-Scale PV Varies Considerably But Has Declined Overall

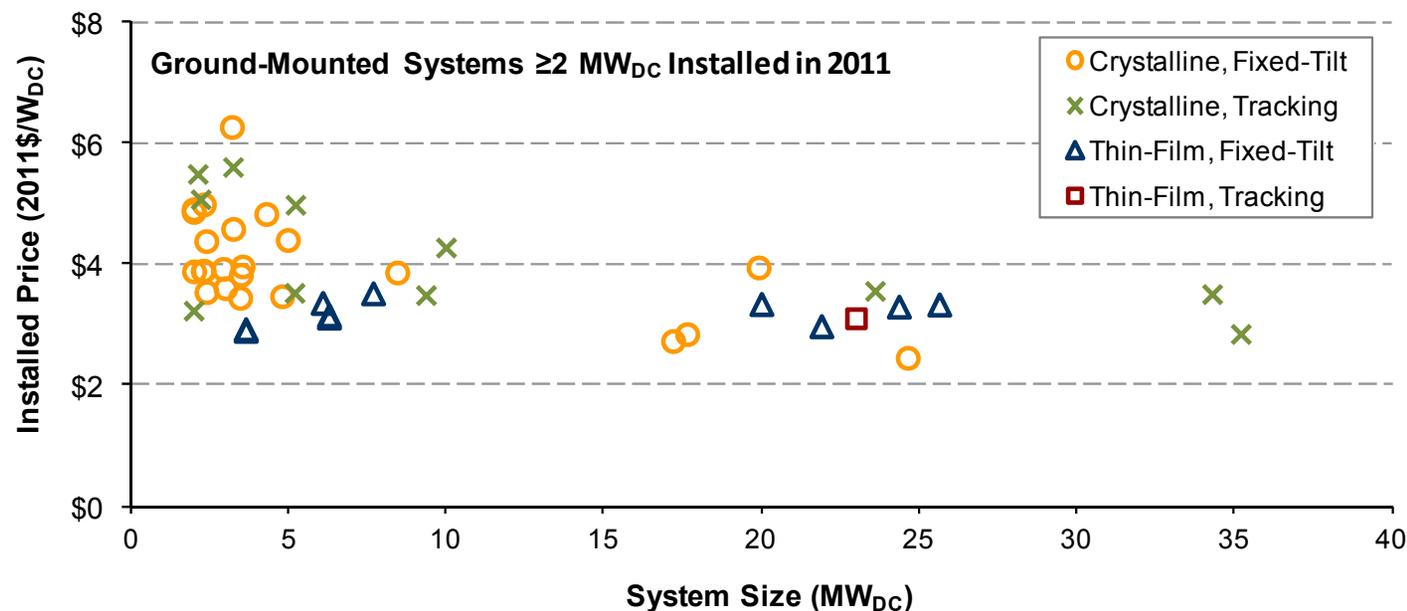
- Among the 49 projects in the sample completed in 2011, installed prices ranged from **\$2.4-\$6.3/W**, with a capacity-weighted average of \$3.4/W (compared to \$4.5/W for >1 MW commercial PV, shown previously)
- Cap-weighted average prices declined from \$3.9/W for projects installed during 2009-2010 and from \$6.2/W for projects installed during 2004-2008



Notes: The figure includes a number of relatively small (2-10 MW) utility-scale projects as well as several "one-off" projects. In addition, the reported installed price of projects completed in any given year may reflect module and other component pricing at the time of project contracting, which may have occurred one or two years prior to installation. For these reasons and others, the data shown here may not accurately depict the installed price of typical utility-scale PV projects completed more recently or currently under development and may not correspond well to recent installed price benchmarks for utility PV.

The Installed Price of Utility-Scale Projects Depends on Project Size and System Configuration

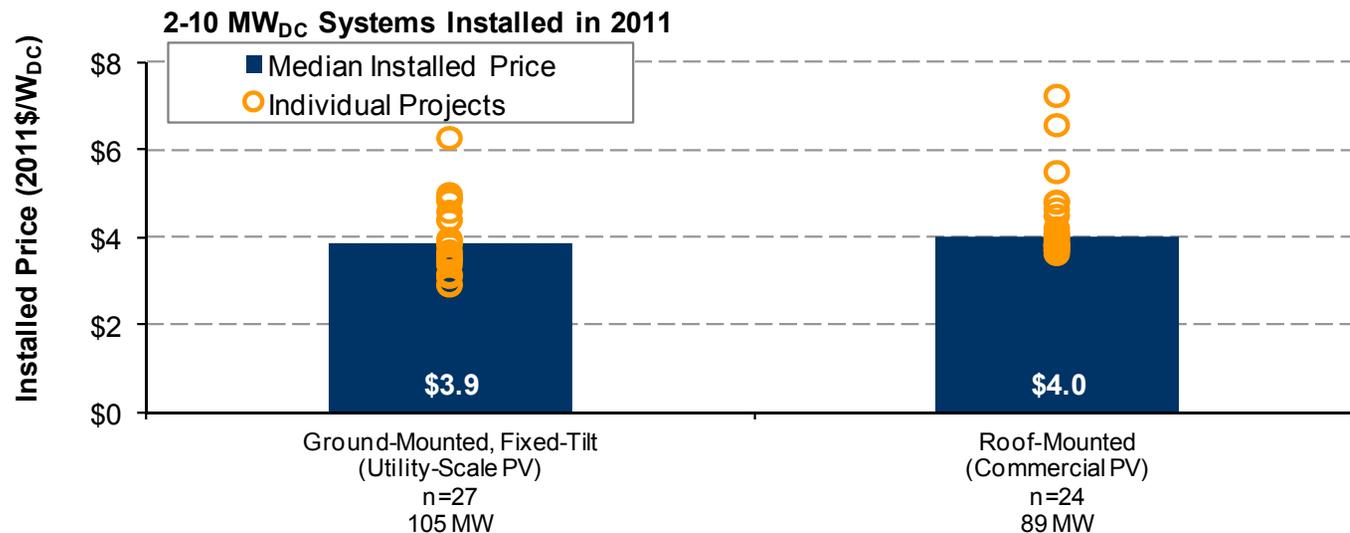
- In 2011, projects >10 MW generally ranged in price from \$2.8-\$3.5/W, while those <10 MW typically ranged from \$3.5-\$5.0/W
- Among projects <10 MW, those with thin-film modules were lowest priced, but the impact of system configuration on installed price is less evident for larger systems



Notes: The figure includes eight thin-film, fixed-tilt systems <10 MW; a number of those systems have almost identical size and installed price and therefore cannot be visually distinguished in the figure. The reported installed price may reflect module and other component pricing at the time of project contracting, which may have occurred one or two years prior to installation. For this reason and others, the data shown here may not accurately depict the installed price of typical utility-scale PV projects completed more recently or currently under development, and may not correspond well to recent installed price benchmarks.

In the 2-10 MW Range, Low Installed Prices Are More Likely for Ground-Mounted than Rooftop Systems

Among 2-10 MW systems installed in 2011, median installed prices for ground-mounted and rooftop systems are nearly identical, but the price distribution for ground-mounted is shifted downward, suggesting a greater potential for lower prices among ground-mounted systems



- Among the lowest-priced third of ground-mounted systems, installed prices range from \$2.9-\$3.5/W, whereas the lowest-priced third of roof-mounted systems range from \$3.6-\$3.8/W

Conclusions and Policy Implications



Conclusions and Policy Implications

- PV installed prices declined substantially in 2010 and 2011, largely as a result of falling module prices, and partial-year data indicate that installed price reductions have continued into 2012 – but it is unclear how much lower module prices can go
- Non-module costs have declined over the long-term, but have remained relatively stagnant in recent years, and have now become a focal point for further cost reductions (e.g., in the U.S. DOE’s SunShot Initiative)
- 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 deep near-term reductions in PV “soft costs” are possible and may accompany deployment scale, though other factors are also clearly important
- Deployment efforts that spur greater efficiencies and competition within the delivery infrastructure, in concert with targeted policies aimed at specific soft costs and basic and applied research and development, may therefore be required in order to sustain continued installed price reductions
- Policymakers may also wish to evaluate whether differential or tailored levels of financial support are warranted for different PV system sizes, market segments, and applications, given the wide variability in installed costs

For More Information...

Download the full report from:

<http://emp.lbl.gov/sites/all/files/LBNL-5919e-REPORT.pdf>

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