
Tracking the Sun III

The Installed Cost of Photovoltaics in the United States from 1998-2009

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Project Overview

Objective: Using project-level data, evaluate trends in the installed cost of grid-connected PV systems throughout the U.S. to answer the following:

- Changes in installed cost over time
- Changes in module and non-module cost over time
- Variation in total installed cost and component-level cost by system size
- Variation in installed cost by country and state
- Installed cost differences between third party-owned and customer-owned systems
- Installed cost differences by customer type, application, and technology
 - residential vs. commercial vs. public sector vs. non-profit
 - residential new construction vs. residential retrofit
 - building-integrated vs. rack-mounted
 - thin-film vs. crystalline silicon
 - module efficiency level
 - tracking vs. fixed-axis
- Changes in PV incentives over time and variation across states
- Changes in net installed costs changed over time and variation across states

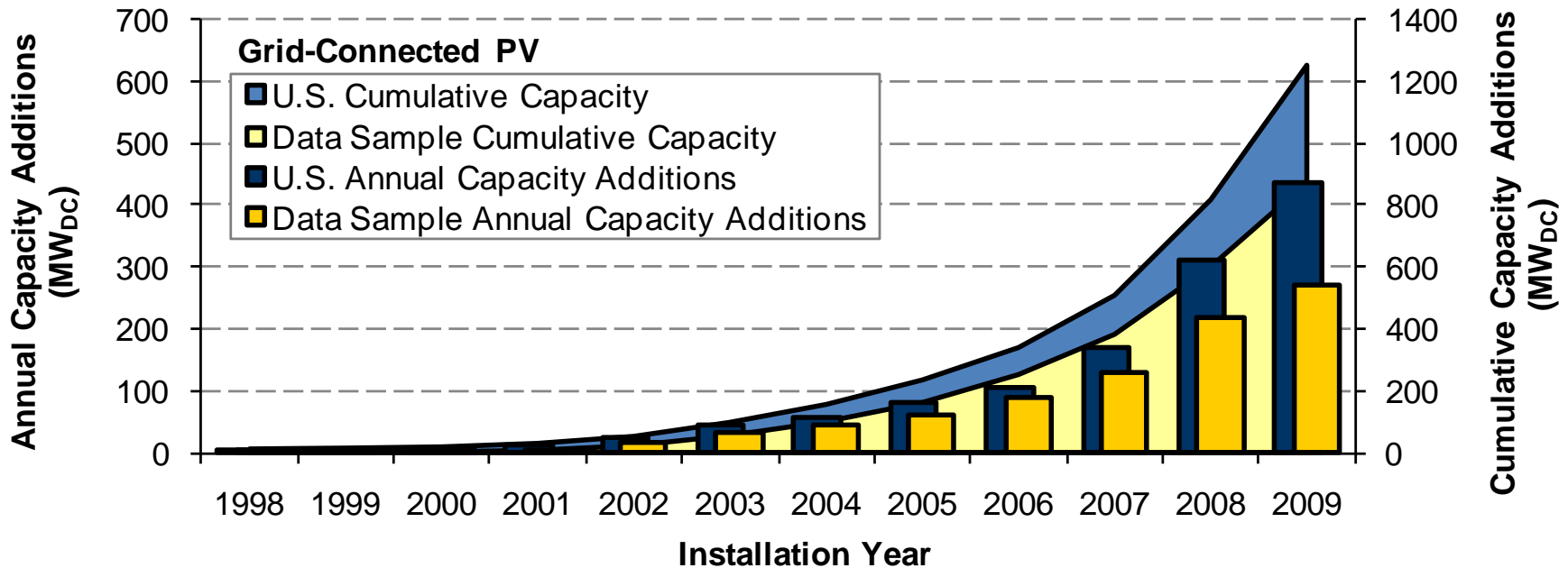
Data and Methodology

- Sought project-level cost data from as many PV incentive programs in the U.S. as reasonably feasible, with some focus on larger programs
- Ultimately, data were obtained from 27 solar incentive programs spanning 16 states, with PV system sizes ranging from 100 W_{DC} to 2.4 MW_{DC}
- Primary sample includes roughly **78,000 grid-connected PV systems** installed from 1998-2009, totaling **874 MW**
 - All systems in the primary sample are installed on the electric-customer side of the meter
 - Additional cost data for eleven ≥ 2 MW systems, several of which are installed on the utility-side of the meter, were obtained from press releases and other public sources
- Reported costs are those paid by the system owner, before any incentives
- Cost data are expressed in real 2009\$, and size data are converted to direct current watts at standard test conditions (denoted as W_{DC} in slides)
- Data were cleaned to only include system costs of \$2-30/W, systems where total incentives were <\$30/W, and only systems with installed cost, size, and incentive level reported

Important Caveats on Interpretation of The Report Findings

- **Unless otherwise indicated, the findings of this report are based on:**
 - **Residential and commercial PV systems;** larger utility-scale systems are lower cost
 - **Historical data through 2009;** preliminary 2010 cost data in the report shows that installed costs declined significantly
 - **The installed cost paid by customers,** which “lag” behind movements in PV module prices charged by manufacturers, and therefore do not reflect recent module price declines
- **For these reasons, the trends summarized in this report may differ from other recent estimates of PV costs**

Primary Sample Represents 70% of Grid-Connected PV Installed in U.S. through 2009

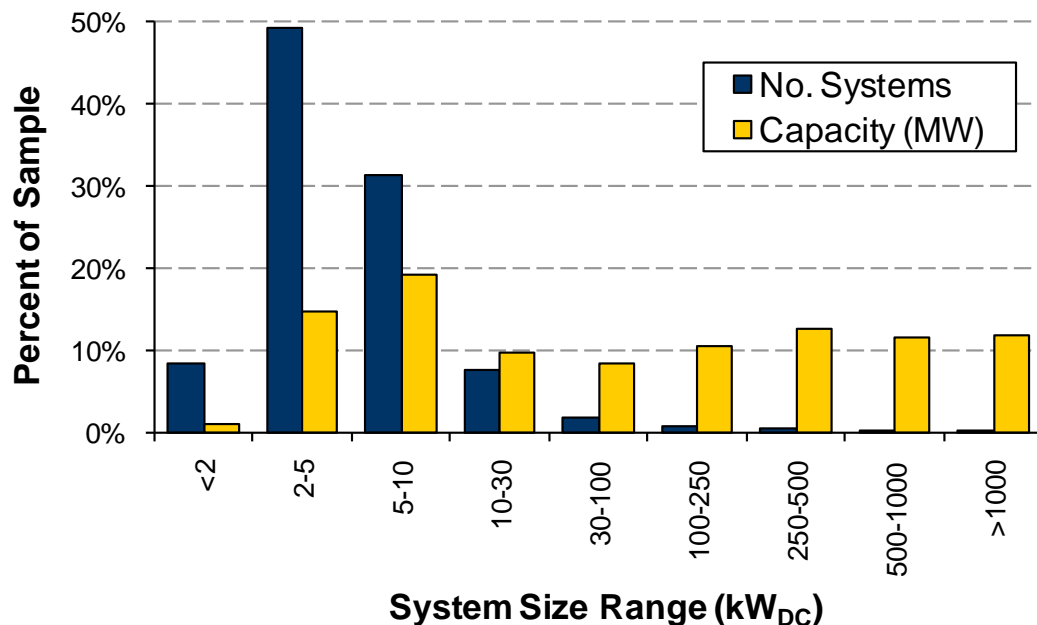
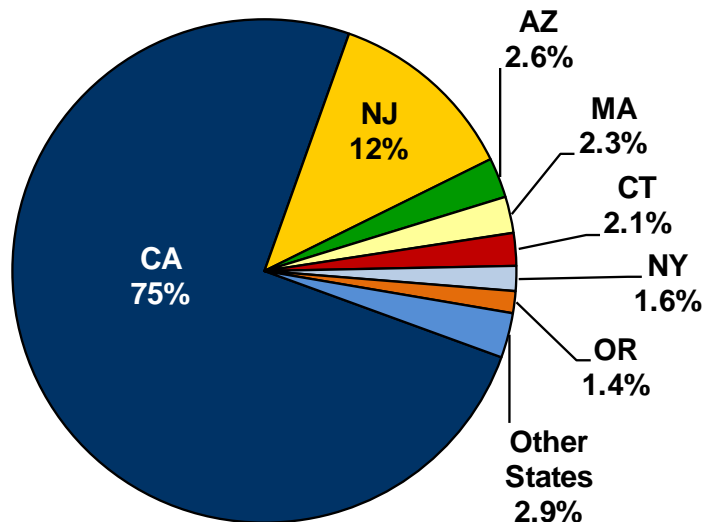


Data source for cumulative and annual U.S. grid-connected PV capacity additions: Sherwood, L. 2010. U.S. Solar Market Trends 2009. Interstate Renewable Energy Council.

- Estimated \$3.3 billion investment in grid-connected, customer-sited PV in the U.S. in 2009; primary data study sample represents \$2.1 billion
- Including the additional eleven ≥ 2 MW_{DC} projects (for which cost data were obtained from press releases and other public sources) in the tally brings the sample to **78%** of cumulative U.S. grid-connected PV capacity through 2009

Summary Information on Dataset: States, System Size, Temporal Distribution

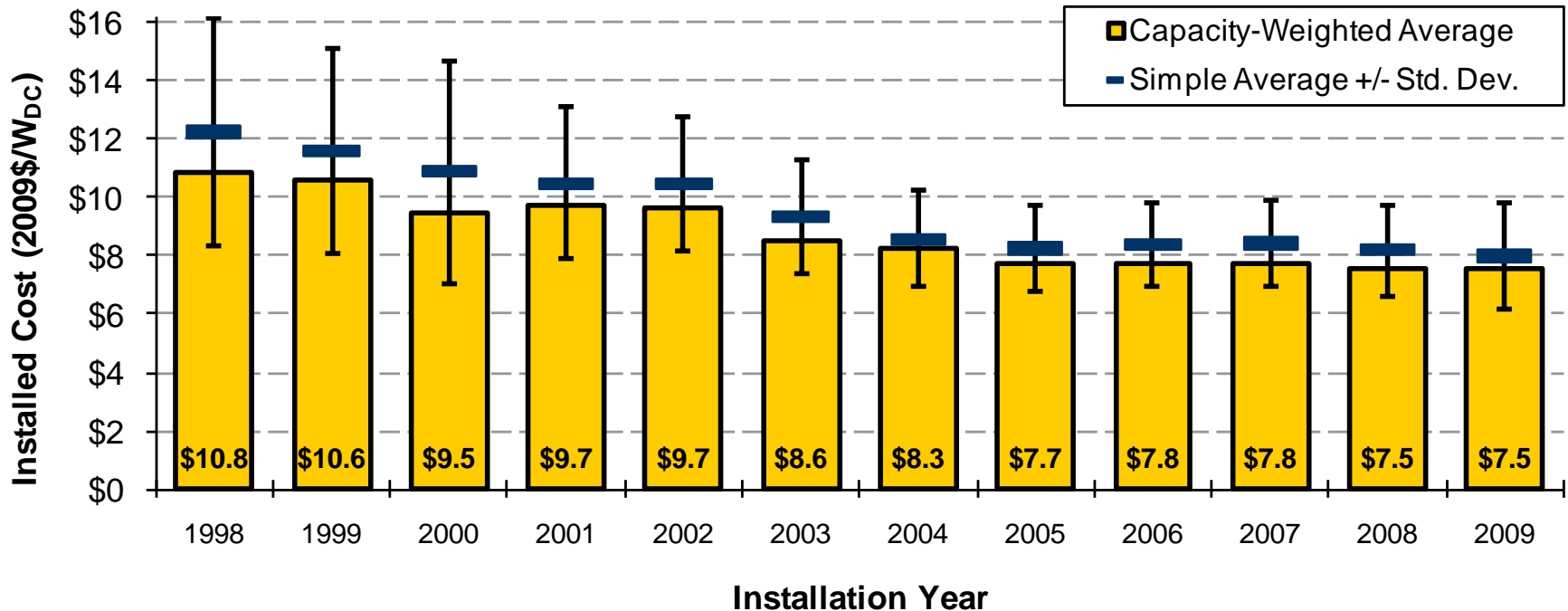
Sample Distribution by Cumulative MW_{DC}



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
No. of Systems	39	180	217	1,308	2,478	3,474	5,589	5,587	8,684	12,635	14,108	23,653	77,952
% of Total	<0.5%	<0.5%	<0.5%	2%	3%	4%	7%	7%	11%	16%	18%	30%	100%
Capacity (MW_{DC})	0.2	0.8	0.9	5.4	15	33	45	62	90	130	219	272	874
% of Total	<0.5%	<0.5%	<0.5%	1%	2%	4%	5%	7%	10%	15%	25%	31%	100%

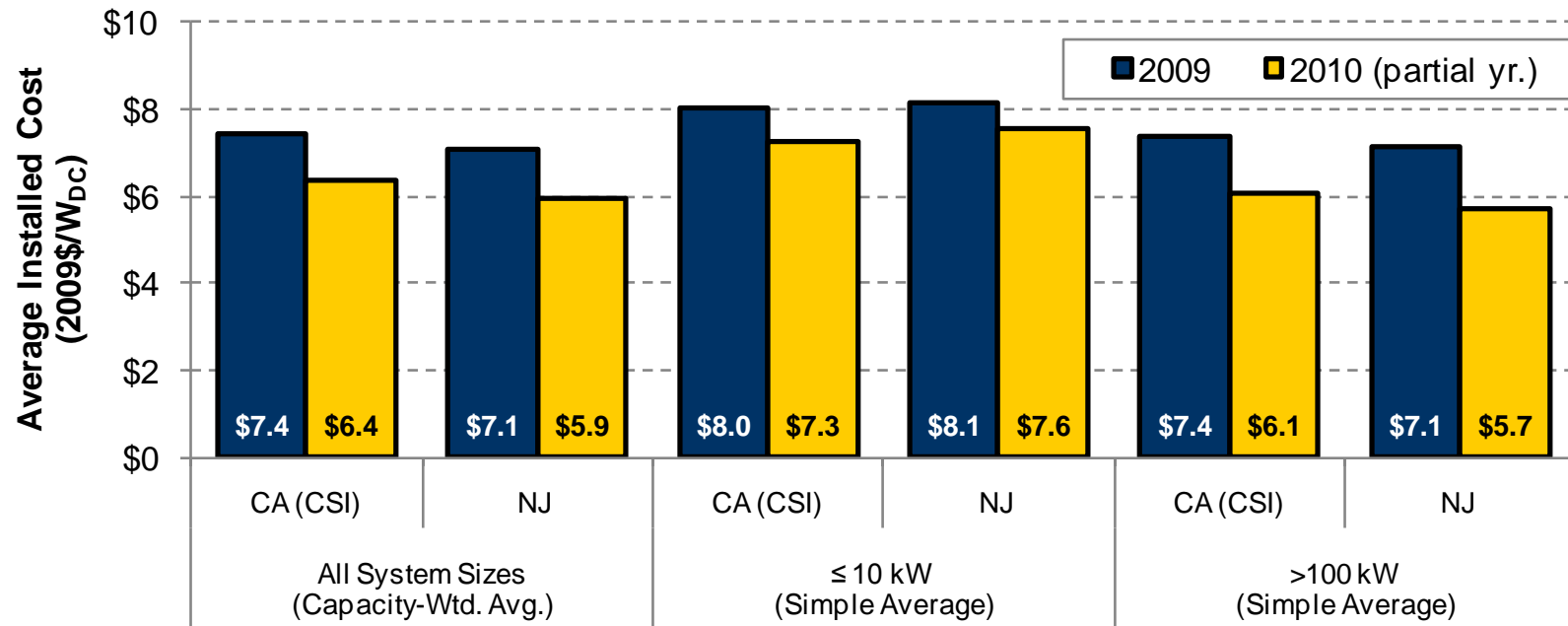
Average Installed Costs Remained Largely Flat from 2008 to 2009

Capacity-weighted average costs were **\$7.5/W_{DC}** in 2009, unchanged from 2008, and a **30%** reduction from 1998 (\$10.8/W_{DC}).



Preliminary Data Suggest Dramatic Installed Cost Reductions Ahead in 2010

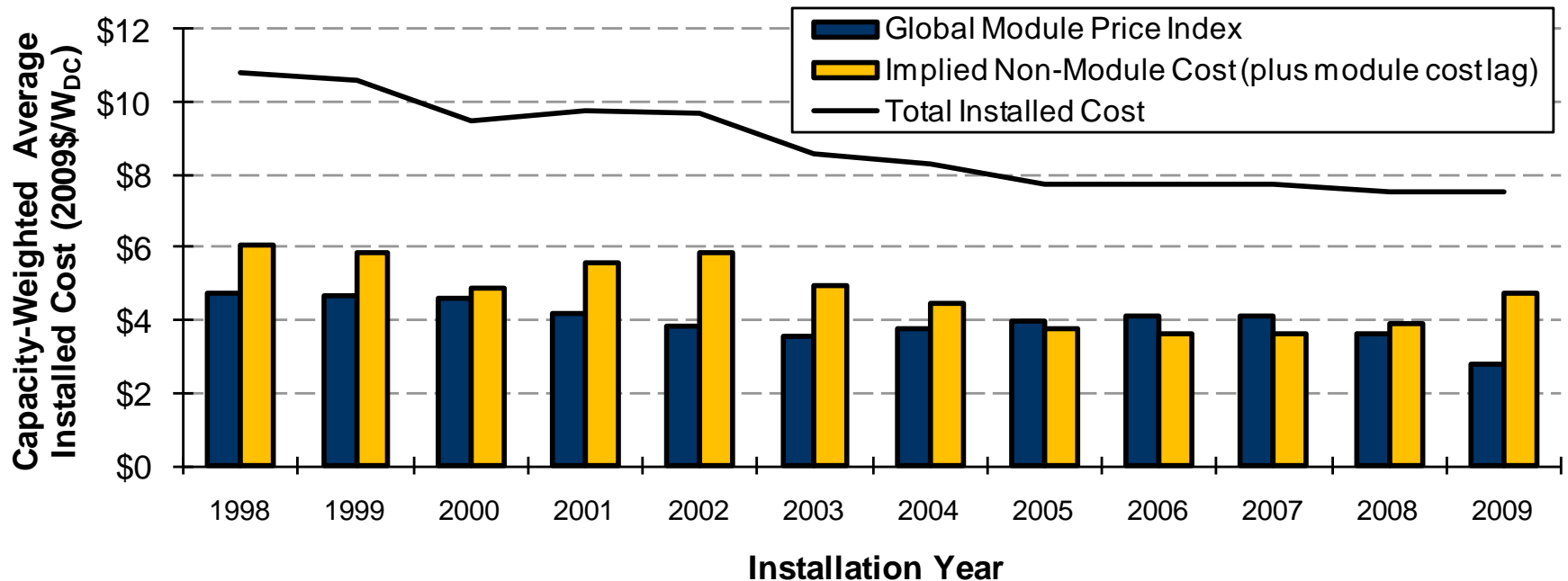
Compared to 2009, the average installed cost of projects within CSI dropped by **\$1.0/W_{DC}** (14%) over the first 10 months of 2010, and among NJ projects, by **\$1.2/W_{DC}** (16%) in the first 6 months of 2010



Notes: CA data are for the CSI program only, while NJ data include systems installed through the CORE Program, Renewable Energy Incentive Program, and SREC Registration Program. The 2010 partial year data extend through November 10, 2010 for CA systems and through June 30, 2010 for NJ systems.

Installed Costs Lagged Wholesale Module Price Movements from 2007-2009

Wholesale module prices declined by **\$1.3/W_{DC}** from 2007 to 2009, while total installed costs declined by only **\$0.2/W_{DC}** over this same period; along with preliminary 2010 cost data, this suggests a significant lag between wholesale module prices and installed costs



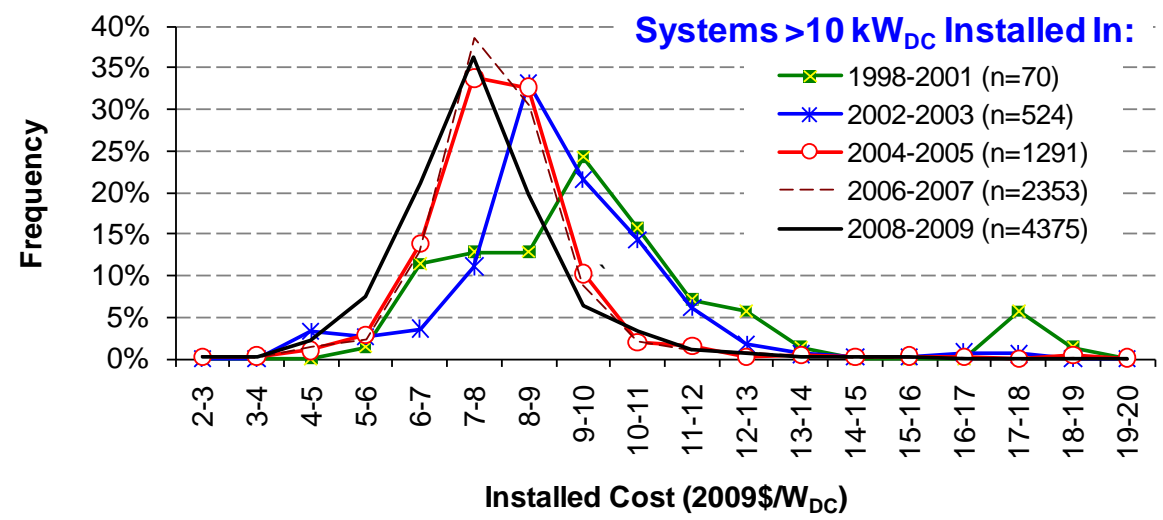
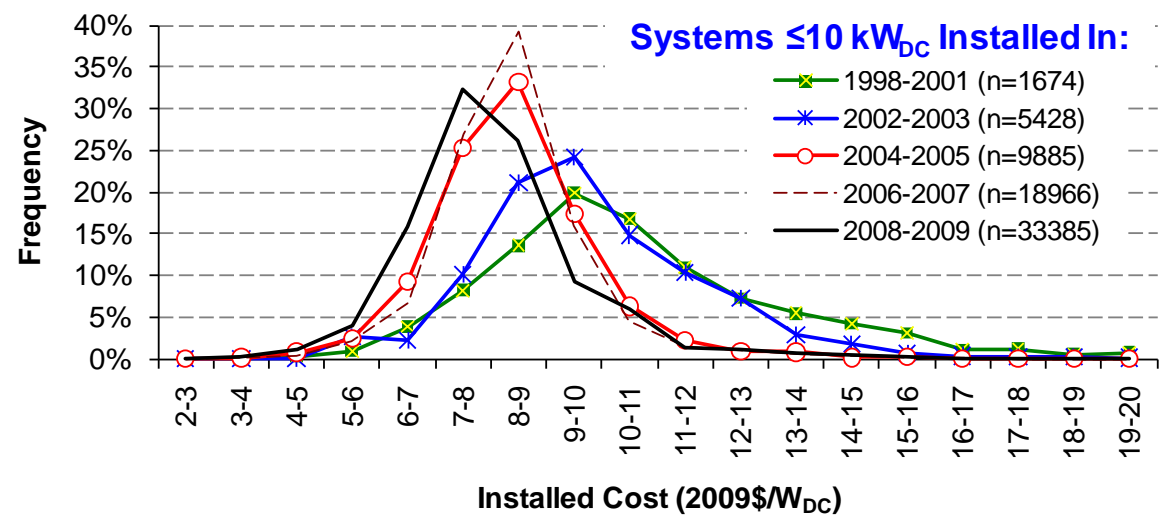
Notes: "Implied Non-Module Cost (plus module cost lag)" is calculated as the reported Total Installed Cost minus Navigant Consulting's Global Module Price Index.

The Historical Narrowing of the Installed Cost Distribution Ceased from 2006 to 2009

Average Costs Declined from 1998 to 2009 Due To:

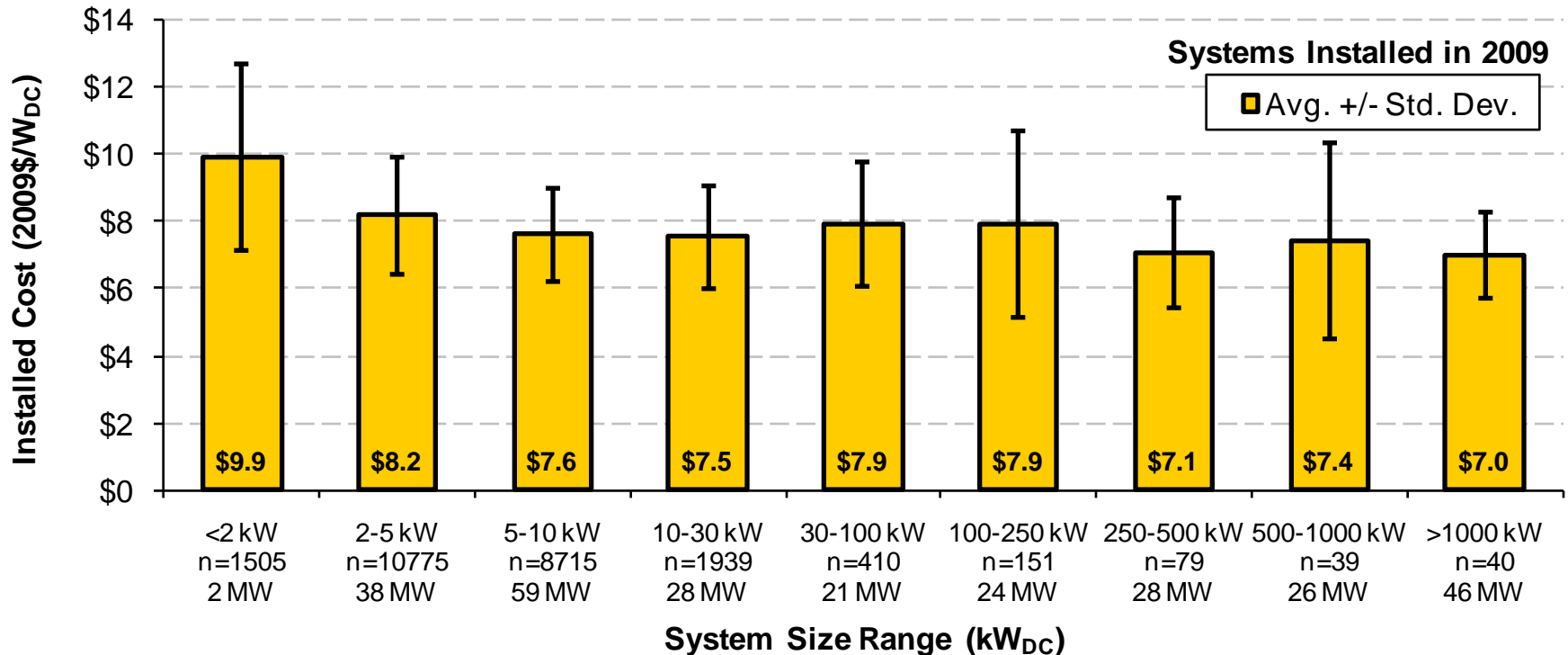
Shifting: Overall shift of the cost distributions toward lower costs

Narrowing: Reduction in high-cost outliers, demonstrating a maturing market in which competition has become more robust



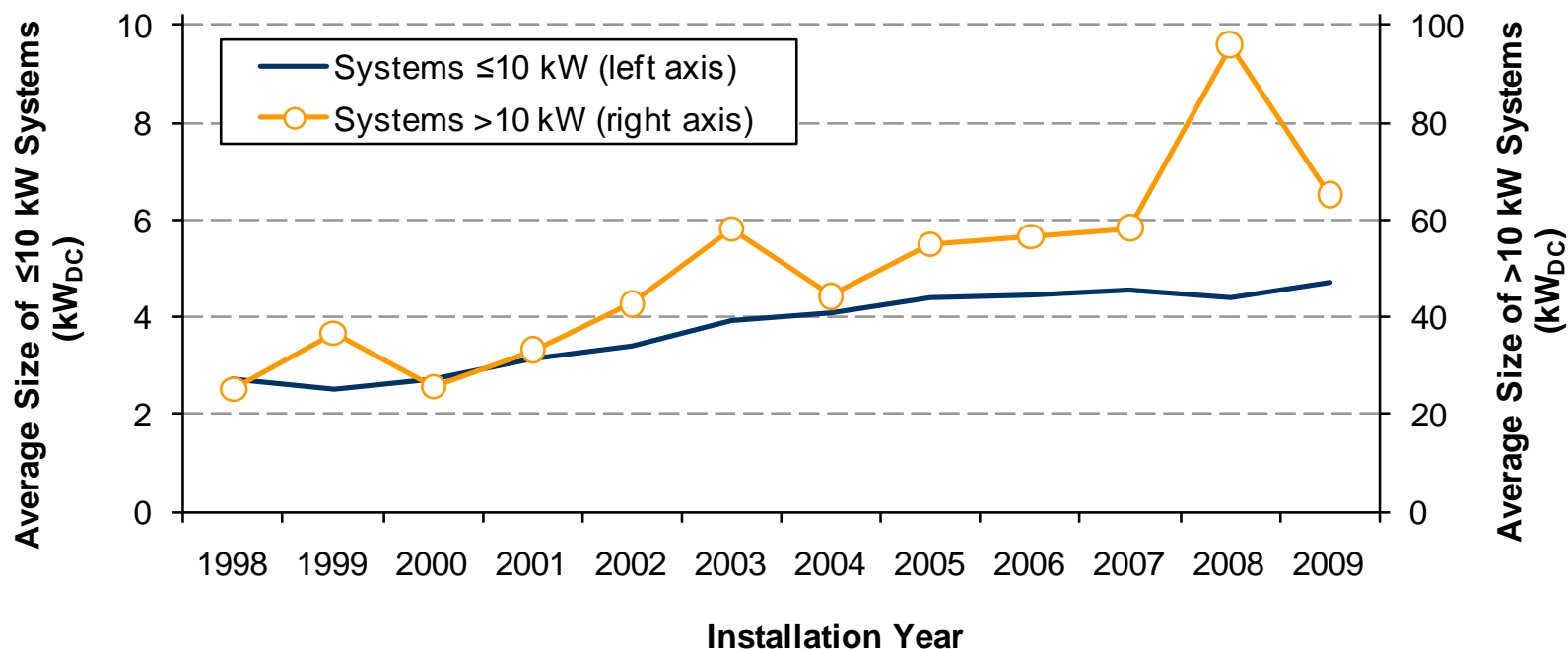
Economies of Scale Drive Down Costs as System Size Increases

>1,000 kW_{DC} systems are **29% cheaper**, on average, than ≤2 kW_{DC} systems; most significant economies of scale occur from 0-10 kW_{DC} and >250 kW_{DC}



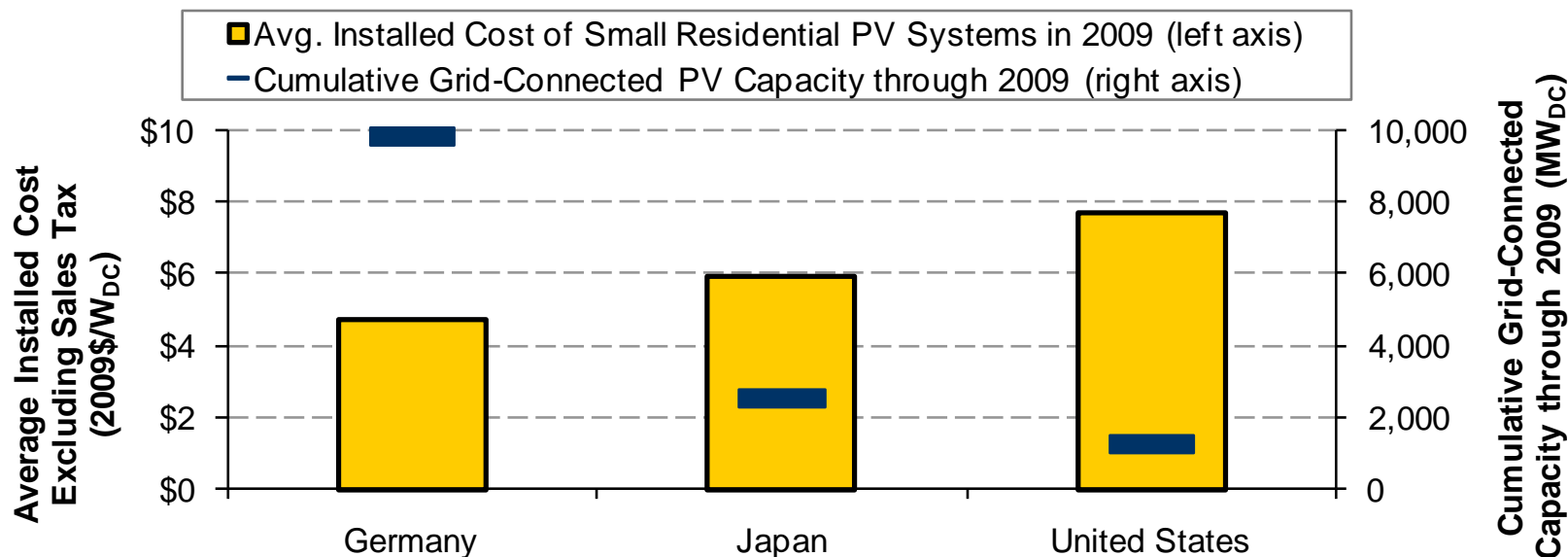
Temporal Cost Reductions Partially Reflect Increasing Average System Size

From 1998 to 2009, the average system size of systems ≤ 10 kW_{DC} increased from 2.7 kW_{DC} to 4.7 kW_{DC}, while >10 kW_{DC} systems increased from 25 kW_{DC} to 67 kW_{DC}; associated economies of scale reduced cost



Avg. Cost of Small Residential PV In the U.S. Exceeds that in Germany and Japan

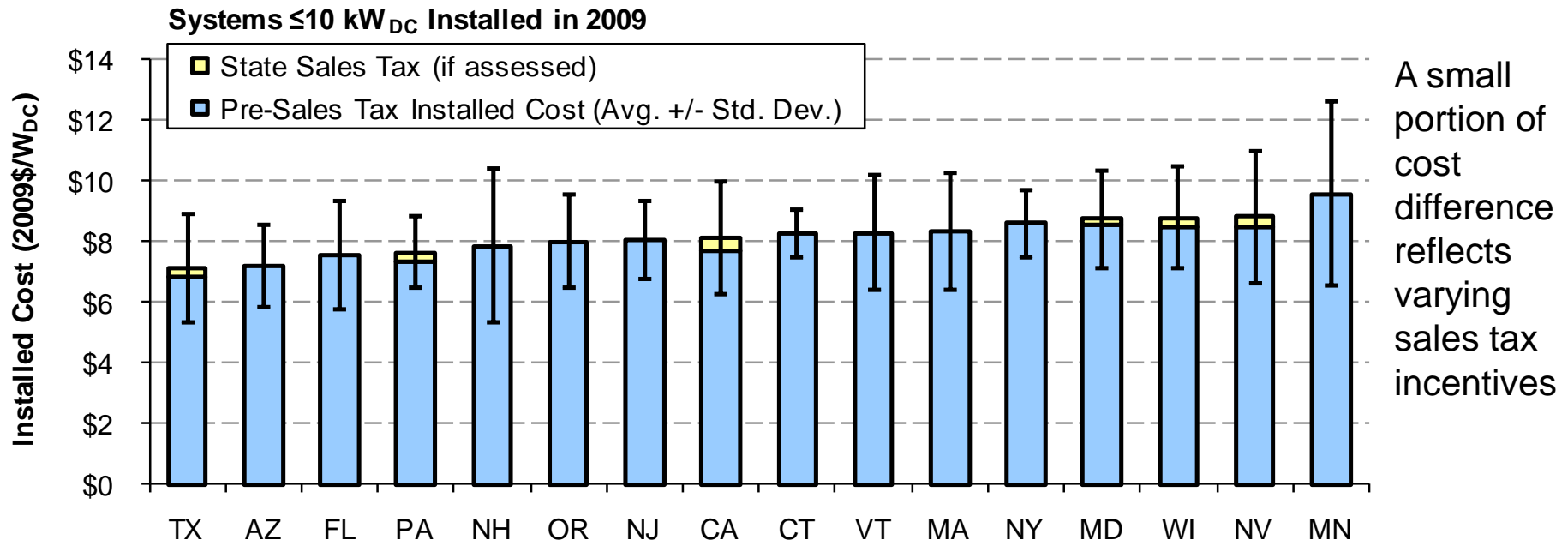
Lower costs in Germany and Japan may be partly attributable to greater deployment scale; highlights potential for further near-term cost reductions in the U.S.



Notes: The Japanese and U.S. cost data are for 2-5 kW systems, while the German cost data are for 3-5 kW systems. Source for Japanese price and cumulative installed capacity data: Yamamoto, M. and O. Ikki. 2010. National Survey Report of PV Power Applications in Japan 2009. Paris, France: International Energy Agency Cooperative Programme on Photovoltaic Power Systems. Source for German price and cumulative installed capacity data: Wissing, L. 2010. National Survey Report of PV Power Applications in Germany 2009. Paris: France: International Energy Agency Cooperative Programme on Photovoltaic Power Systems.

Installed Costs Vary Widely Across States

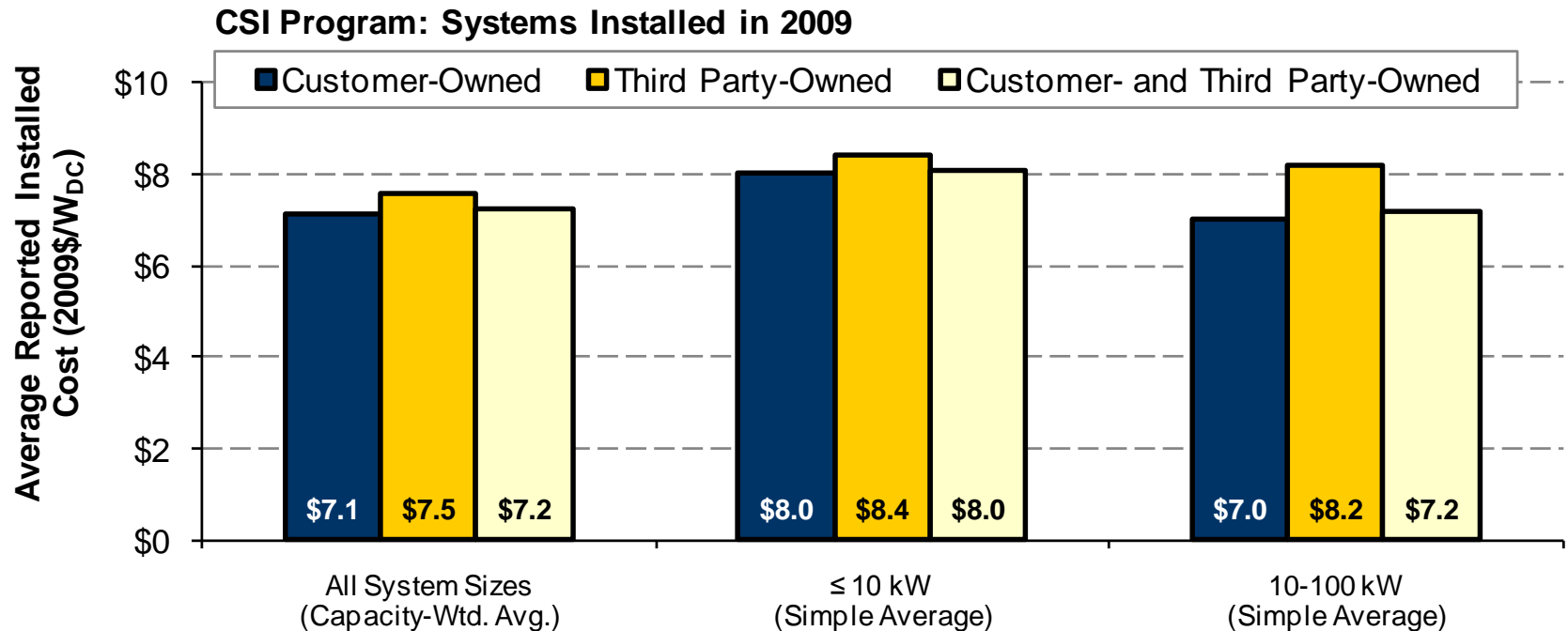
Variation in installed costs among $<10 \text{ kW}_{\text{DC}}$ systems may partially reflect differences in market size and maturity, but other local factors are evidently also important



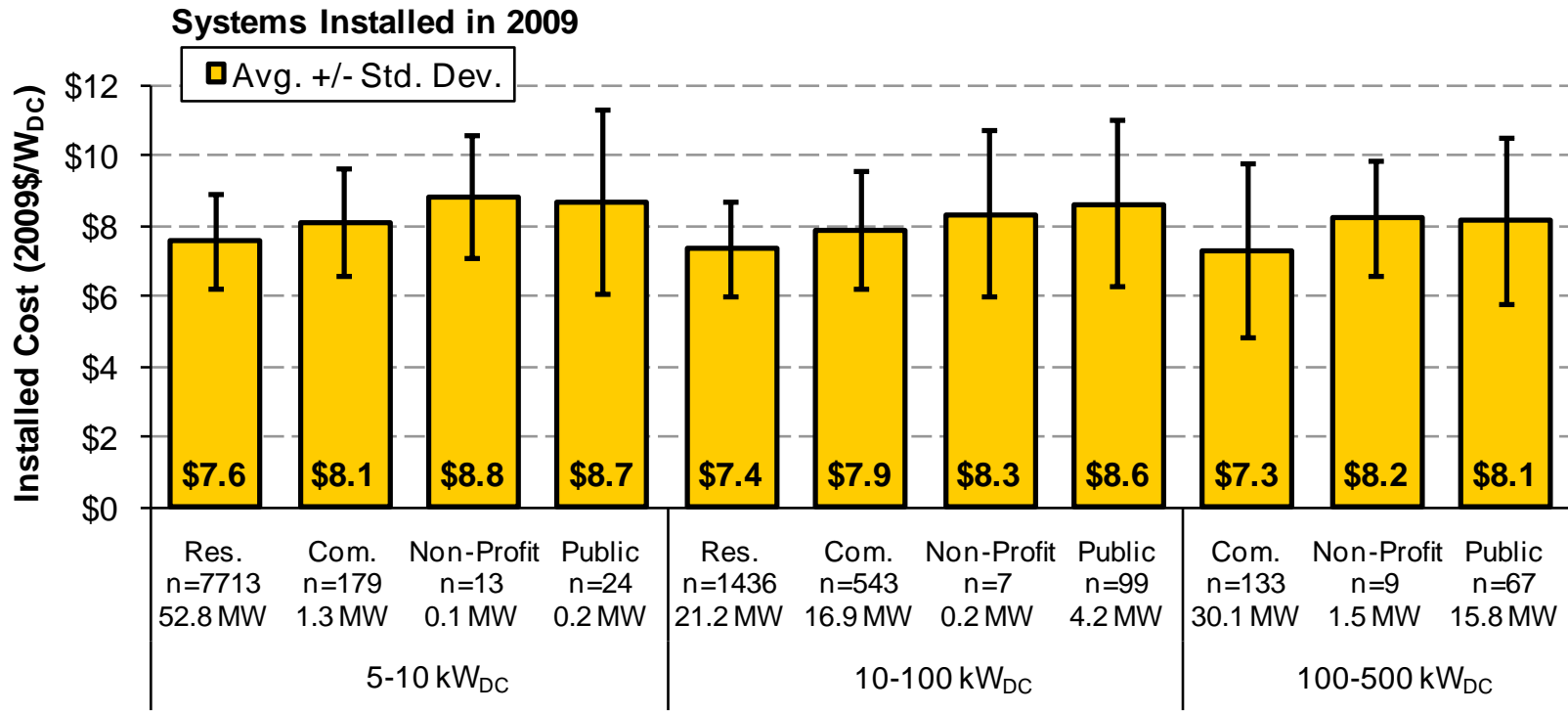
Notes: State Sales Tax and Pre-State Sales Tax Installed Cost were calculated from 2009 sales tax rates in each state (local sales taxes were not considered). Sales tax was assumed to have been assessed only on hardware costs, which, in turn, were assumed to constitute 65% of the total pre-sales-tax installed cost.

Costs Were Higher for Third Party-Owned than for Customer-Owned Systems

Cost data reported for third party-owned systems may include financing costs and maintenance services, which are not included in cost data for customer-owned systems



Residential PV Had Lower Costs than Other Similarly Sized Systems

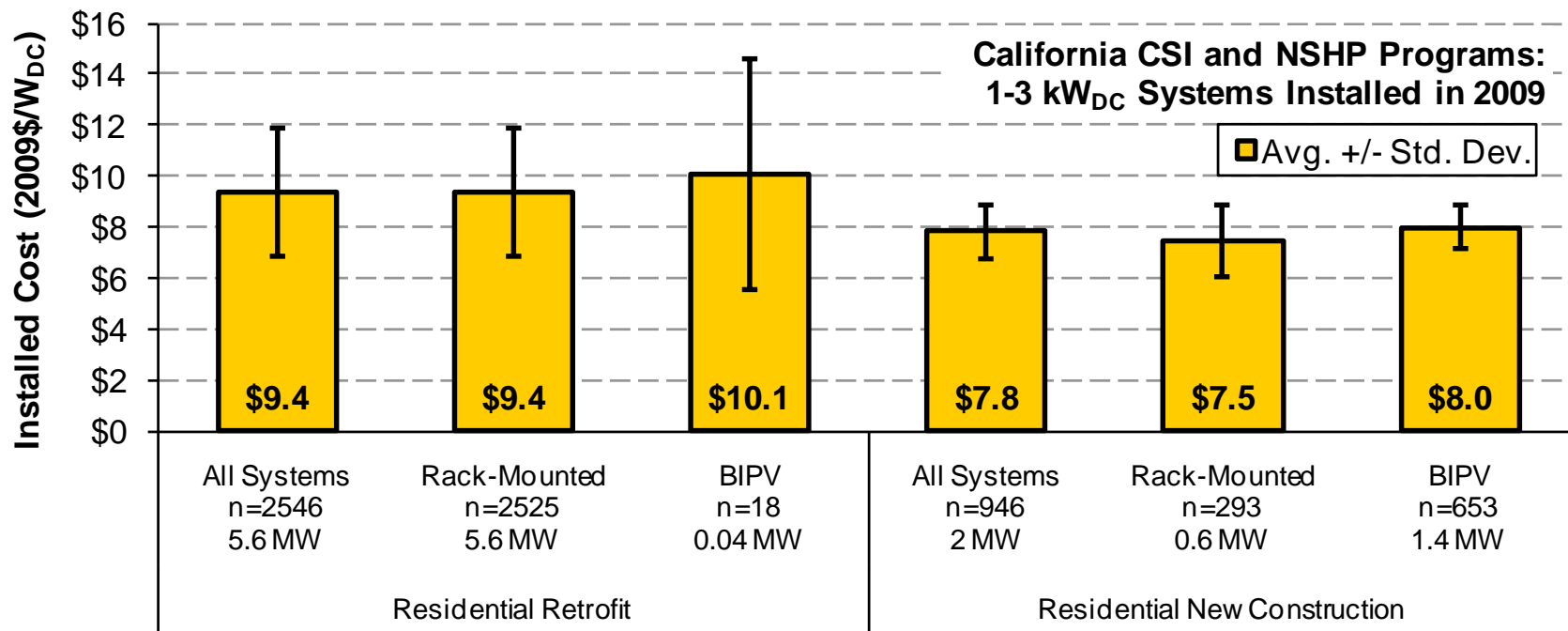


- Among 5-10 kW_{DC} systems installed in 2009, residential PV had an average installed cost \$0.5/W_{DC} less than commercial and \$1.1/W_{DC} less than public sector
- Public-sector PV had higher costs than similarly sized commercial PV (e.g., \$0.7/W_{DC} higher among 10-100 kW_{DC} systems)



The New Construction Market Offers Cost Advantages for Residential PV

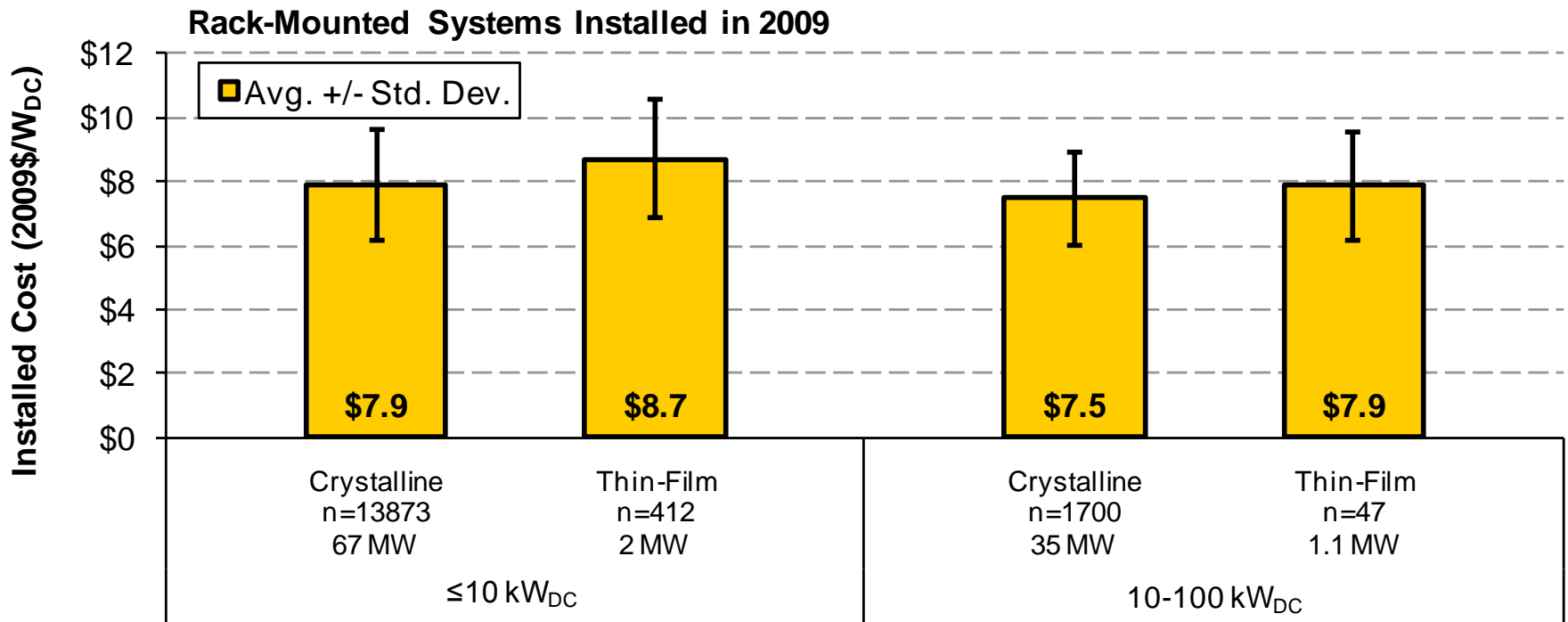
In 2009, residential new construction systems cost **\$1.6/W_{DC}** less, on average, than similarly sized retrofit systems (or **\$1.9/W_{DC}** less if comparing only rack-mounted systems)



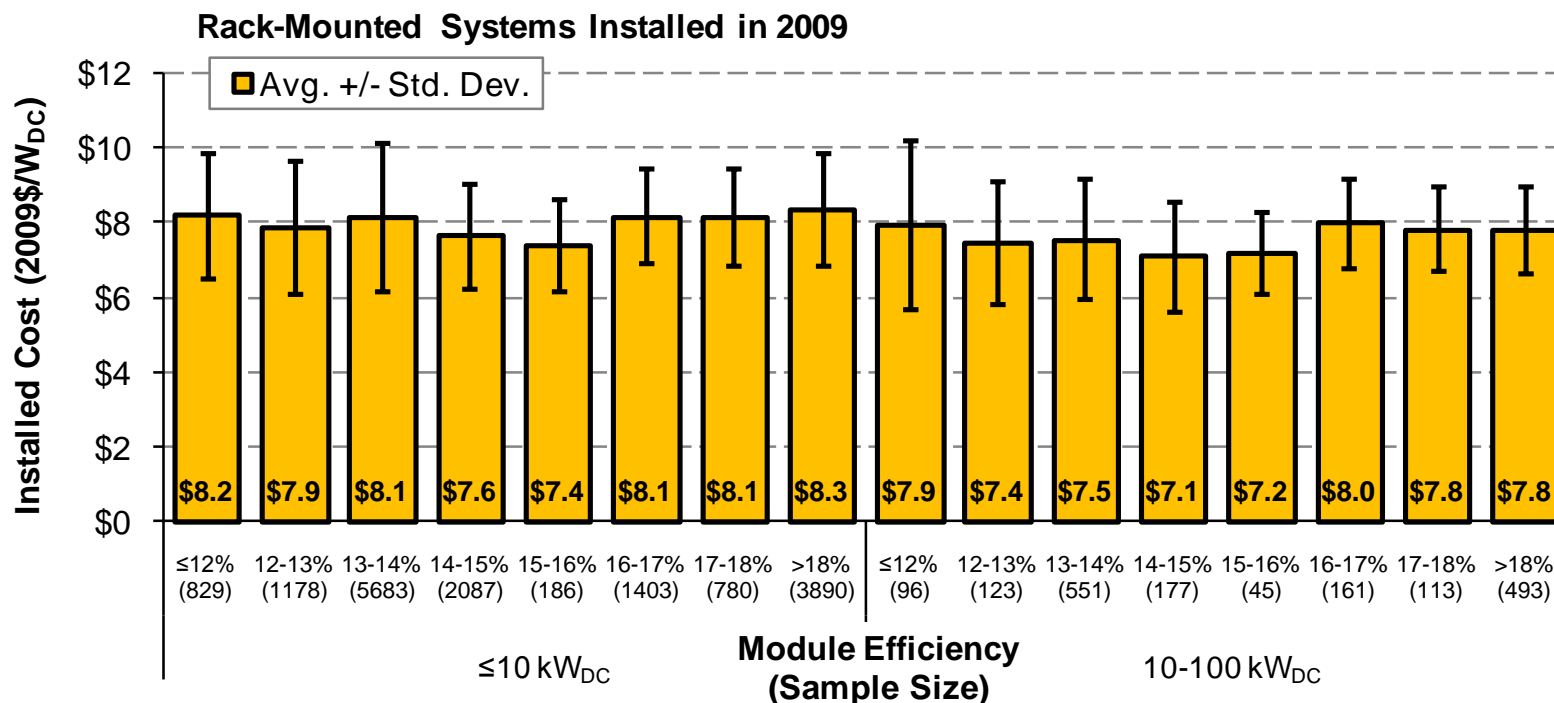
Note : The number of rack-mounted systems plus BIPV systems may not sum to the total number of systems, as some systems could not be identified as either rack-mounted or BIPV.

Thin-Film Systems Had Higher Installed Costs than Crystalline Systems

In 2009, rack-mounted thin-film systems $\leq 10 \text{ kW}_{\text{DC}}$ cost **\$0.8/ W_{DC}** more, on average, than similarly sized crystalline systems

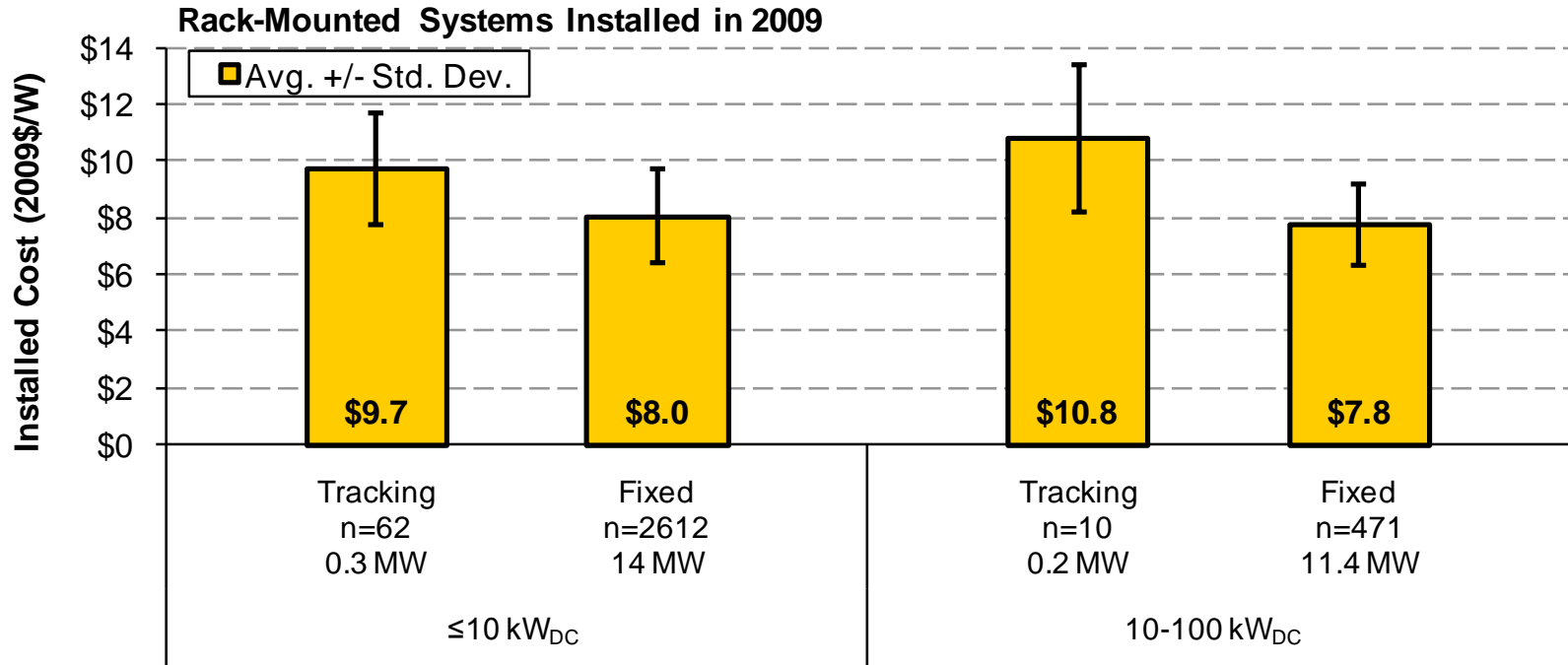


Systems with Mid-Range Module Efficiencies Had the Lowest Average Cost in 2009



- Among ≤10 kW_{DC} rack-mounted systems, those with module efficiency of 15-16% had the lowest installed cost (\$7.4/W_{DC}), compared to \$8.2/W_{DC} for systems with efficiency ≤12% and \$8.3/W_{DC} for systems with efficiency >18%

Systems with Tracking Had Higher Installed Cost than Fixed-Axis Systems



- Within the $\leq 10 \text{ kW}_{\text{DC}}$ size range, systems with tracking had an average cost $\$1.7/W_{\text{DC}}$ (or 21%) greater than fixed-axis systems, reflecting added cost of tracking equipment and ground-mounting
- In the $10\text{-}100 \text{ kW}_{\text{DC}}$ size range, tracking systems also had higher installed costs, though the sample size is quite limited

Conclusions

- Average pre-incentive installed costs remained flat from 2008 to 2009 at $\$7.5/W_{DC}$
 - Lifting of the dollar cap on the Federal ITC for residential PV in 2009 led to a 24% year-on-year decline in the average net installed cost for residential PV
- Preliminary 2010 data shows significant cost reductions relative to 2009, as a result of the decline in global module prices
- From 1998-2009, PV costs declined substantially as a result of reductions in both module and non-module costs
- This trend, along with the narrowing of cost distributions, suggests that PV deployment policies in the U.S. have achieved some success in fostering competition and spurring efficiencies in the delivery infrastructure
- Lower average costs in Japan and Germany (and among some of the larger PV markets in the US) suggest that deeper near-term installed cost reductions are possible and may accompany deployment scale
- Low average costs among some small state markets show that local factors can also be important determinants to cost reductions

For More Information...

Download the full report from:

<http://eetd.lbl.gov/ea/ems/re-pubs.html>

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