Tracking the Sun IV

An Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998 to 2010

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- Report Summary -

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Environmental Energy Technologies Division • Energy Analysis Department

Project Overview

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

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

Data Sources and Methodology

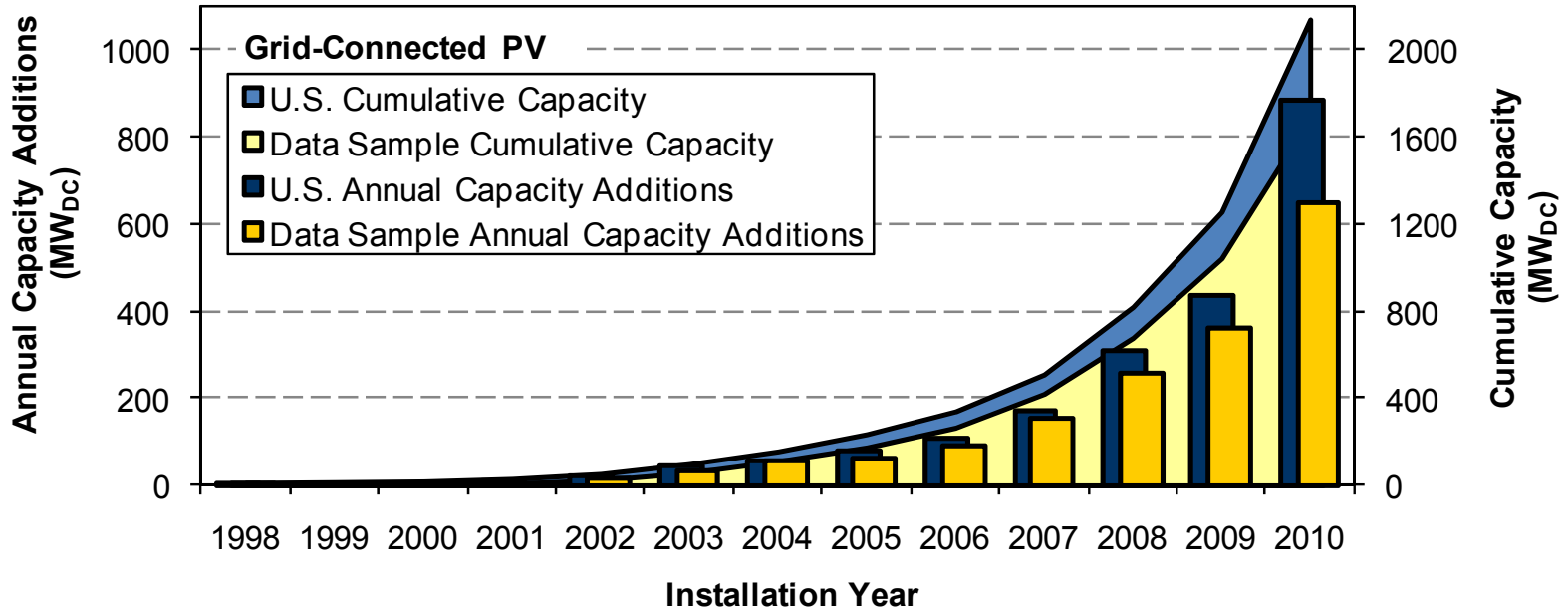
- Data sample includes both behind-the-meter PV (i.e., residential and commercial) and utility-sector PV (i.e., connected directly to the utility system)
- Cost data for behind-the-meter PV projects were sourced primarily from state and utility PV incentive programs (32 programs in total), supplemented with data from the U.S. Treasury Department's Section 1603 Grant Program database and other public sources
- Cost data for utility-sector PV projects were sourced from the 1603 Grant Program, FERC Form 1 filings, SEC filings, company presentations, and trade press articles
- Cost data are expressed in real 2010$, and size data are converted to direct current watts at standard test conditions (denoted as W_{DC} in slides)
- Data were cleaned to exclude systems with missing data for installed cost, system size, or installation date, as well as those systems with a cost <$2/W or >$30/W
- For project data derived from the Section 1603 Grant Program database, installed costs are estimated based on the reported grant amount, by assuming that the grant is equal to 30% of total installed costs

Important Limitations in the Data Presented within This Report

- ***The cost data are historical*****,** focusing primarily on projects installed through 2010, and therefore do not reflect the cost of more-recently installed projects or the costs currently being quoted for prospective projects
- ***The cost data differ from current cost benchmarks for a variety of reasons*** (e.g., differences in timing, definitions, system size, location, project characteristics, and developer/owner profit margins)
- ***The cost data represent the up-front cost rather the levelized cost of electricity*** and therefore do not account for improvements in performance over time or differences in performance between projects
- ***The utility-sector PV cost 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-sector PV projects
- ***The installed cost data for third party-owned projects within the sample are somewhat ambiguous,*** in some cases representing the project's assessed "fair market value"; however, any bias in the installed cost data for third party-owned systems does not appear to have significantly skewed the overall cost trends

The Sample Represents a Large Fraction of All PV Capacity in the U.S. through 2010

- The final dataset, after all data cleaning was completed, consists of more than 116,500 PV systems totaling 1,685 MW (including 1,400 MW of behind-the-meter PV and 285 MW of utility-sector PV)
- The sample represents approximately 79% of all cumulative grid-connected PV capacity installed in the United States through 2010, and about 73% of all annual capacity additions in 2010



Data sources for U.S. grid-connected PV capacity additions: Larry Sherwood (Interstate Renewable Energy Council) and SEIA/GTM.

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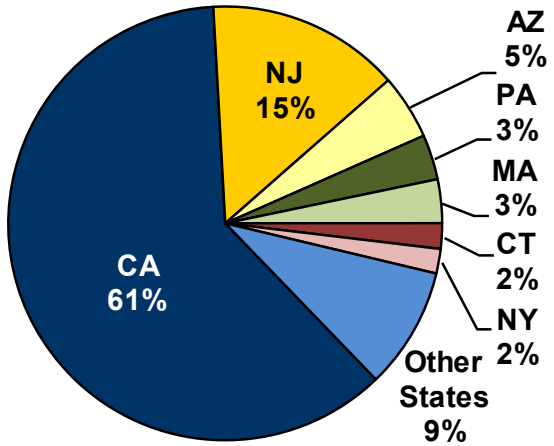
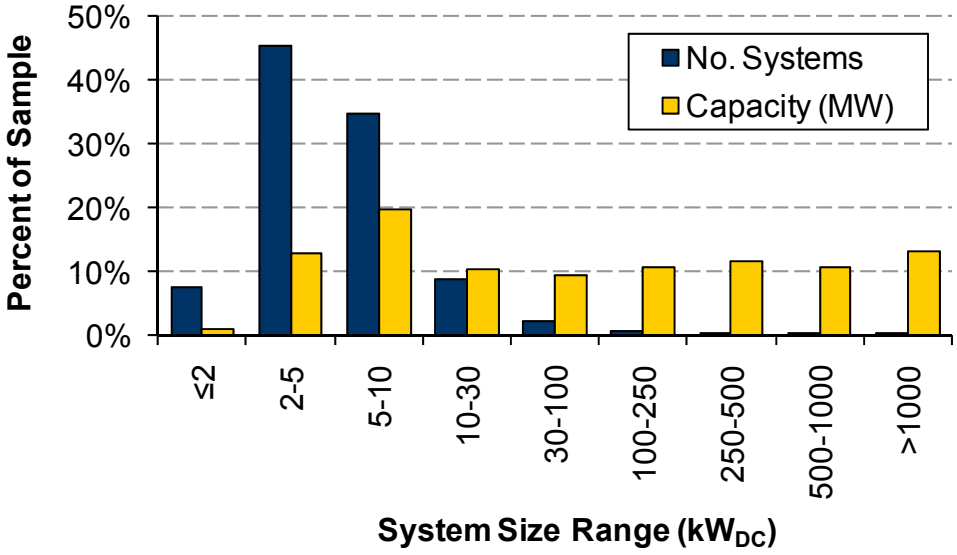
Sample Description for Behind-the-Meter PV: Distribution Across States and by System Size

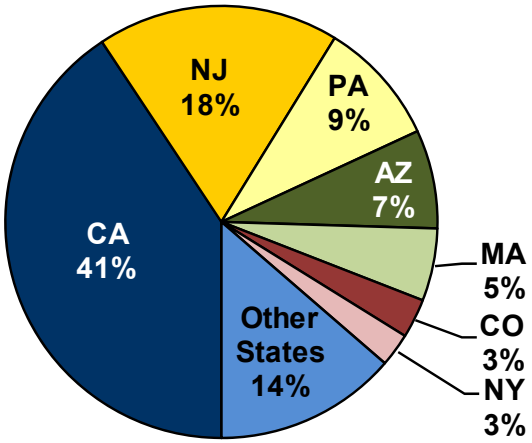
Distribution of Capacity Across States (1998-2010)



Sample Distribution by System Size



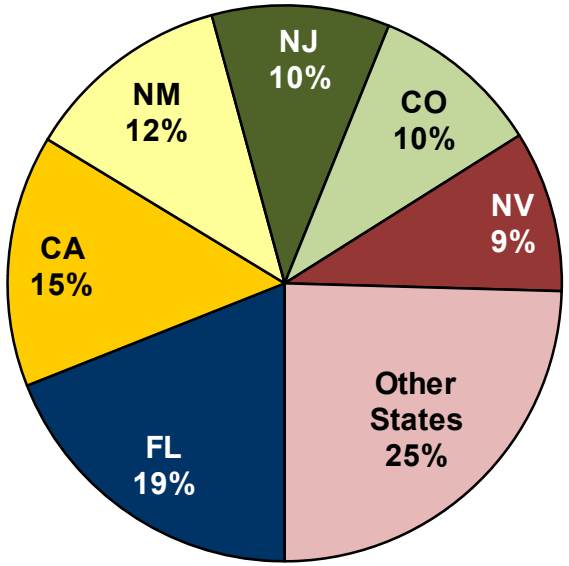
Distribution of Capacity Across States (2010 only)



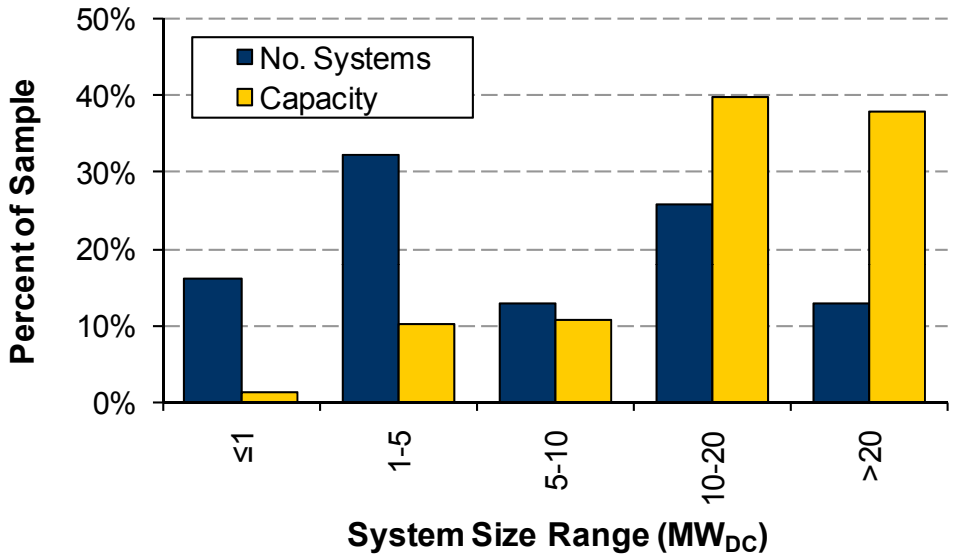
- CA and NJ represent the majority of all installed capacity in the data sample, though the 2010 capacity additions are more evenly distributed across states
- The vast majority of systems are relatively small (<10 kW), though the capacity is evenly distributed across system sizes

Sample Description for Utility-Sector PV: Distribution Across States and by System Size

Distribution of Capacity Across States



Sample Distribution by System Size



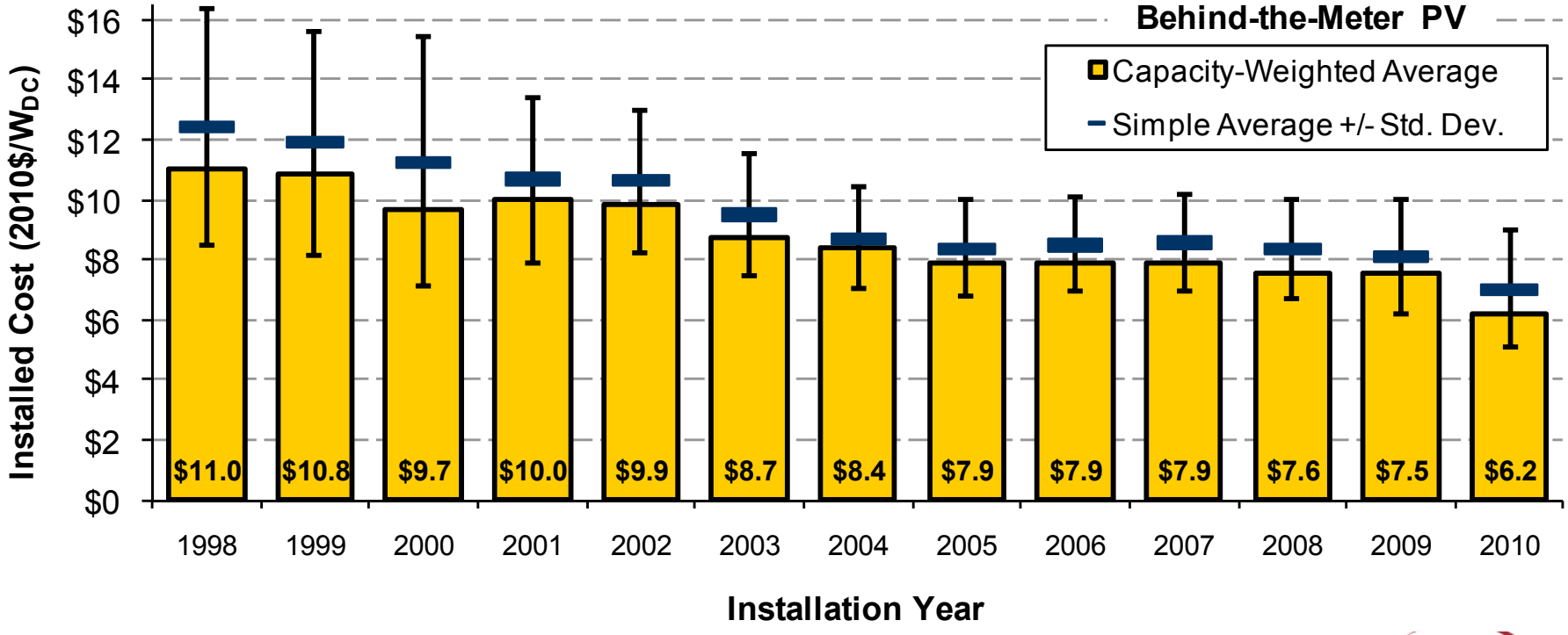
- The 31 utility-sector PV systems in the data sample are located in a total of thirteen states, with 75% of that capacity distributed across six of these states (Florida, California, New Mexico, New Jersey, Colorado, and Nevada)
- The utility-sector PV systems in the data sample range in size from 500 kW to 34.4 MW, and include a number of wholesale rooftop PV projects that would not typically be classified as “utility-scale”

Installed Cost Trends for Behind-the-Meter PV

(Prior to Receipt of Financial Incentives, Tax Credits, Renewable Energy Certificate Revenues, etc.)

Average Installed Costs Declined Precipitously from 2009 to 2010

The capacity-weighted average cost was **$6.2/W** for systems installed in 2010, falling by **17%** from 2009 (a **$1.3/W** year-over-year decline) and 43% below 1998



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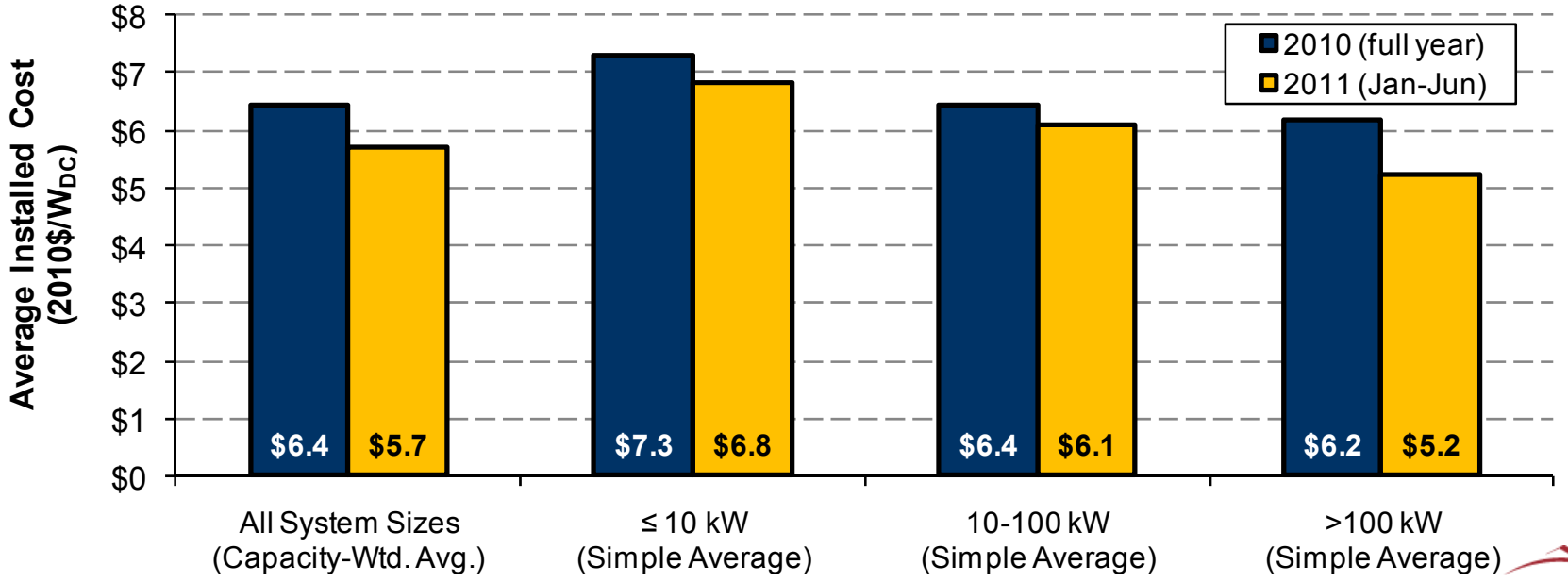
Preliminary Data from CSI Show That Steep Cost Reductions Continued into 2011

The capacity-weighted average cost across all system sizes fell by **$0.7/W** or 11% from 2010 to the first half of 2011, with the largest cost reductions occurring among >100 kW systems

Average Installed Costs For Behind-the-Meter Systems Funded through the California Solar Initiative (CSI) Program: 2010 vs. the First-Half of 2011



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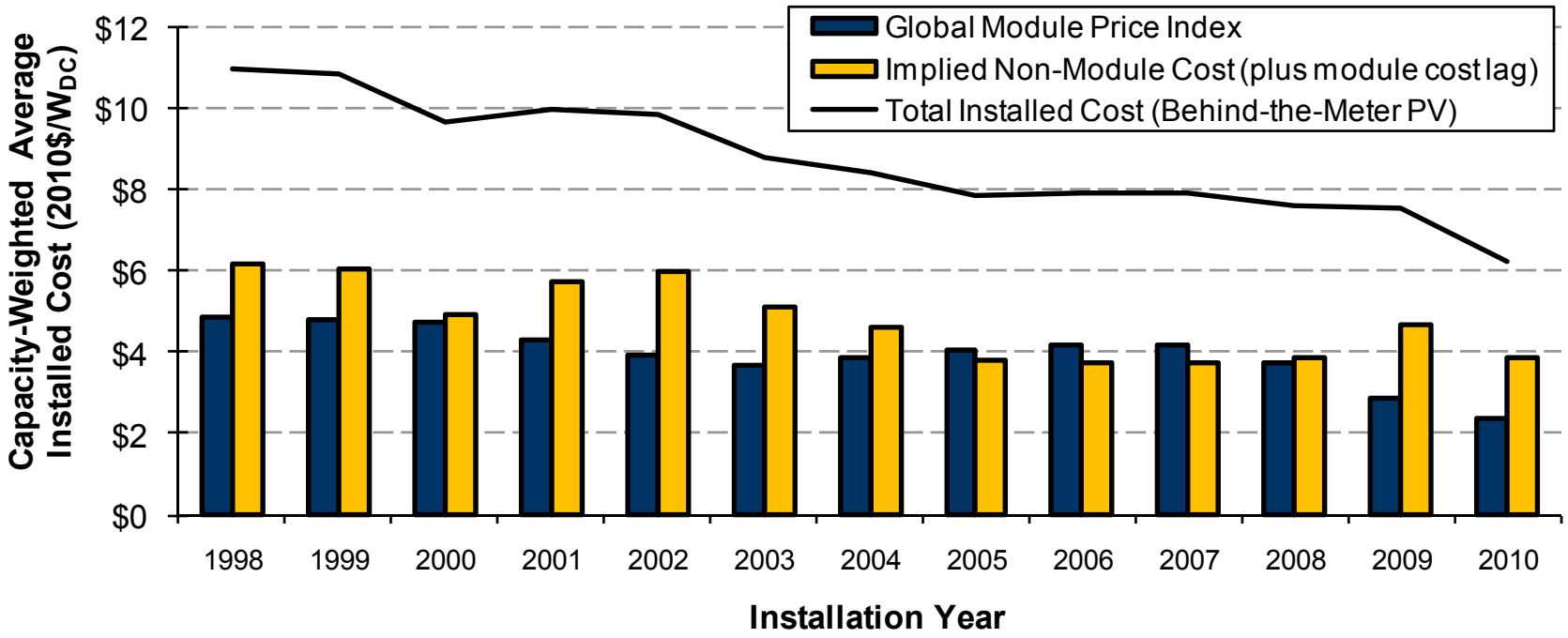
Recent Declines in Installed Costs Followed Several Years of Falling Module Prices

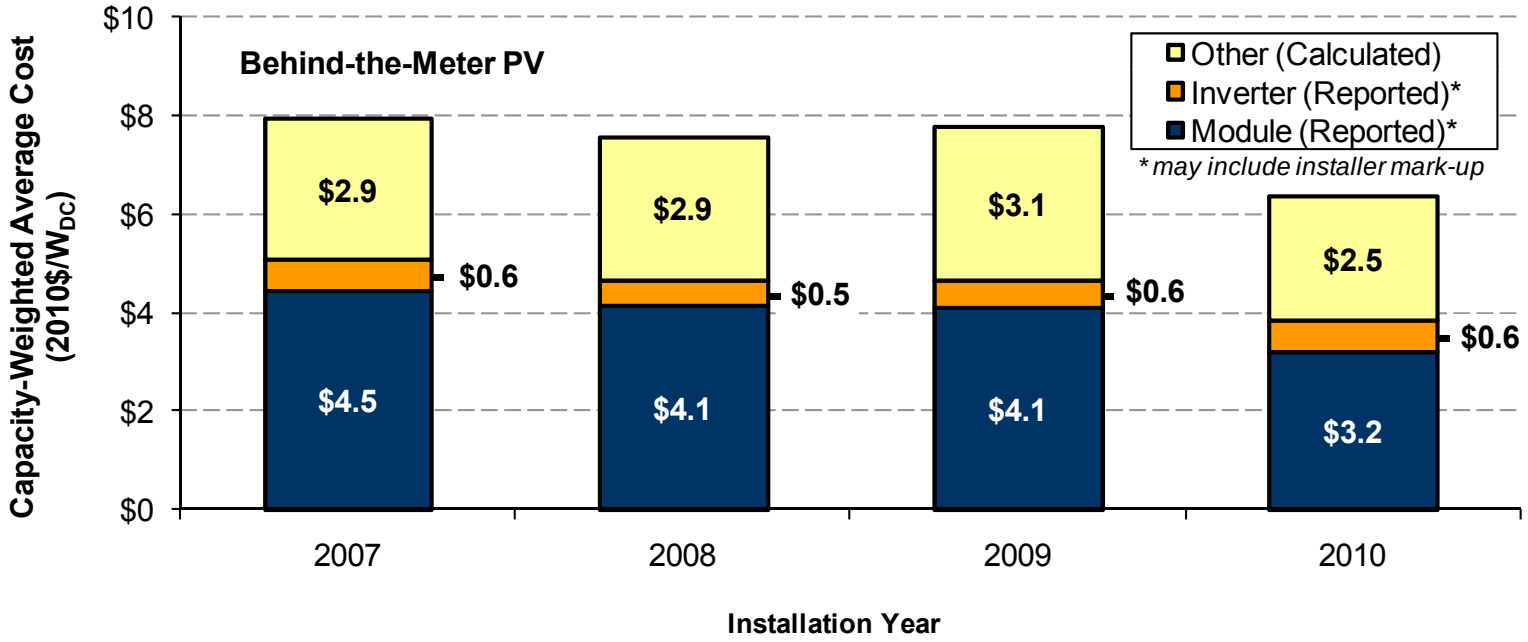
Global average wholesale module prices began a steep decline in 2008, falling by **$1.4/W** from 2008-2010, with movements in average total installed cost lagging behind



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 Installed Cost Drop in 2010 Was Also the Result of Falling Balance-of-Systems Costs

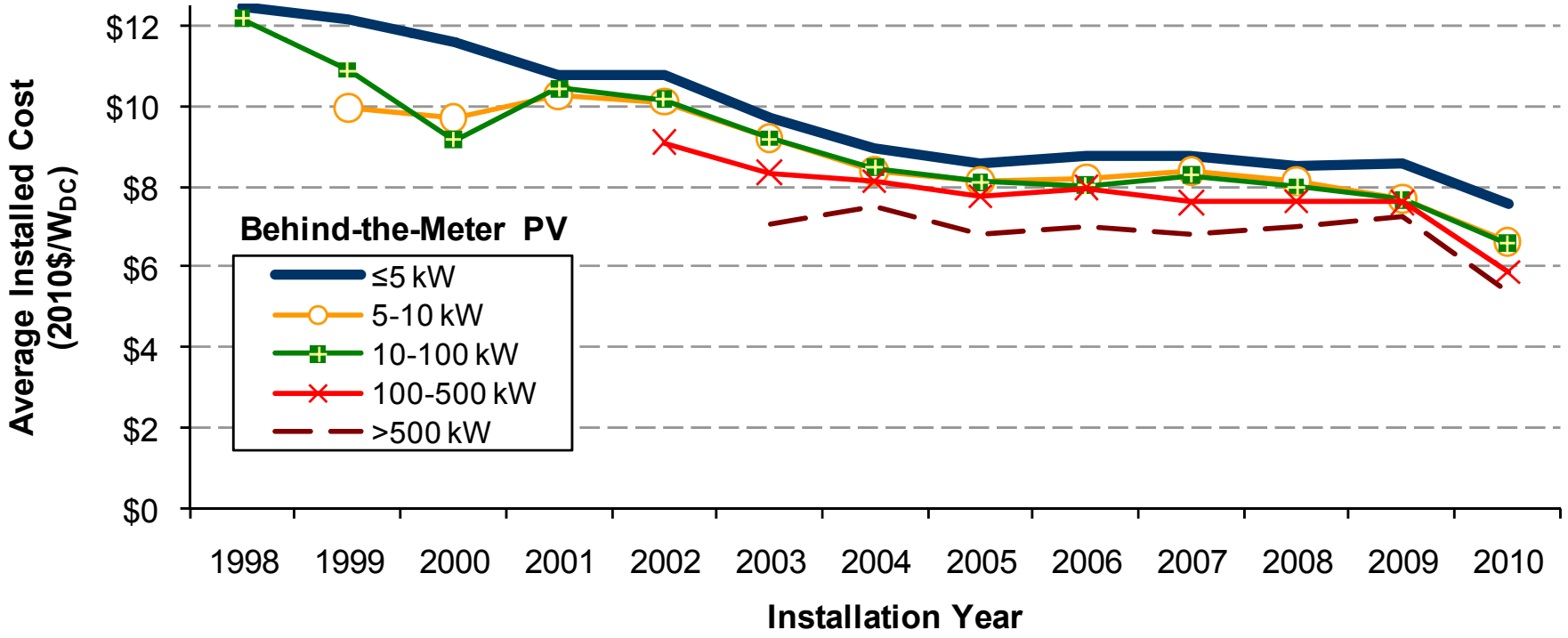
Based on component-level cost data reported by installers, non-module/non-inverter costs fell by **$0.6/W** from 2009 to 2010 and represented **40%** of the total drop in installed costs



Notes: Installer-reported module and inverter cost data presented here should not be interpreted to represent the wholesale prices for those components at the time of project installation, as these data likely include some mark-up and/or may reflect wholesale component prices at the time that the installation contract was signed (rather than at the time the project was installed). "Other" costs are calculated as the difference between the reported total installed cost for each system and the reported module and inverter costs.

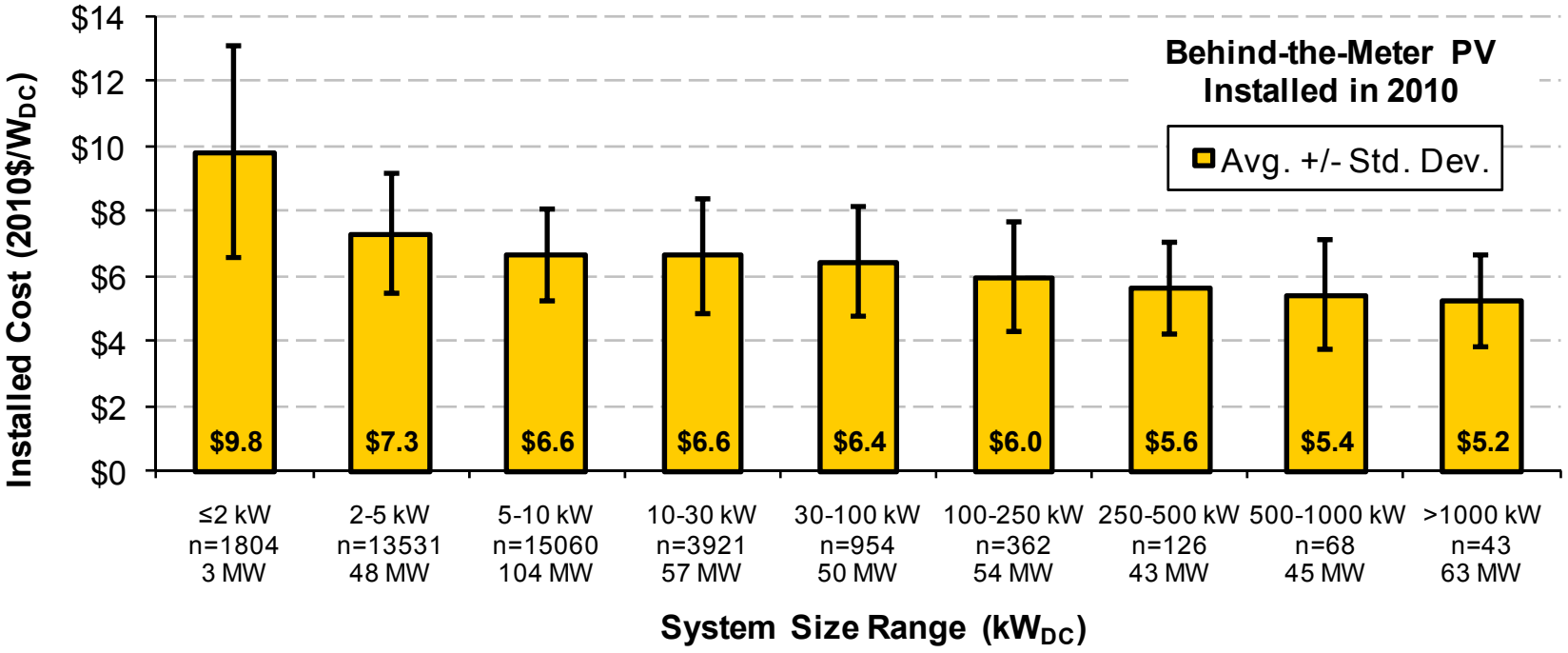
Installed Cost Reductions Were Greatest for Large Systems in 2010

Average installed costs declined by **$1.9/W** (26%) for systems >500 kW in 2010, compared to **$0.9/W** (11%) for ≤5 kW systems



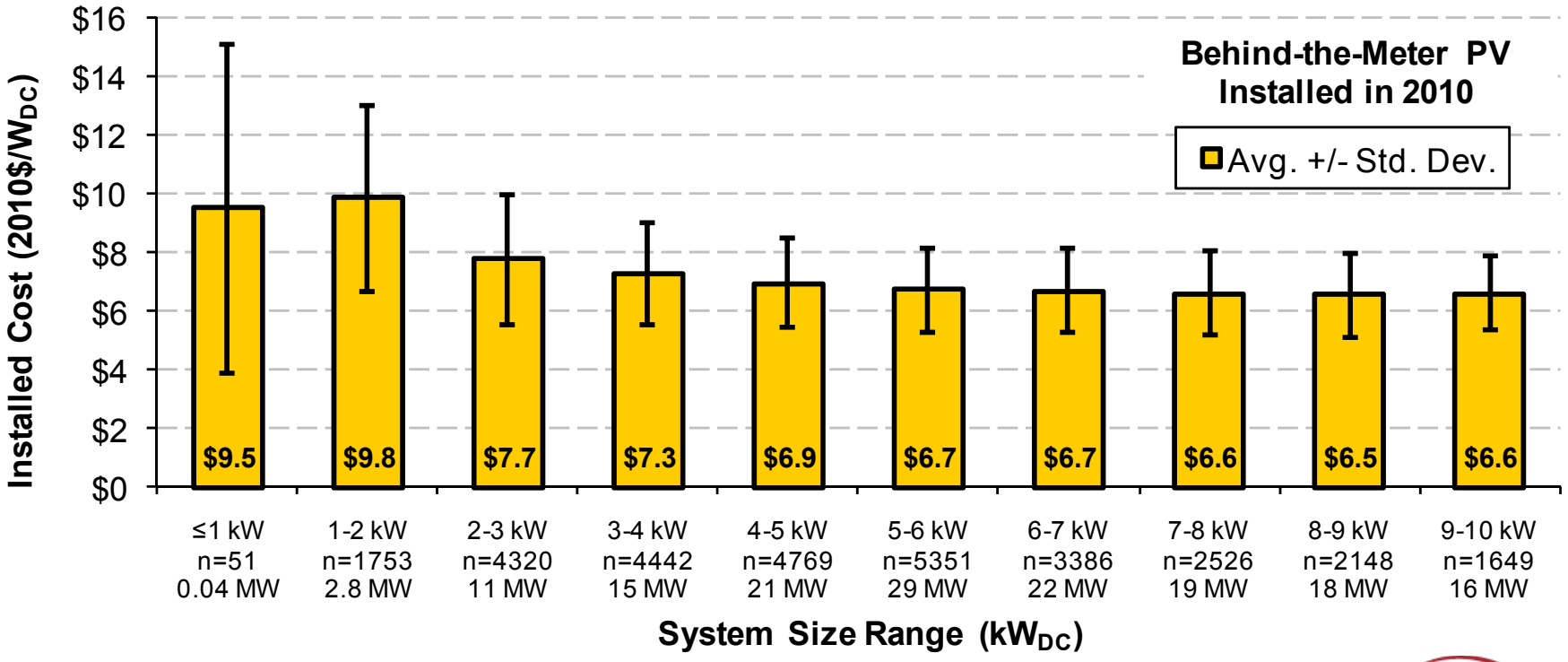
Average Installed Costs Declined with System Size

Among behind-the-meter systems installed in 2010, the average installed cost of >1,000 kW systems was **47% lower** than for systems ≤2 kW, though economies of scale are not continuous with system size



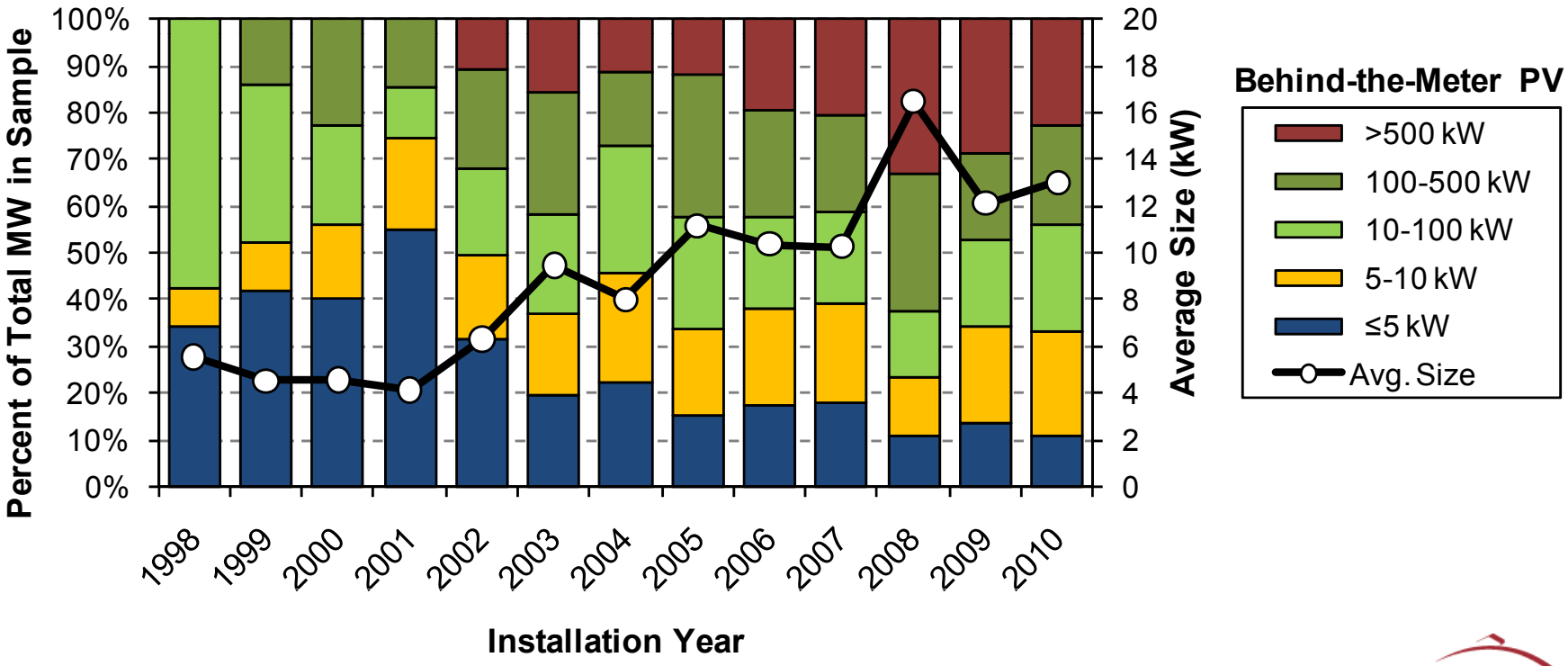
Among Small Systems, Economies of Scale Were Strongest up to 5 kW

The average installed cost of 4-5 kW systems was **29%** lower than for 1-2 kW systems, at which point economies of scale tapered off for small and mid-sized systems



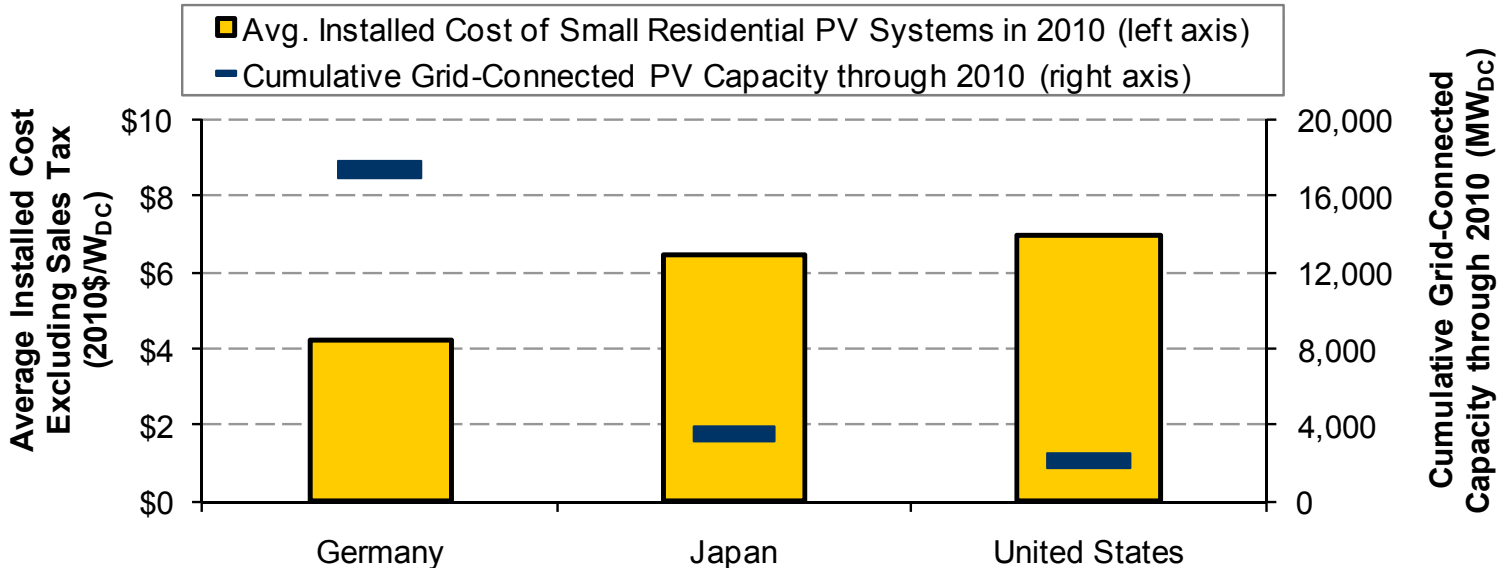
Temporal Cost Reductions Partially Reflect Increasing System Sizes Over Time

Systems larger than 100 kW constituted over 40% of 2010 capacity additions in the data sample, compared to 0% of the capacity additions in 1998



The Average Cost of Small Residential PV in the U.S. Was Significantly Higher Than in Germany

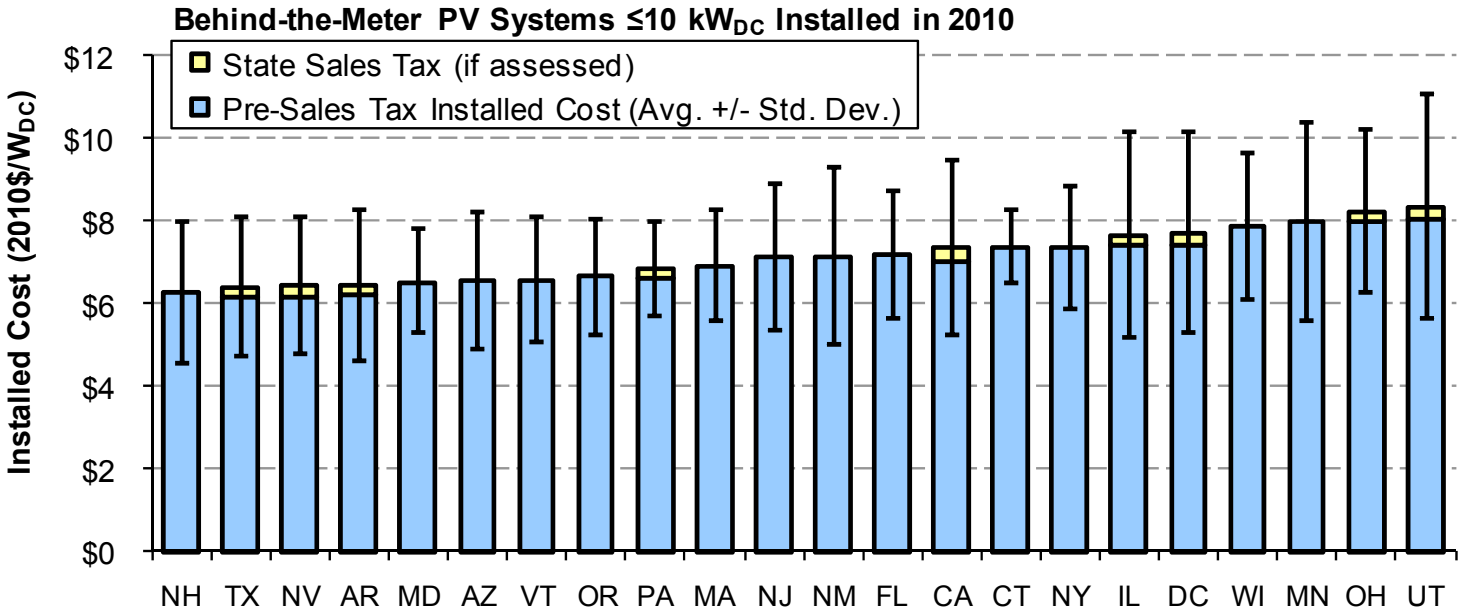
Among small residential systems installed in 2010, average installed costs in the U.S. **($6.9/W**) were substantially greater than in Germany **($4.2/W**), which may be partly attributable to differences in deployment scale



Notes: Data for Germany and Japan are based on the most-recent respective country reports prepared for the International Energy Agency Cooperative Programme on Photovoltaic Power Systems. The German and U.S. cost data are for 2-5 kW systems, while the Japanese cost data are for 3-5 kW systems. The German cost data represents the average of reported year-end installed costs for 2009 ($4.7/W) and 2010 ($3.7/W).

Installed Costs Vary Considerably Across States

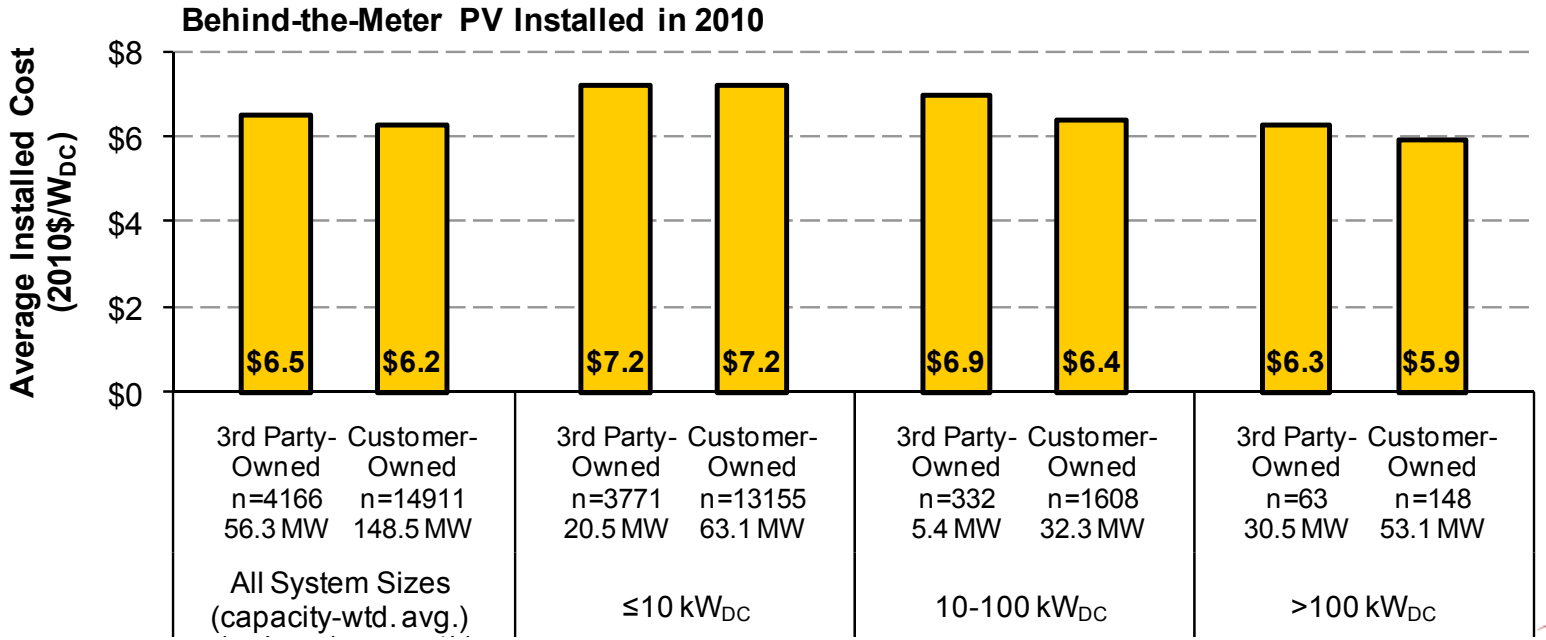
Across the 22 states in the data sample, the average installed cost of <10 kW systems installed in 2010 ranged from **$6.3/W** in New Hampshire to **$8.4/W** in Utah, reflecting differences in market size and maturity, but also other local factors



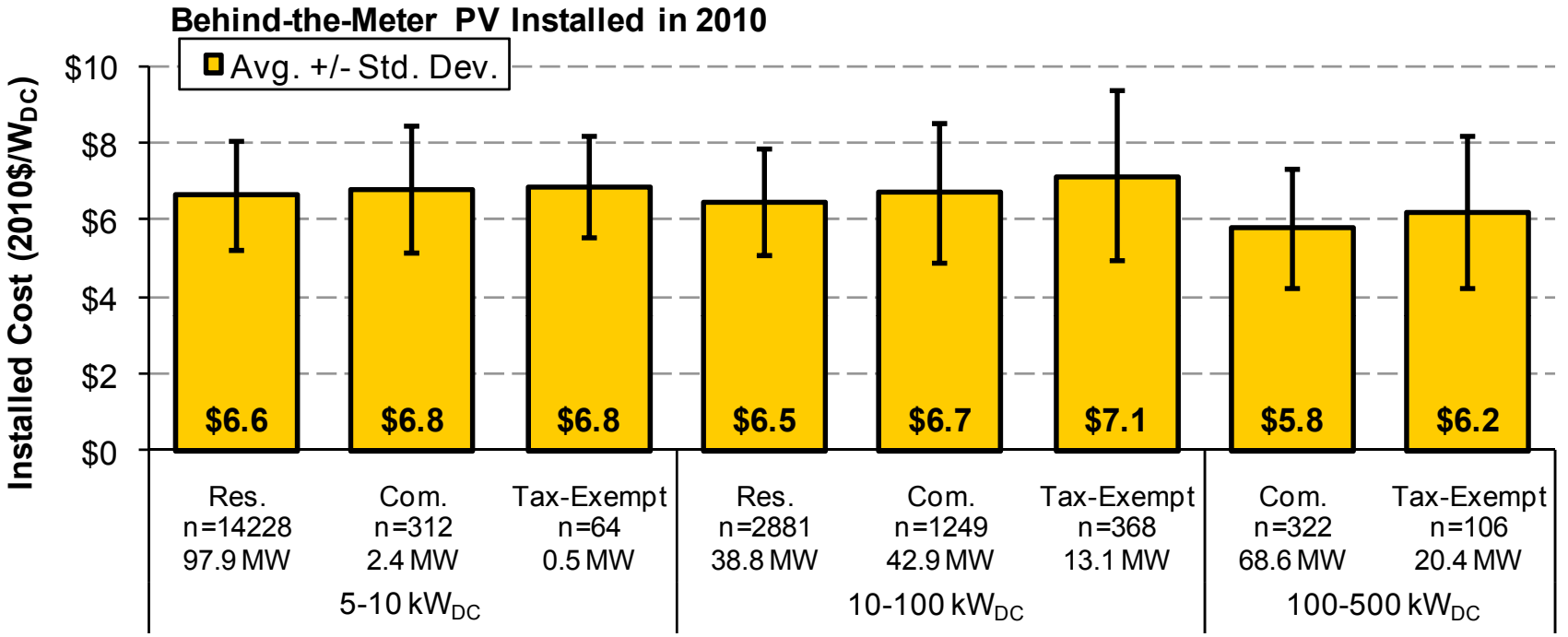
Notes: The figure includes only those states for which data were provided by PV incentive program administrators and only if data were provided for at least five systems. State Sales Tax and Pre-State Sales Tax Installed Cost were calculated from sales tax rates in each state (local sales taxes were not considered). Sales tax was assumed to have been assessed only on hardware costs, which were assumed to constitute 60% of the total pre-sales-tax installed cost.

Installed Costs Reported for Third Party-Owned PV Were Slightly Higher than for Customer-Owned PV

- Cost data reported to PV incentive program administrators by *integrated* 3rd party providers (i.e., companies that provide both installation and financing) may represent the assessed "fair market value" rather than the cost to install the project
- The impact of any bias on the overall study results, however, appears to be modest (e.g., a difference of **$0.3/W** between the capacity-weighted average cost reported for all 3rd party-owned and all customer-owned systems in 2010)



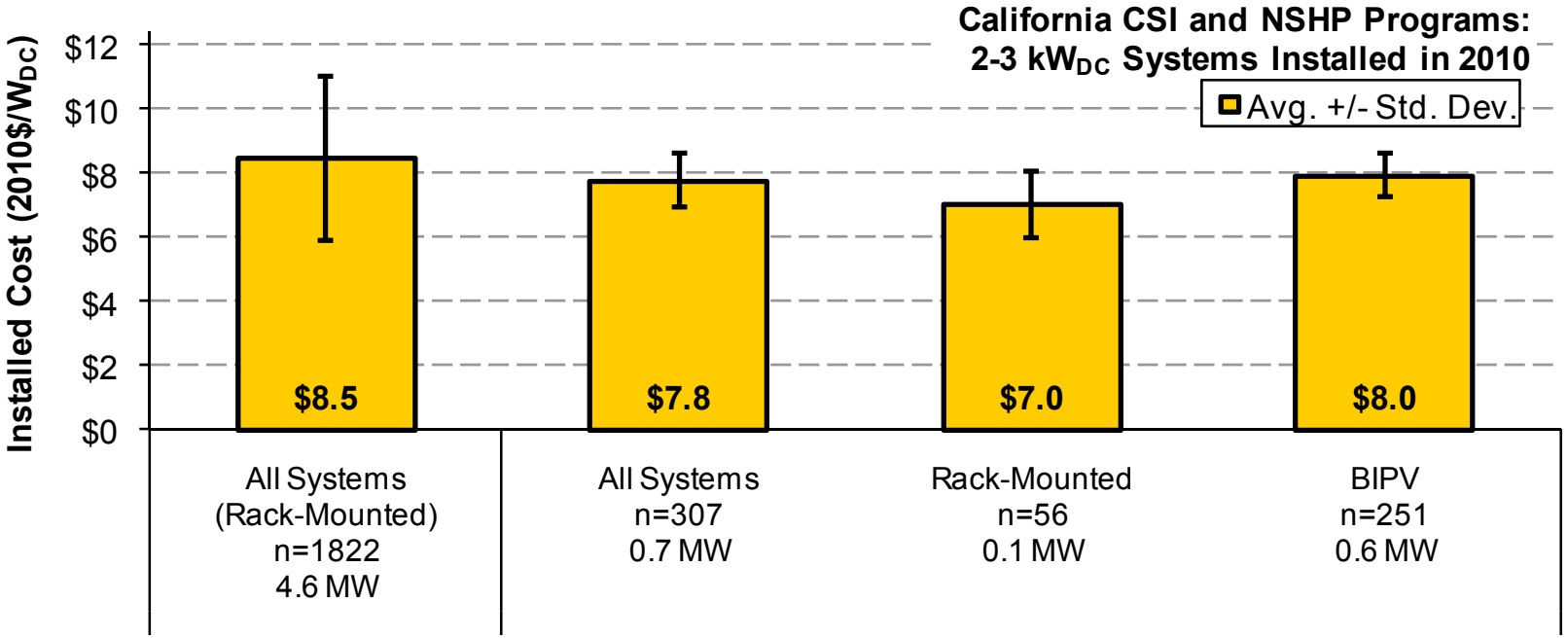
Installed Costs Varied Modestly Across Customer Segments When Comparing Similarly Sized Systems



- Within the 5-10 kW and 10-100 kW size ranges, average installed costs were lowest for systems hosted by residential customers, possibly attributable to a higher degree of standardization and/or lower transaction costs
- Similarly, average installed costs were generally highest for systems hosted by tax-exempt customers, potentially reflecting relatively high transaction costs and a higher incidence of third party ownership

The New Construction Market Offers Cost Advantages for Small Residential Systems

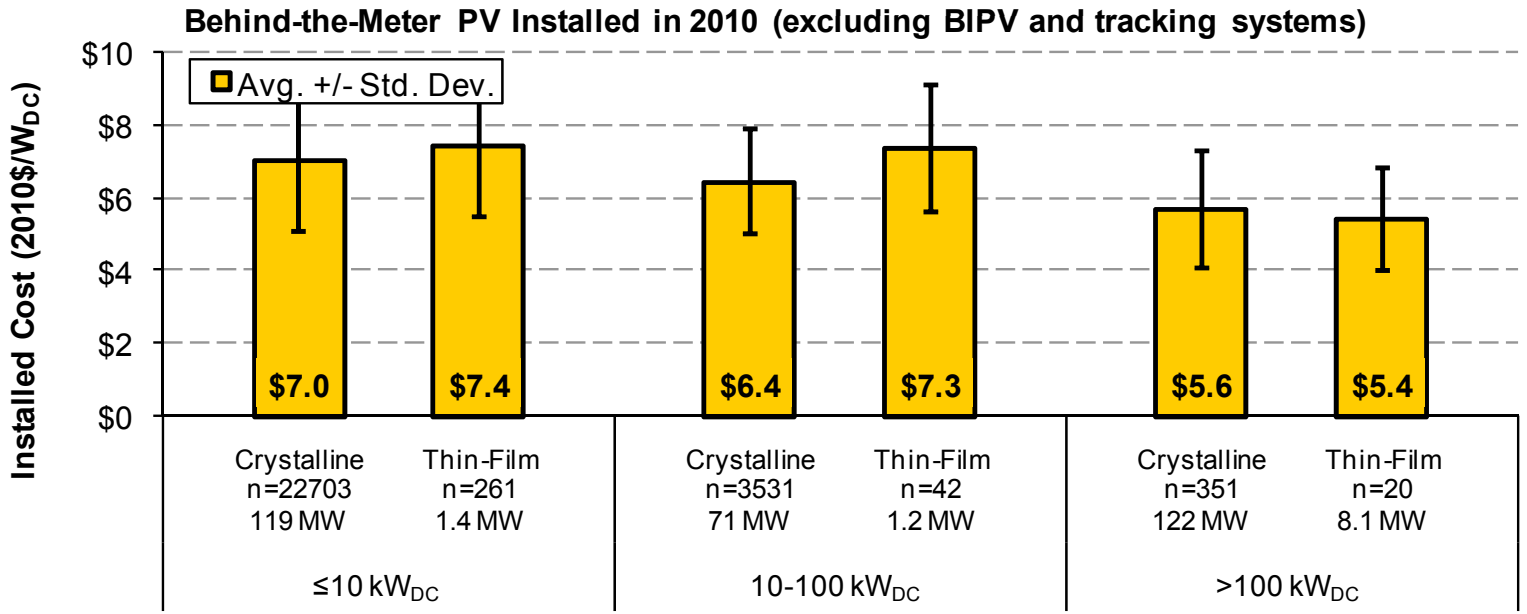
Focusing on 2-3 kW systems installed in California in 2010, residential new construction systems cost **$0.7/W** less, on average, than residential retrofit systems, or **$1.5/W** less if comparing only rack-mounted systems



Notes: Values shown for residential 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.

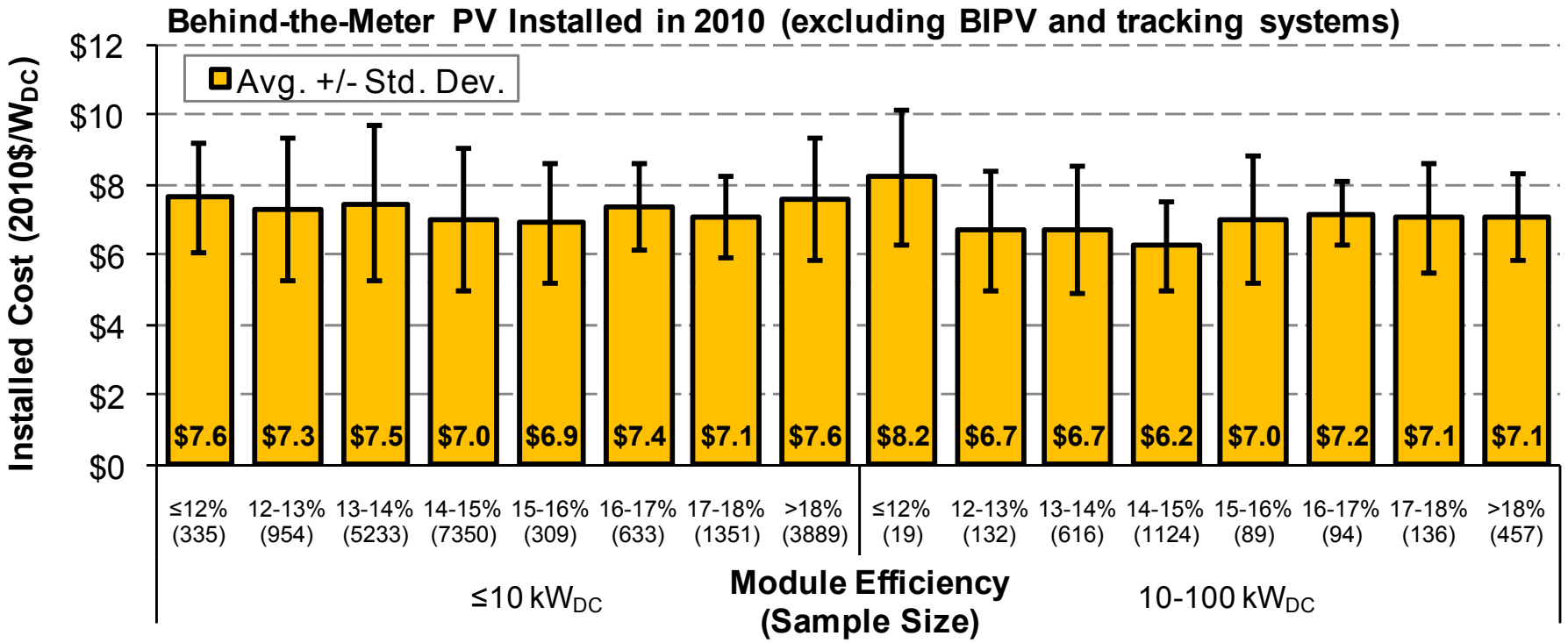
Small and Mid-Size Thin-Film Systems Had Higher Installed Costs than Crystalline Systems

Thin-film systems in the ≤10 kW and 10-100 kW size ranges had higher average installed costs than comparably-sized crystalline systems, suggesting that higher balance of system costs may have offset lower module prices for systems in those size ranges



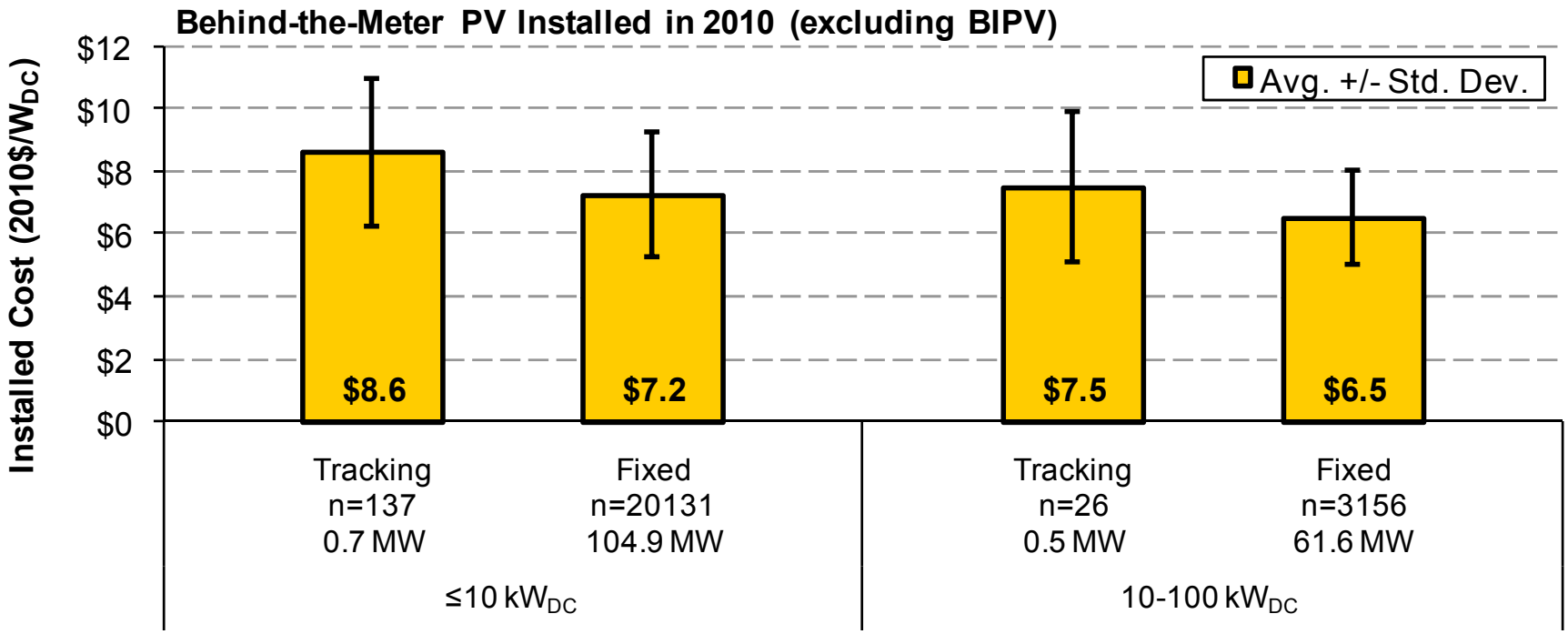
Notes: The data sample used for this comparison excludes all identifiable BIPV and tracking systems in order to eliminate any biases associated with a higher incidence of BIPV among thin-film systems and/or a higher incidence of tracking equipment among crystalline systems.

Systems with Mid-Range Module Efficiencies Had the Lowest Average Installed Cost in 2010



- Among ≤10 kW systems, those with a module efficiency of 15-16% had the lowest installed cost, while among 10-100 kW systems, those with a module efficiency of 14-15% had the lowest average cost

Small and Mid-Sized Systems with Tracking Had Higher Installed Costs than Fixed-Tilt Systems



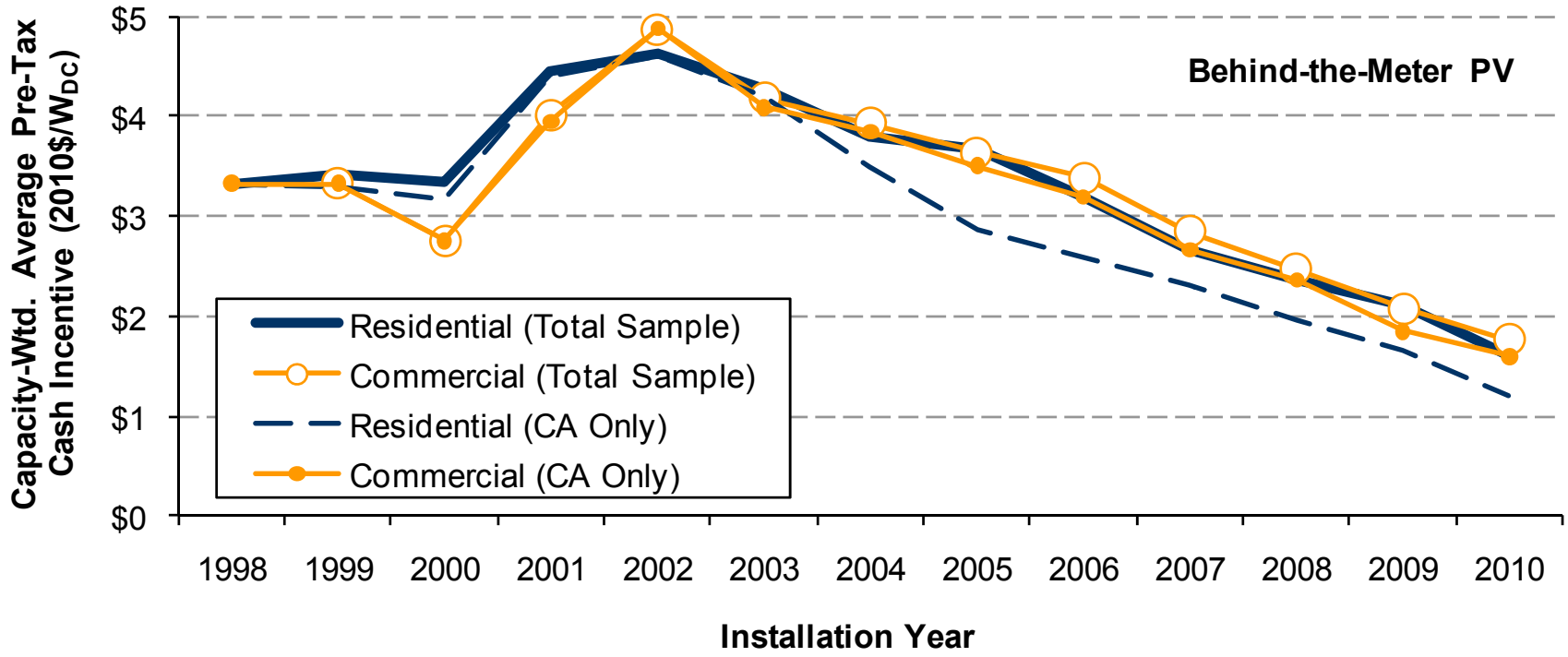
- The average installed cost of systems with tracking was $1.4/W higher in 2010 than for fixed-tilt systems within the ≤10 kW size range, and was $1.0/W higher within the 10-100 kW range
- Some caution is warranted in generalizing from these results, however, given the small sample size of tracking systems

Incentive and Net Installed Cost Trends for Behind-the-Meter PV

Key Assumptions Used to Derive Incentive Trends and Net Installed Costs

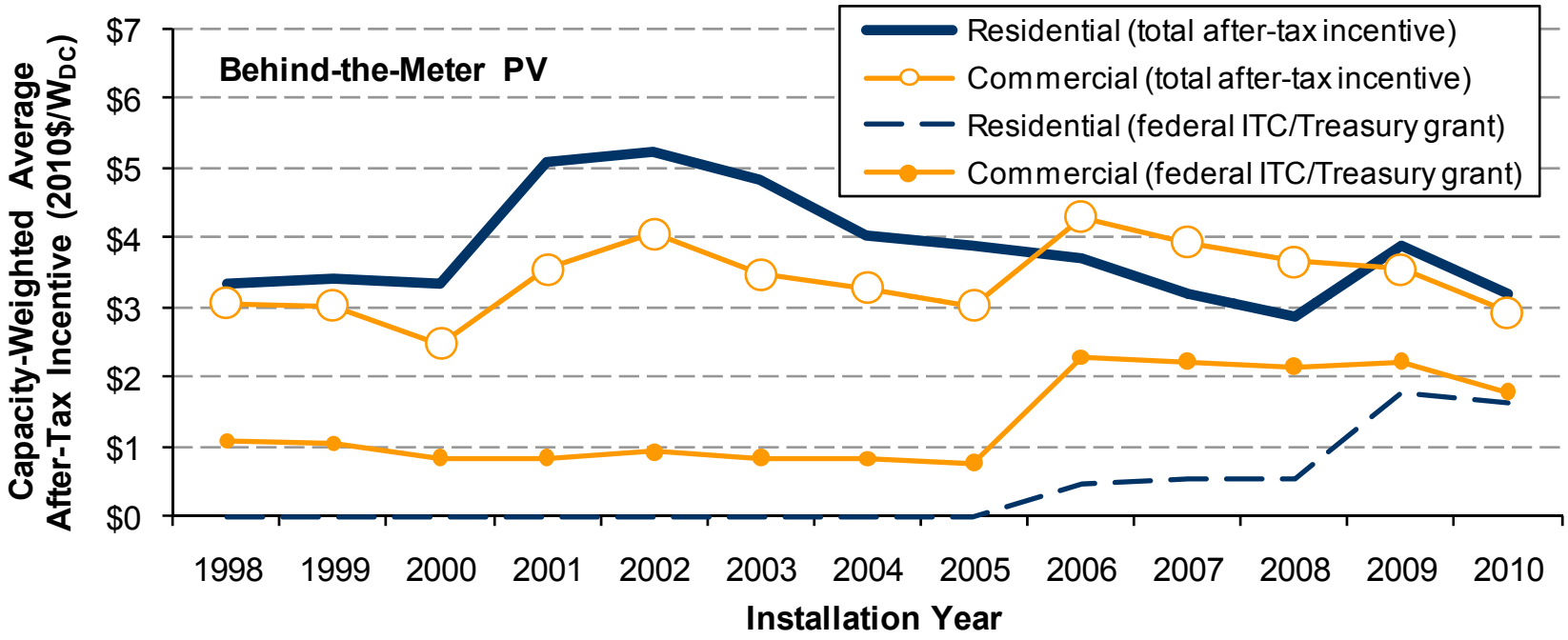
- The total value of incentives and the *net installed cost* (i.e., up-front cost to the owner *after* receipt of incentives) was calculated for each system
- The analysis only accounts for the following incentives:
  - Cash incentives provided by the PV incentive programs in the data sample
  - The federal investment tax credit (ITC), the U.S. Treasury grant in lieu of the ITC, and any available state ITCs
- The analysis does not account for:
  - Cash incentives provided by PV incentive programs outside of the data sample
  - The value of accelerated depreciation (applicable to commercial PV only)
  - Revenue from *future* sales of renewable energy certificates (RECs)
- The analysis is based on the subset of the behind-the-meter data sample (96% of the systems and 78% of the installed capacity) for which the requisite data was available
- 10 kW was used to delineate between residential and commercial PV if no other information was available on customer type

State/Utility Cash Incentives Continued Their Decline in 2010



- The capacity-weighted average pre-tax cash incentive in 2010 was $1.6/W for residential systems and $1.8/W for commercial systems – dropping by $0.5/W and $0.3/W, respectively, from the prior year
- The long-term trend in incentive levels follows the trajectory in CA, which makes up the majority of systems in the data sample

Installed Cost Declines in 2010 Reduced the Value of the Federal ITC, Further Lowering Total Incentive Levels



- The average value of the federal ITC (or Treasury grant in lieu of the ITC), which is based on a percentage of installed cost, fell slightly in 2010 as costs dropped
- The average combined after-tax value of state/utility cash incentives, state ITCs, and the federal ITCs (or cash grant) was $3.2/W for residential PV and $2.9/W for commercial PV, both down 17% from 2009 levels

REC Revenues Add to Overall Incentives, But Impact Varies Widely

Because the revenue from future REC sales is highly uncertain, it is **not** incorporated into this analysis

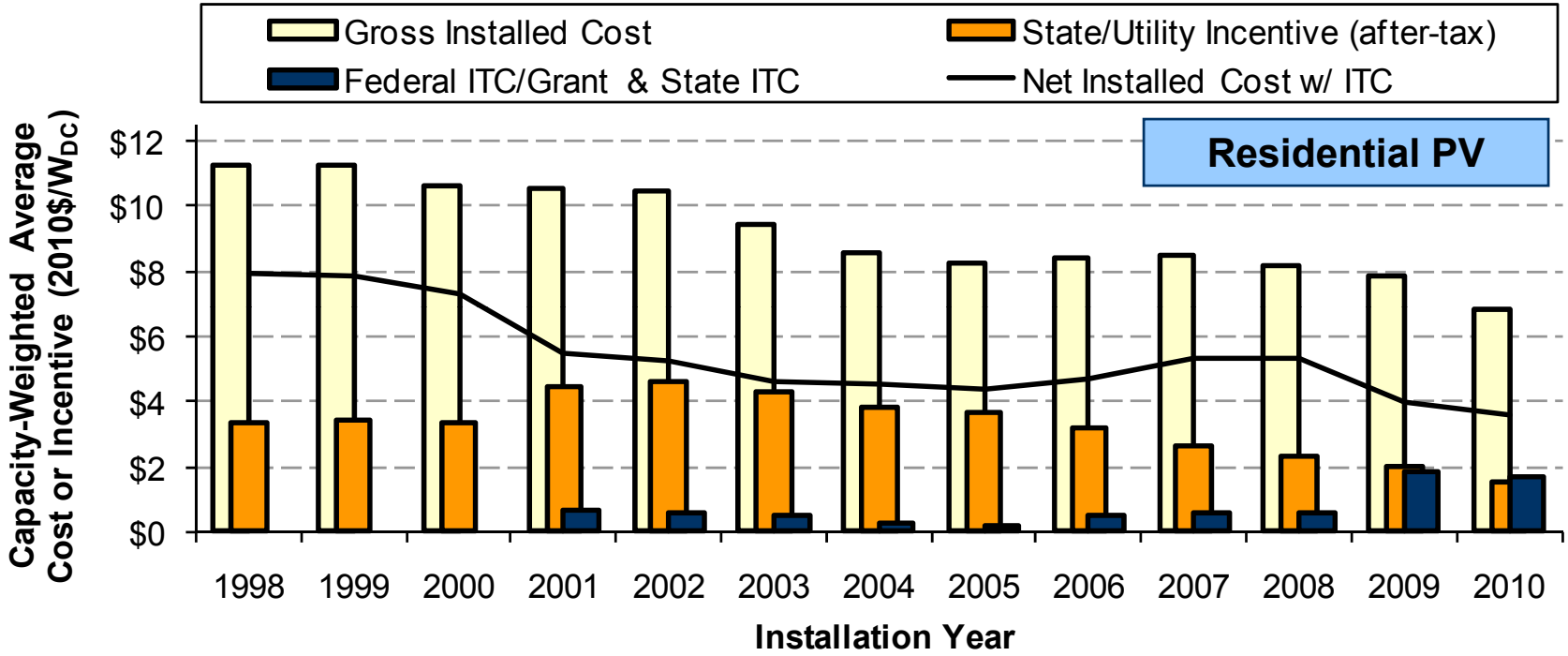
In general, the revenue potential from the sale of RECs depends on where the system is located and what REC markets are available:

1. **RPS Solar Set-Aside Markets**: Solar REC prices vary widely across states, over time, and between spot-market and long-term contract sales. A hypothetical SREC price of $200/MWh (in line with recent long-term contracts in some states in 2010, though prices in many markets declined in 2011) is equivalent to an up-front incentive of roughly **$2.0/W** on a present-value basis*
2. **Traditional RPS Markets** (no solar set-aside): Annual average spot market prices in 2010 ranged from $0.9/MWh to $23/MWh across RPS states, equivalent to an up-front incentive of **$0.01/W** to **$0.23/W***
3. **Voluntary REC Markets**: Annual average spot-market prices in most regions were roughly $0.9/MWh in 2010, equivalent to **$0.01/W***

** Source of historical REC price data: Spectron and PJM-GATS*

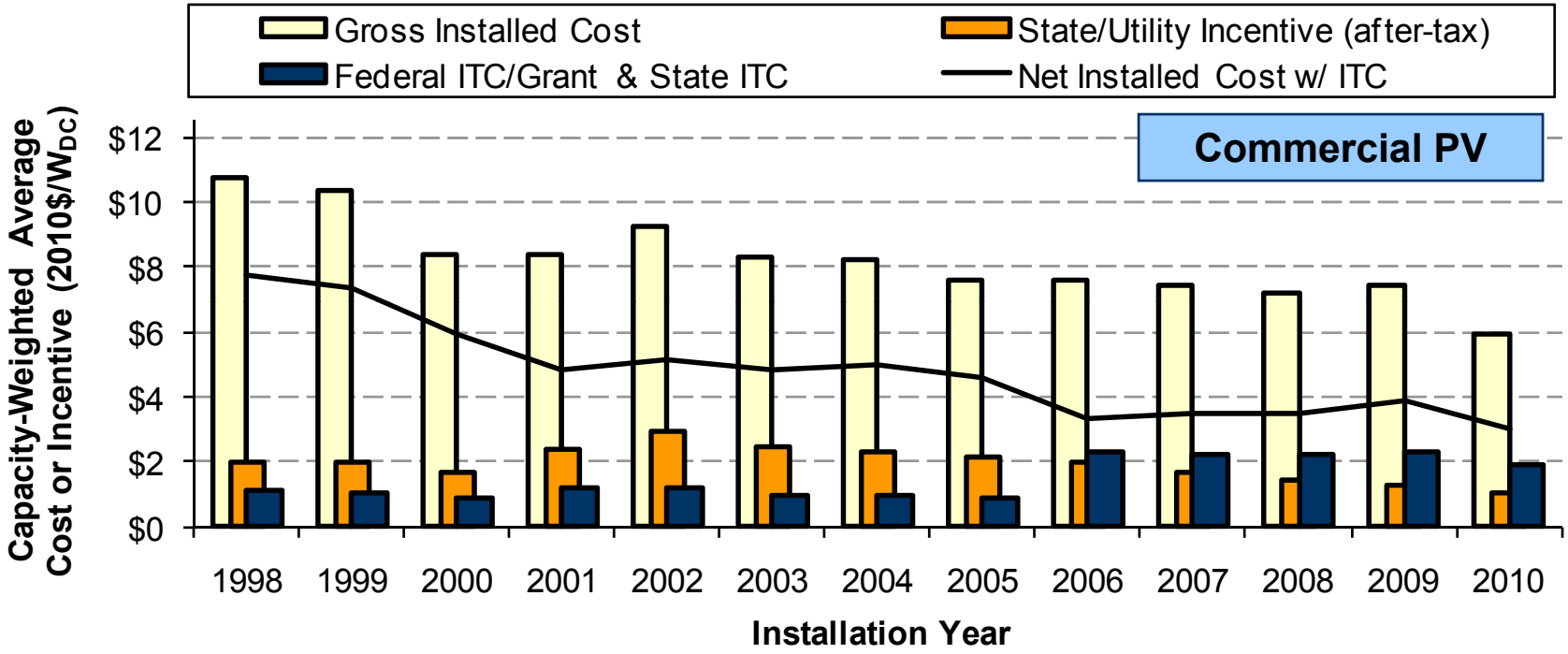
*** $/W estimates calculated assuming a 20-year payment stream,10% nominal discount rate, 1,200 kWh_{AC}/kW_{DC} in Year 1, and 0.5% /year degradation*

Net Installed Costs Fell for Residential PV in 2010, But the Drop Was Dampened by Falling Incentives



- The average net installed cost of residential PV fell by 9% in 2010 to **$3.6/W**, its all-time low
- The drop in average *net* installed costs for residential PV in 2010 is equal to just 36% of the reduction in *gross* installed costs, due to the offsetting effect of falling incentive levels

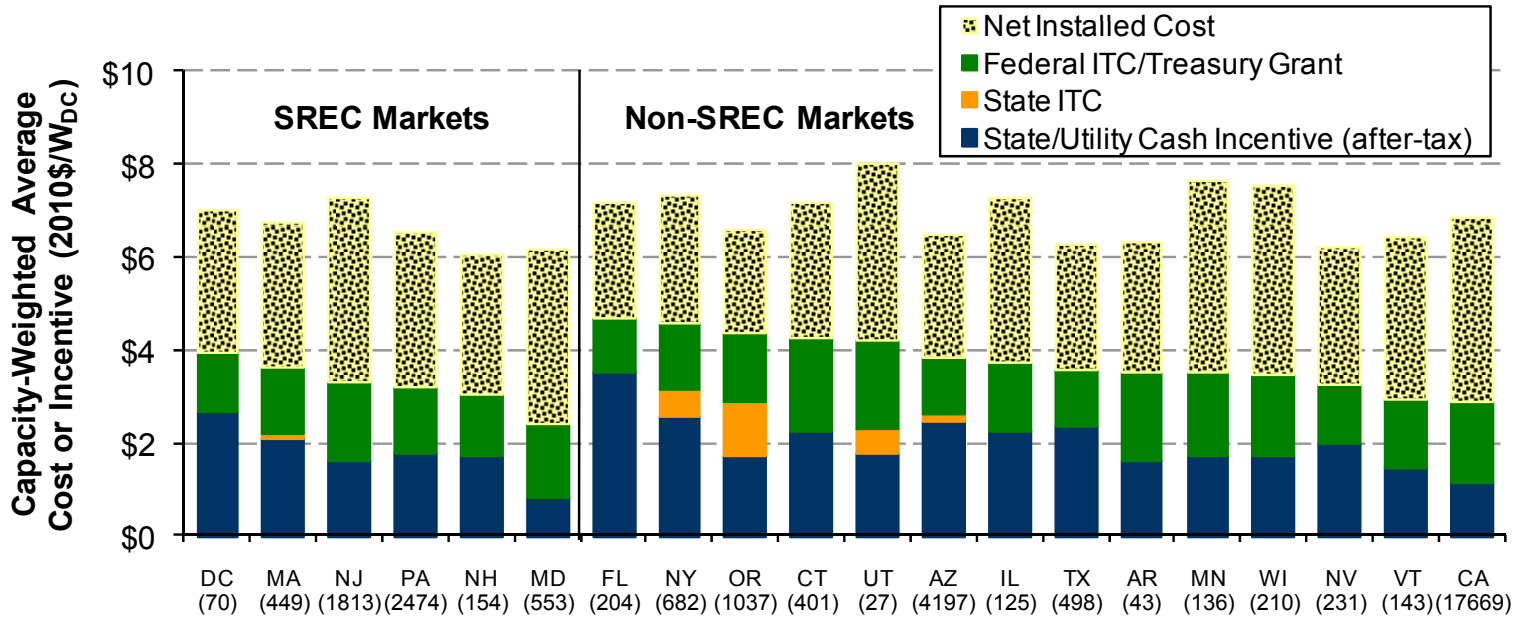
…As Was Also the Case for Commercial PV



- The average net installed cost of commercial PV fell by 22% in 2010 to **$3.0/W**, also an all-time low
- The drop in average *net* installed costs for commercial PV in 2010 is equal to 58% of the reduction in *gross* installed costs

Incentives and Net Installed Costs Diverged Widely Across States for Residential PV...

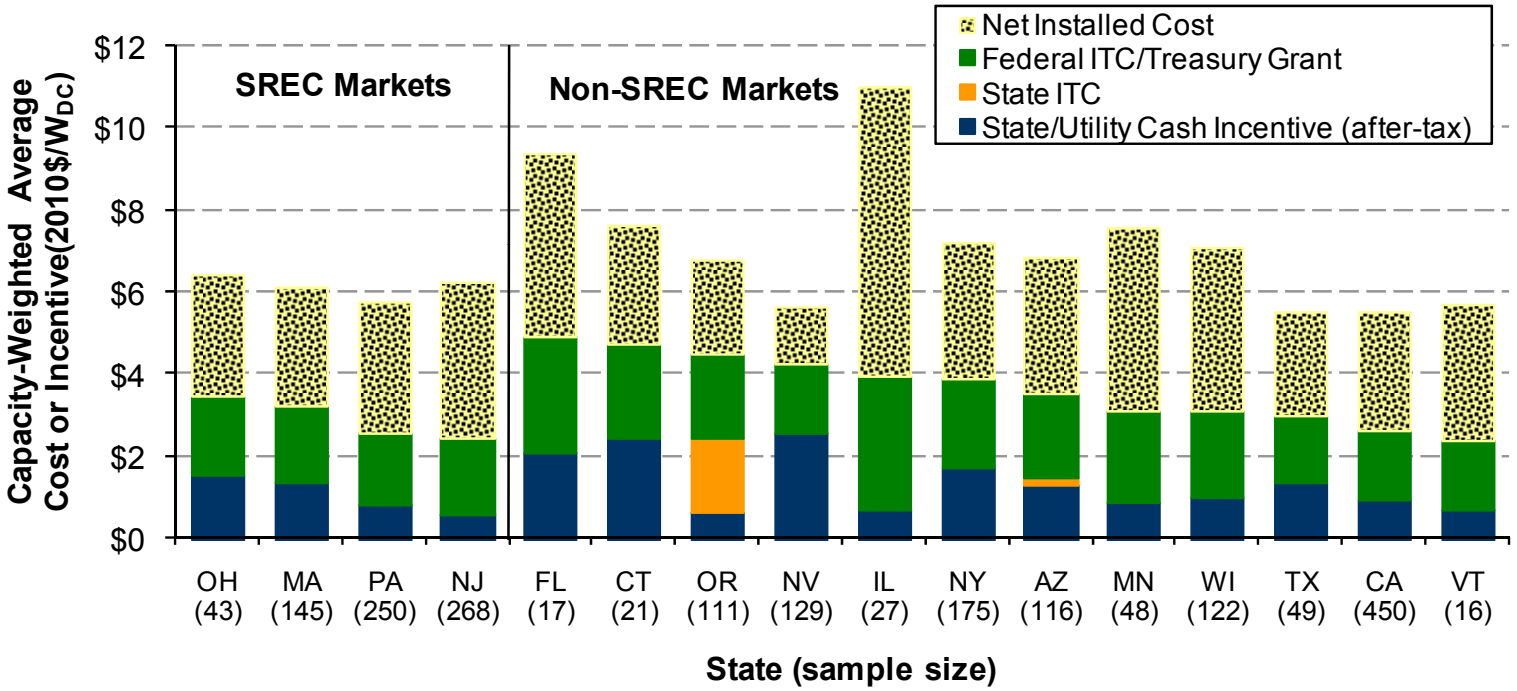
After-Tax Incentives and Net Installed Cost for Residential PV in 2010



- Average combined after-tax incentives (cash incentives plus ITCs/treasury grant) for residential PV ranged from $2.4/W in MD to $4.7/W in FL in 2010
- Net installed costs were lowest in Oregon ($2.2/W) and highest in Minnesota ($4.2/W)
- Results in SREC markets could look significantly different if SREC revenues were counted

...And Also for Commercial PV

After-Tax Incentives and Net Installed Cost for Commercial PV in 2010



- Average combined after-tax incentives (cash incentives plus ITCs) ranged from $2.4/W in NJ and VT to $4.9/W in FL
- Net installed costs ranged from a low of $2.3/W in OR and NJ to a high of $7.0/W in IL
- Again, the results for SREC markets could look significantly different if SREC revenues were counted

Installed Cost Trends for "Utility-Sector" PV

(PV Connected to the Utility System)

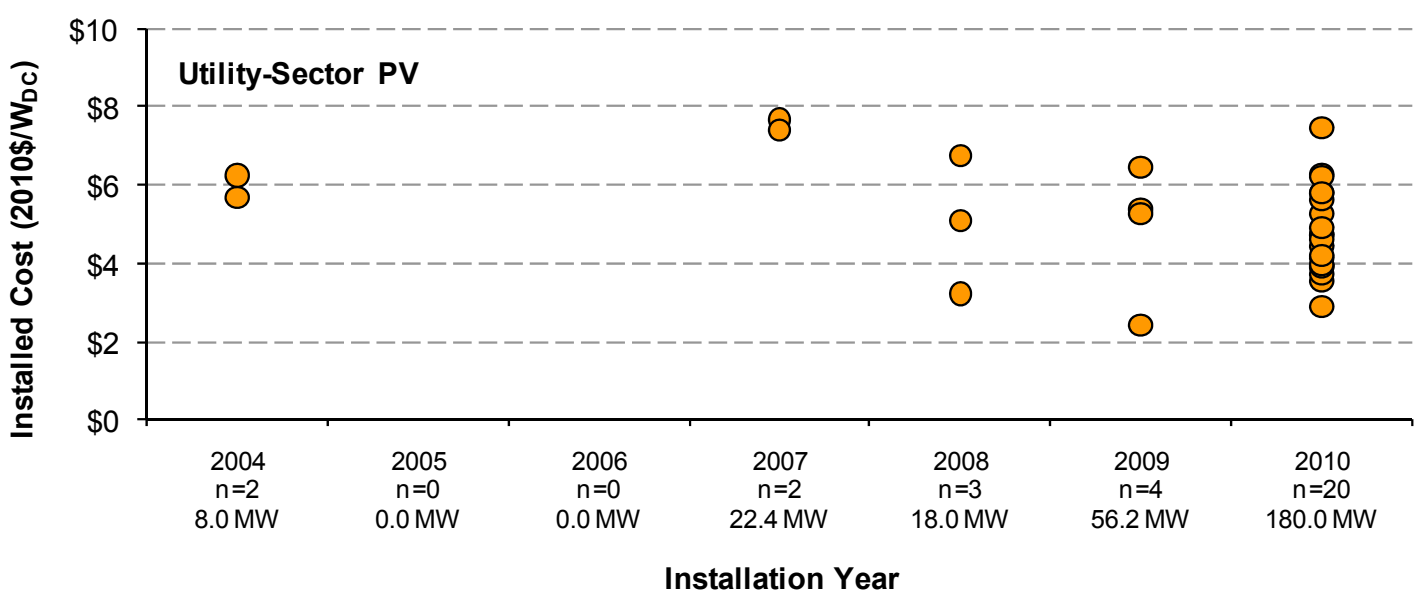
Important Caveats for Utility-Sector PV Installed Cost Data

The utility-sector installed cost data presented herein must be interpreted with a certain degree of caution, for several reasons:

- ***Small sample size with atypical utility-sector PV projects.*** The sample is relatively small and includes a number of small wholesale distributed PV projects as well as a number of larger "one-off" projects with atypical project characteristics
- ***Lag in component pricing.*** The installed costs of some projects may reflect component pricing one or two years prior to project completion, and therefore the data sample may not fully capture the recent decline in component prices
- ***Reliability of data sources.*** The cost data are derived from varied sources and, in some instances (e.g., trade press articles and press releases), are arguably less reliable than the cost data presented earlier for behind-the-meter PV systems
- ***Focus on installed cost rather than levelized cost.*** The focus on installed cost ignores performance-related differences and other factors that influence the levelized cost of electricity, a more comprehensive cost metric for utility-sector PV

The Installed Cost of Utility-Sector PV Varies Considerably Across Projects

Among the 20 projects in the data sample completed in 2010, installed costs ranged from **$2.9/W** to **$7.4/W**, reflecting differences in project size, system configuration, and the unique characteristics of individual projects

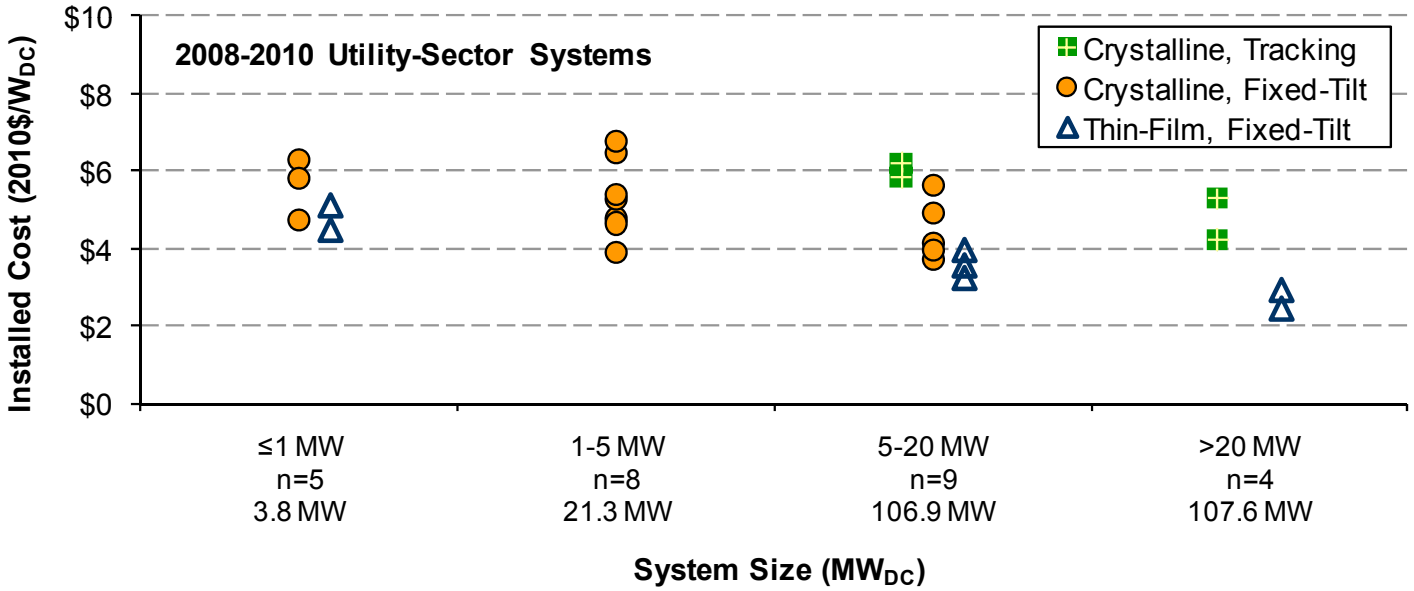


Notes: The figure includes a number of relatively small wholesale distributed PV projects as well as several "one-off" projects. In addition, the reported installed cost of projects completed in any given year may reflect module and other component pricing at the time of project contracting, which may have occurred one or two years prior to installation. For these reasons and others, the data may not provide an accurate depiction of the current cost of typical utility PV projects and may not correspond to recent cost benchmarks for utility PV.

- Recent benchmarks for utility-sector PV generally range from $3.8/W to $4.4/W, which differ from the cost data presented here for a variety of reasons (timing, system size, location, project characteristics, developer/owner profit margins).

The Installed Cost of Utility-Sector PV Depends on System Size and Configuration

- For each system configuration, installed costs decline with increasing system size
- As to be expected, thin-film systems had the lowest installed cost, and crystalline systems with tracking had the highest installed cost (e.g., among >5 MW systems, installed costs ranged from **$2.4-$3.9/W** for thin-film systems vs. **$4.2-$6.2/W** for crystalline systems with tracking)



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Conclusions and Policy Implications

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- PV installed costs declined substantially in 2010, resulting from falling module prices and non-module costs, and partial-year data indicate that steep installed cost reductions have continued into 2011
- While declines in module prices largely reflect global conditions, declines in non-module costs suggest 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 Germany 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
- Targeted policies aimed at specific cost barriers, in concert with basic and applied research and development, may therefore be required in order to sustain the pace of installed cost reductions on a long-term basis
- 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://eetd.lbl.gov/ea/ems/re-pubs.html

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