Tracking the Sun III

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

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- Report Summary -

December 2010

Thanks to the U.S. DOE's Solar Energy Technologies Program and the Clean Energy States Alliance for supporting this work

Project Overview

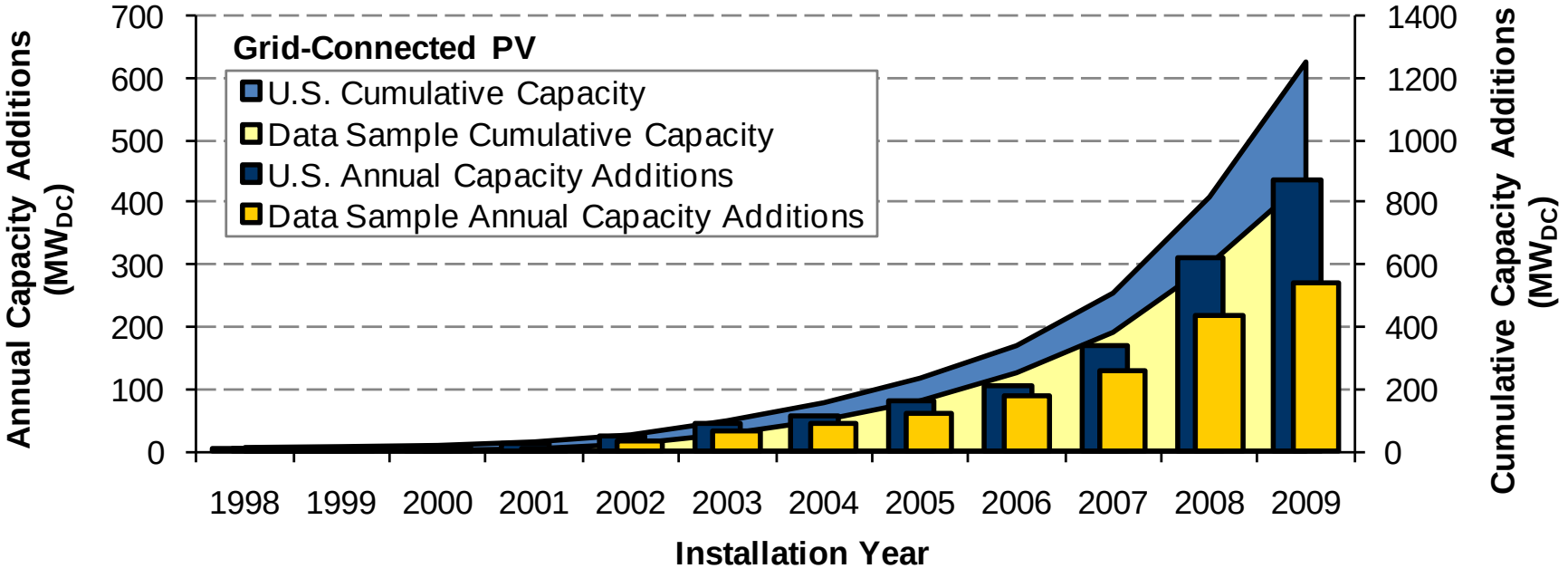
Objective: Using project-level data, evaluate trends in the installed cost of grid-connected PV systems throughout the U.S. to answer the following:

- 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 2.3 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

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

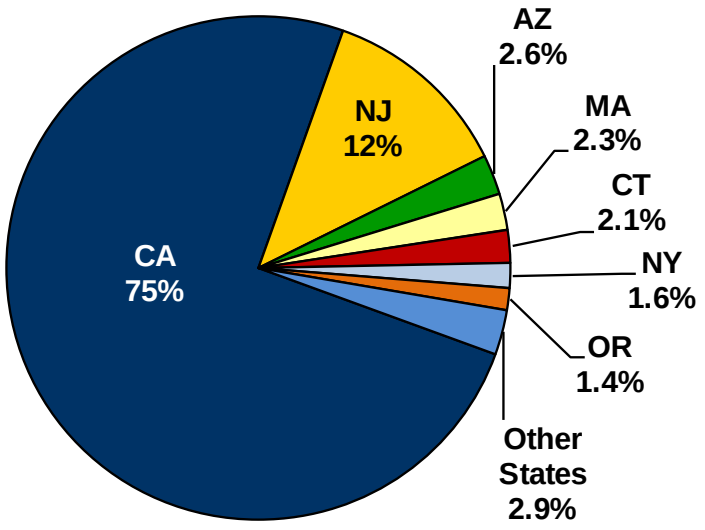


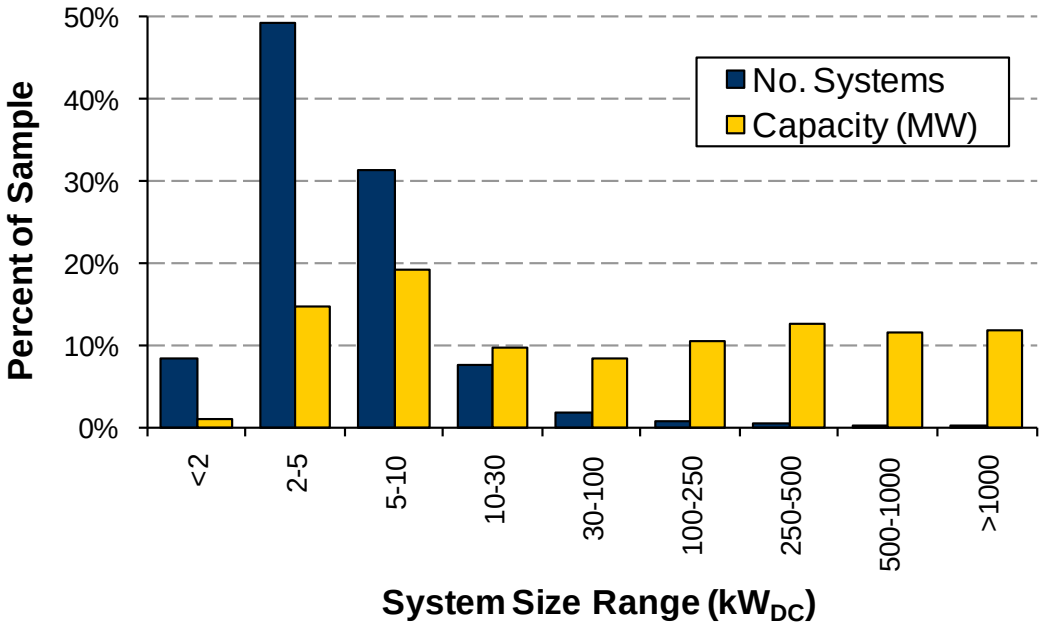
Data source for cumulative and annual U.S. grid-connected PV capacity additions: Sherwood, L. 2010. U.S. Solar Market Trends 2009. Interstate Renewable Energy Council.

- 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}





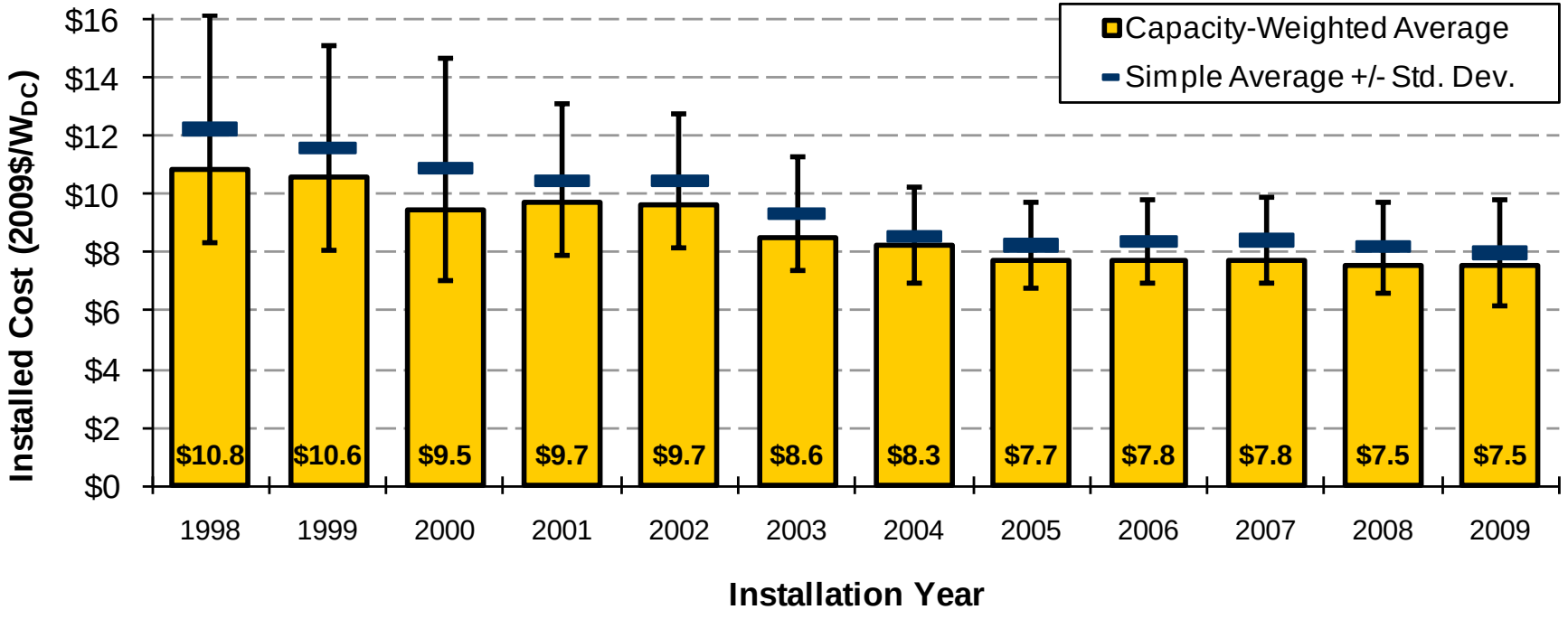
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
No. of Systems	39	180	217	1,308	2,478	3,474	5,589	5,587	8,684	12,635	14,108	23,653	***77,952***
% of Total	*<0.5%*	*<0.5%*	*<0.5%*	*2%*	*3%*	*4%*	*7%*	*7%*	*11%*	*16%*	*18%*	*30%*	***100%***
Capacity (MW_{DC})	0.2	0.8	0.9	5.4	15	33	45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

PV Installed Cost Trends

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

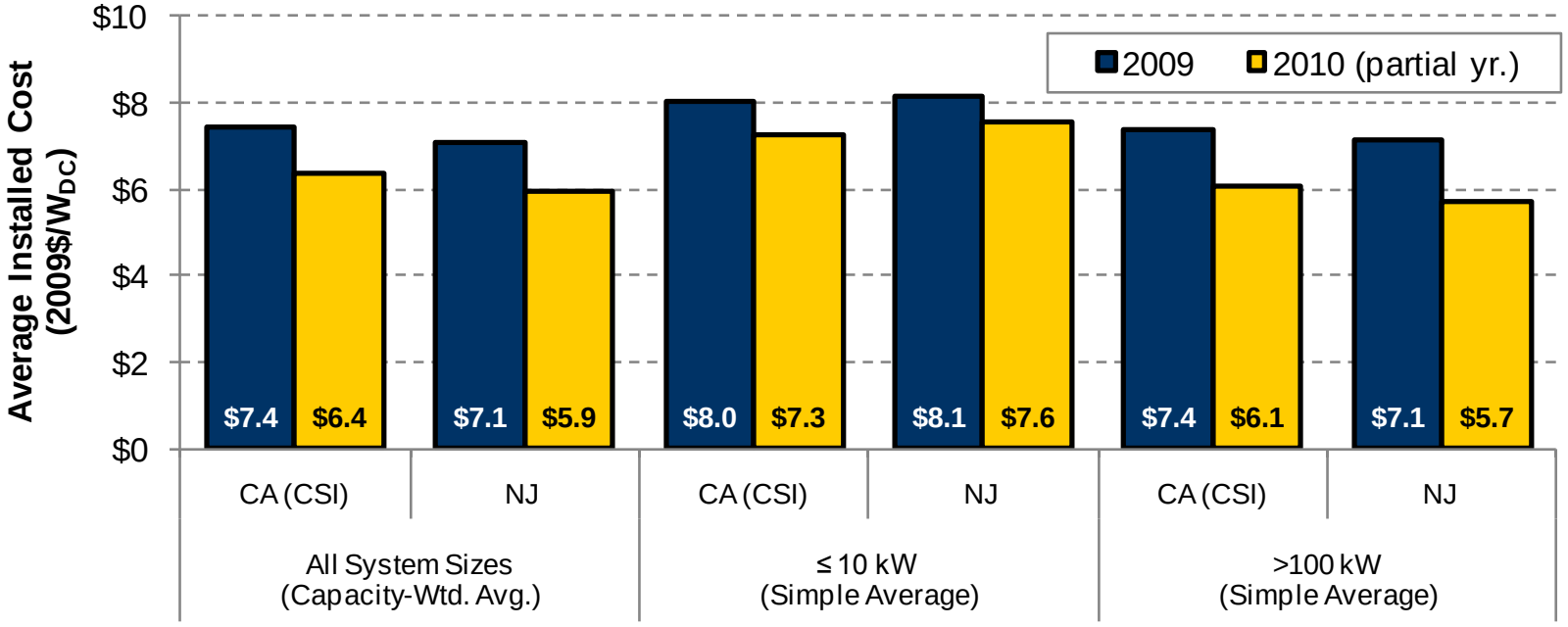
Average Installed Costs Remained Largely Flat from 2008 to 2009

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

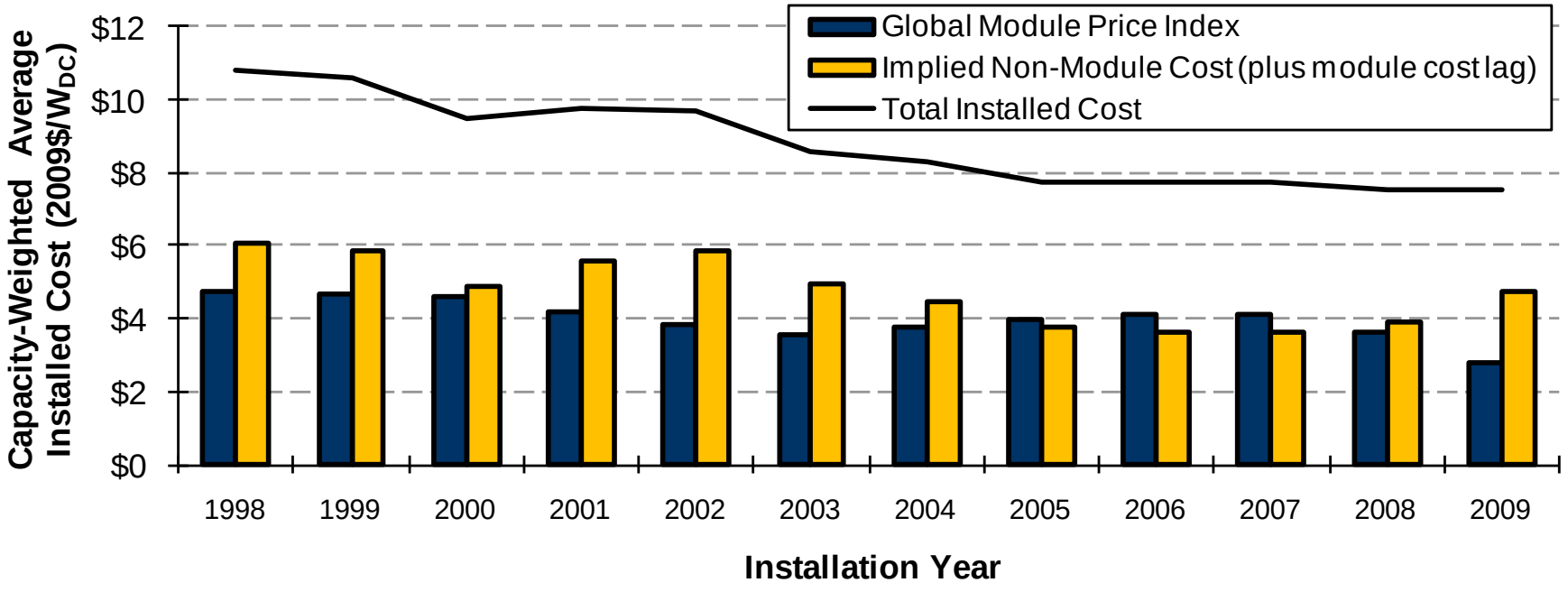
Compared to 2009, the average installed cost of projects within CSI dropped by **$1.0/W$_{DC}$** (14%) over the first 10 months of 2010, and among NJ projects, by **$1.2/W$_{DC}$** (16%) in the first 6 months of 2010



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

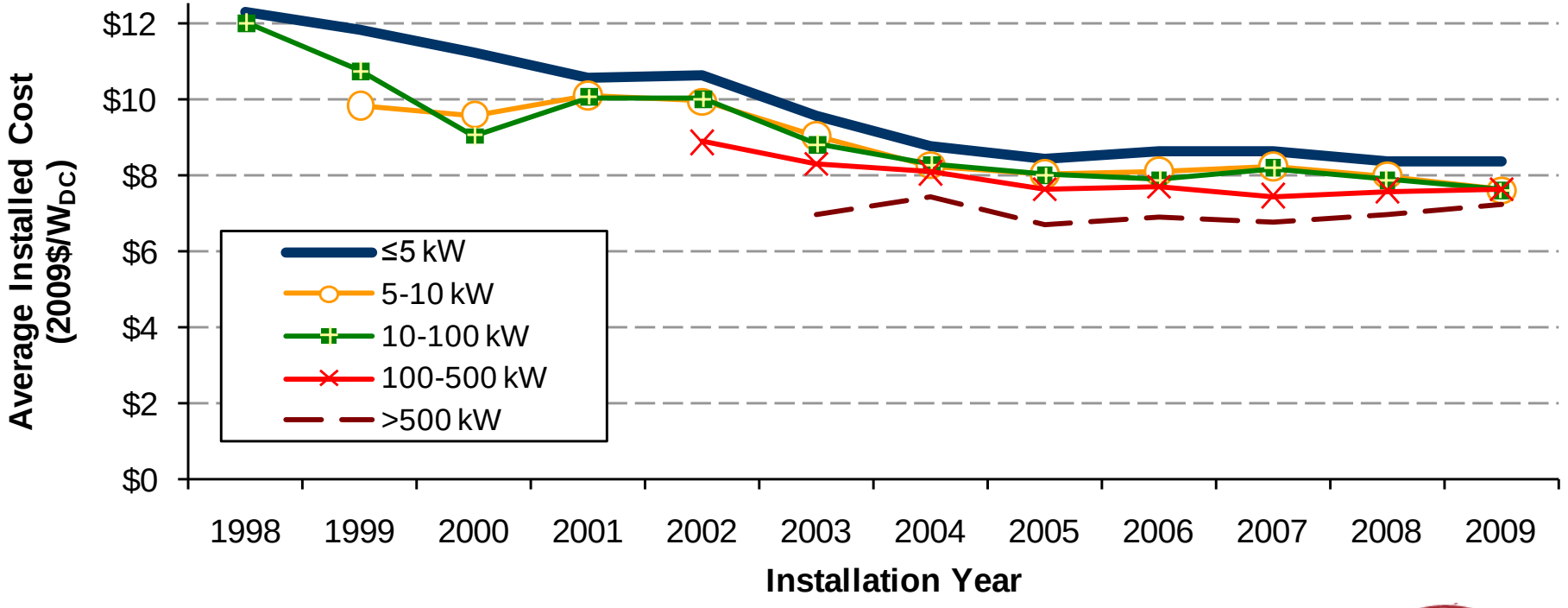
Wholesale module prices declined by **$1.3/W$_{DC}$** from 2007 to 2009, while total installed costs declined by only **$0.2/W$_{DC}$** over this same period; along with preliminary 2010 cost data, this suggests a significant lag between wholesale module prices and installed costs



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.

Historical Cost Reductions Are Most Evident Among Smaller Systems

From 1999-2009, the average cost of systems ≤5 kW_{DC} declined by \$3.4/W_{DC}; limited available data for systems >100 kW_{DC} during early years of the analysis period

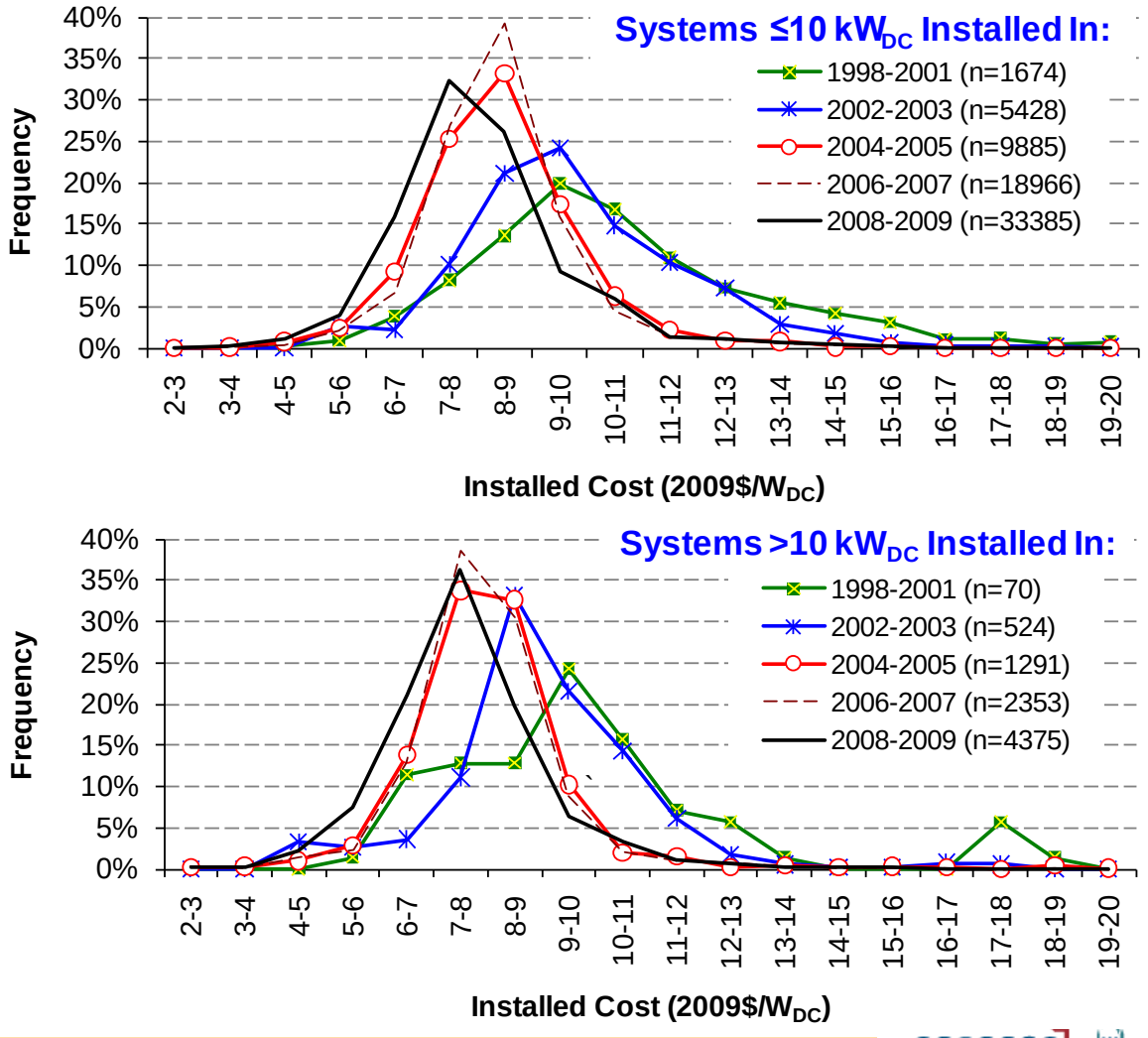


The Historical Narrowing of the Installed Cost Distribution Ceased from 2006 to 2009

Average Costs Declined from 1998 to 2009 Due To:

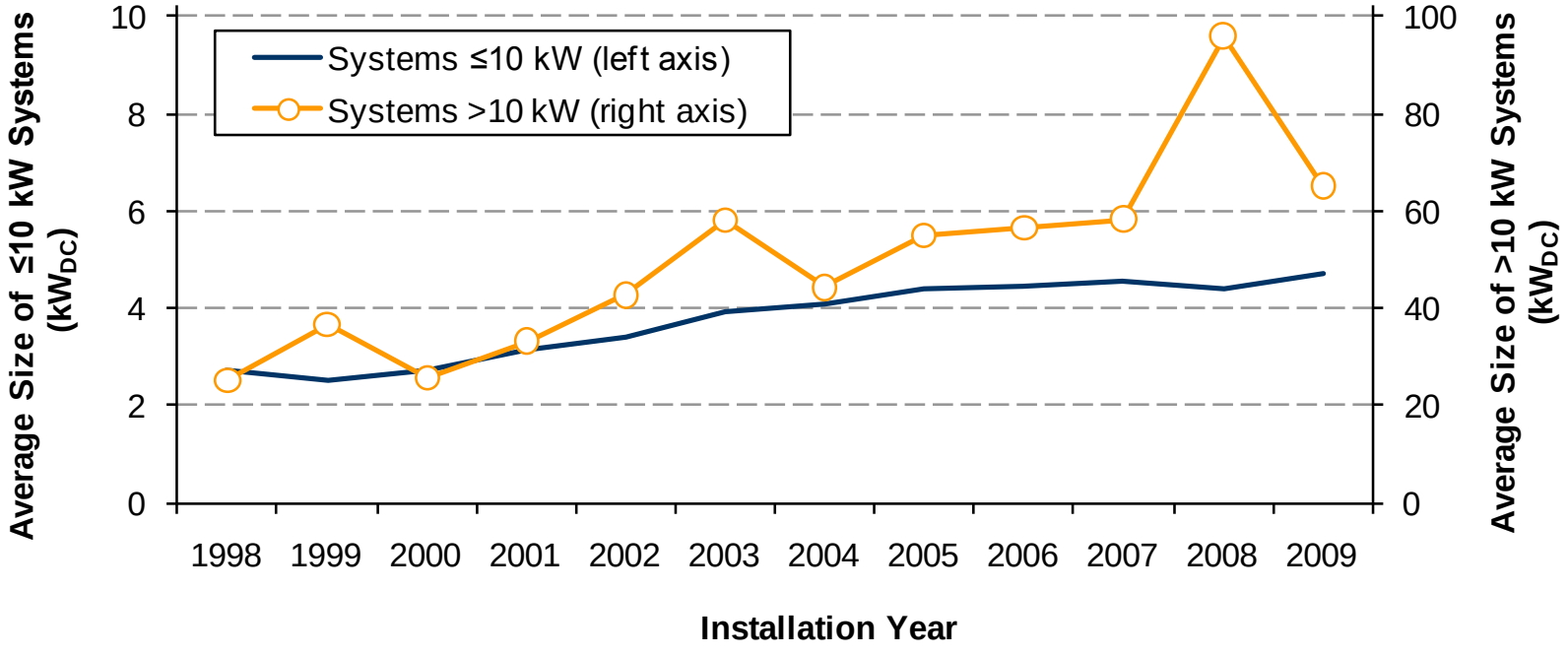
Shifting: Overall shift of the cost distributions toward lower costs

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



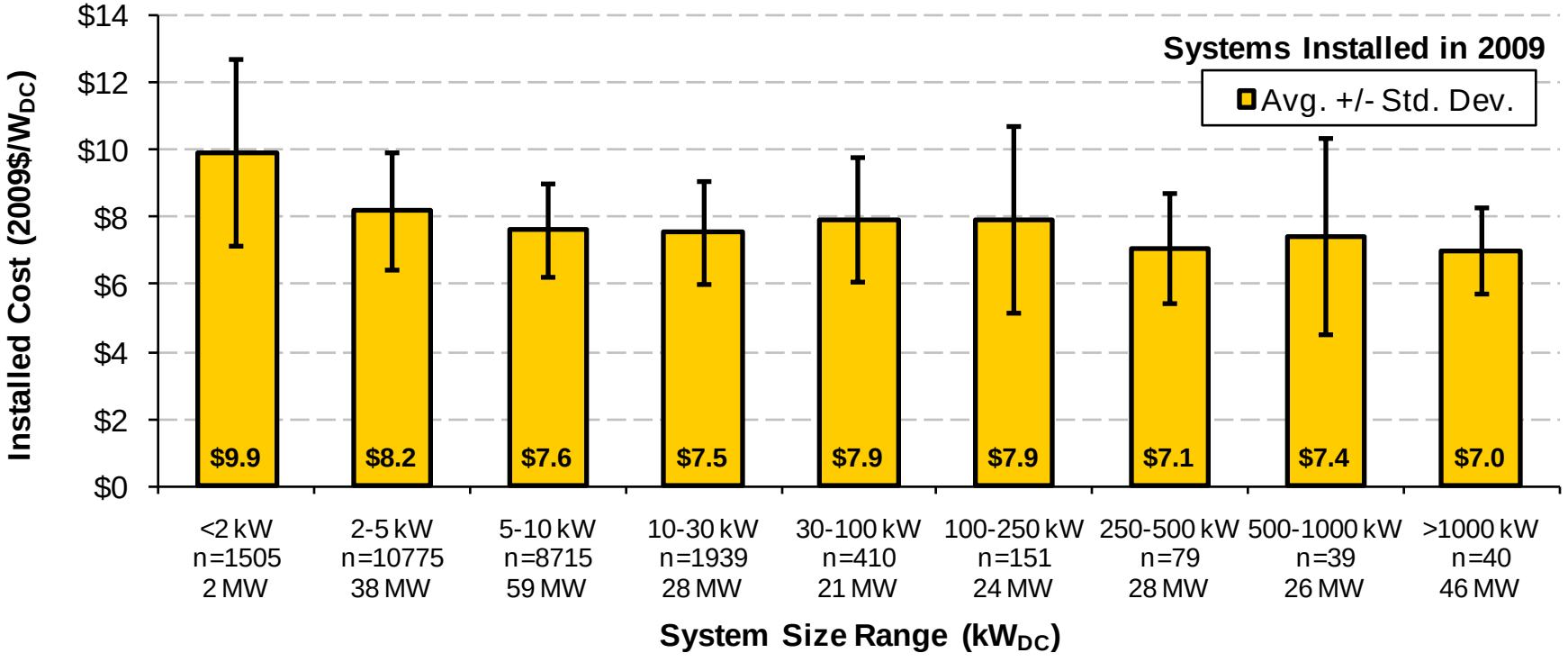
Temporal Cost Reductions Partially Reflect Increasing Average System Size

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



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}



Several Large Projects *Not* in the Primary Sample Have Particularly Low Installed Costs

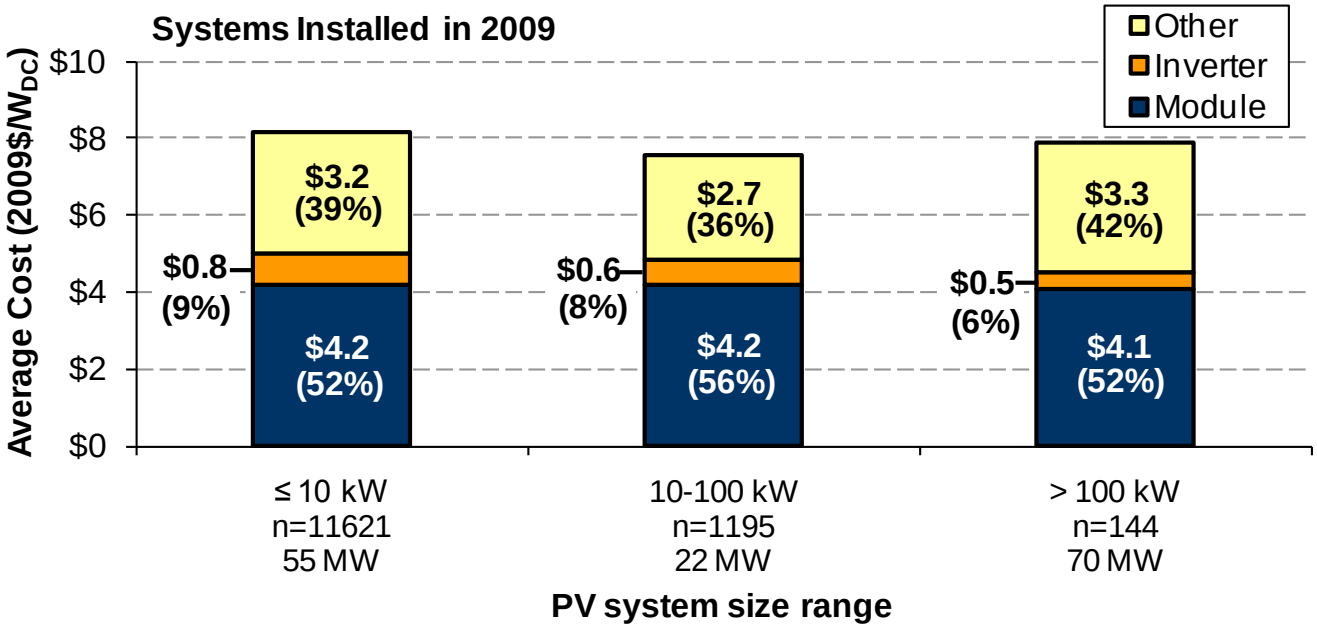
Location	Year of Installation	Plant Size (kW_{DC})	Installed Cost (2009$/$W_{DC}$)	Tracking System Design
Arcadia, FL	2009	30,000	5.1	single axis
Blythe, CA	2009	25,200	2.5	none (fixed-axis)
Boulder City, NV	2008	12,600	3.2	none (fixed-axis)
Fairless Hills, PA	2008	3,000	6.6	none (fixed-axis)
Fontana, CA	2008	2,400	4.2	none (fixed-axis)
Riverside, CA	2008	2,000	6.5	none (fixed-axis)
Nellis, NV	2007	14,200	7.3	single axis
Alamosa, CO	2007	8,220	7.6	fixed, single axis, and double axis
Fort Carson, CO	2007	2,000	6.5	none (fixed-axis)
Springerville, AZ	2001-2004	4,590	6.1	none (fixed-axis)
Prescott Airport, AZ	2002-2006	3,388	5.6	single axis and double axis

Data obtained from assorted public sources (press releases, regulatory filings, etc.)

- Two utility-scale projects installed in 2009 (in Arcadia, FL and Blythe, CA) have costs ($5.1/$W_{DC}$ and $2.5/$W_{DC}$) well below the average for >1,000 kW_{DC} systems in the primary sample ($7.0/$W_{DC}$)
- Several of the secondary-sample projects have tracking systems, and are therefore likely to attain higher performance and a lower levelized cost of electricity (even if the installed cost is higher)

Non-Module/Inverter Costs Were Lowest for Mid-Sized Systems in 2009

Figure presents component-level cost data provided by three programs: California Solar Initiative, Minnesota Solar Electric Rebate Program, and Wisconsin Focus on Energy Cash-Back Rewards Program



- **Module and inverter costs** were relatively constant across systems sizes, indicative of the "commoditized" nature of those components
- **Other** (non-module/non-inverter) costs were lowest for 10-100 kW_{DC} systems, potentially reflecting a combination of economies of scale (compared to smaller systems) and relatively high levels of standardization (compared to larger systems)
  - Higher cost for >100 kW systems may partly reflect higher penetration of tracking systems

In Prior Years, Module Costs Have Been Lower for Large Systems

Module, Inverter, and Other Costs ($/$W_{DC}$) over Time

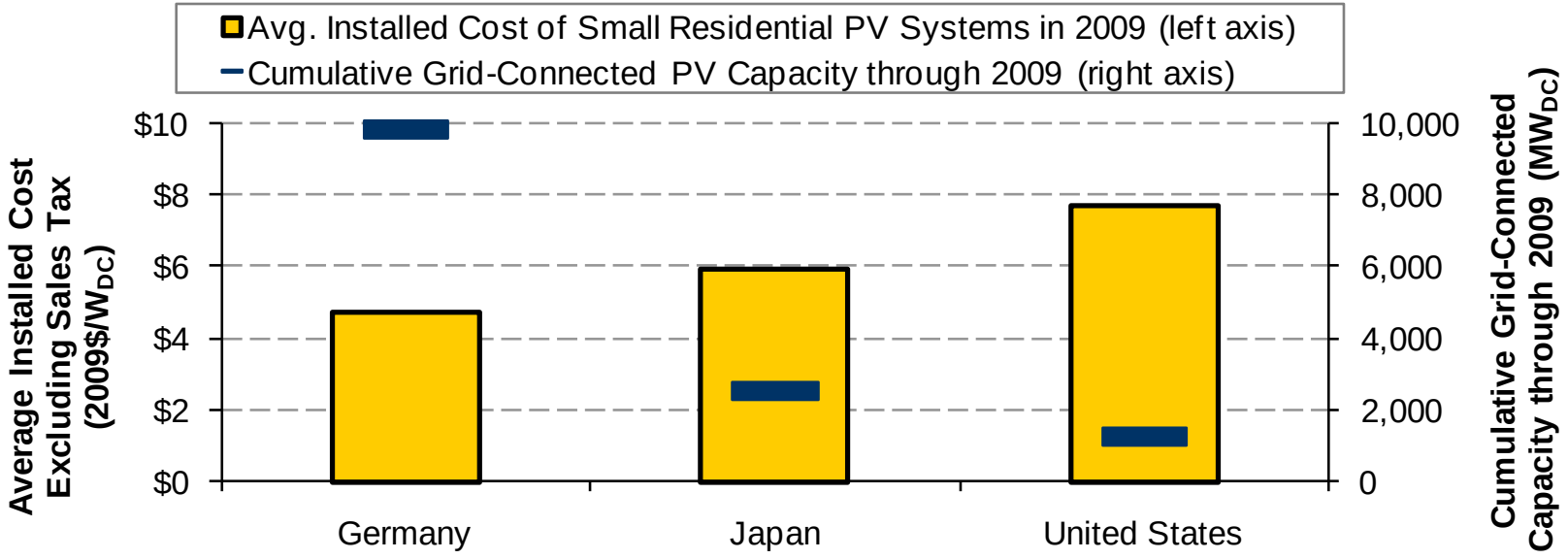
Installation Year	All System Sizes (capacity-weighted average)			≤ 10 kW			10-100 kW			>100 kW		
	Mod.	Inv.	Oth.	Mod.	Inv.	Oth.	Mod.	Inv.	Oth.	Mod.	Inv.	Oth.
2007	$4.3	$0.6	$2.8	$4.8	$0.7	$2.9	$4.7	$0.7	$2.7	$3.8	$0.4	$3.0
2008	$4.1	$0.5	$2.9	$4.6	$0.7	$2.9	$4.5	$0.6	$2.6	$3.9	$0.5	$3.0
2009	$4.0	$0.6	$3.0	$4.2	$0.8	$3.2	$4.2	$0.6	$2.7	$4.1	$0.5	$3.3

Notes: The results presented in this table are based on component-level cost data provided by the California Solar Initiative, Minnesota's Solar Electric Rebate Program, and the Wisconsin Focus on Energy Cash-Back Rewards Program.

- Average module costs for systems >100 kW_{DC} were \$1.0/W_{DC} less than for systems ≤10 kW_{DC} in 2007, and \$0.7/W_{DC} less in 2008
- Larger systems may benefit from bulk purchasing discount, though this was not evident in 2009 (and small systems may also benefit if installer purchases modules in bulk)
- Other (non-module/non-inverter) costs were consistently lowest for 10-100 kW_{DC} systems over the 2007-2009 period

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

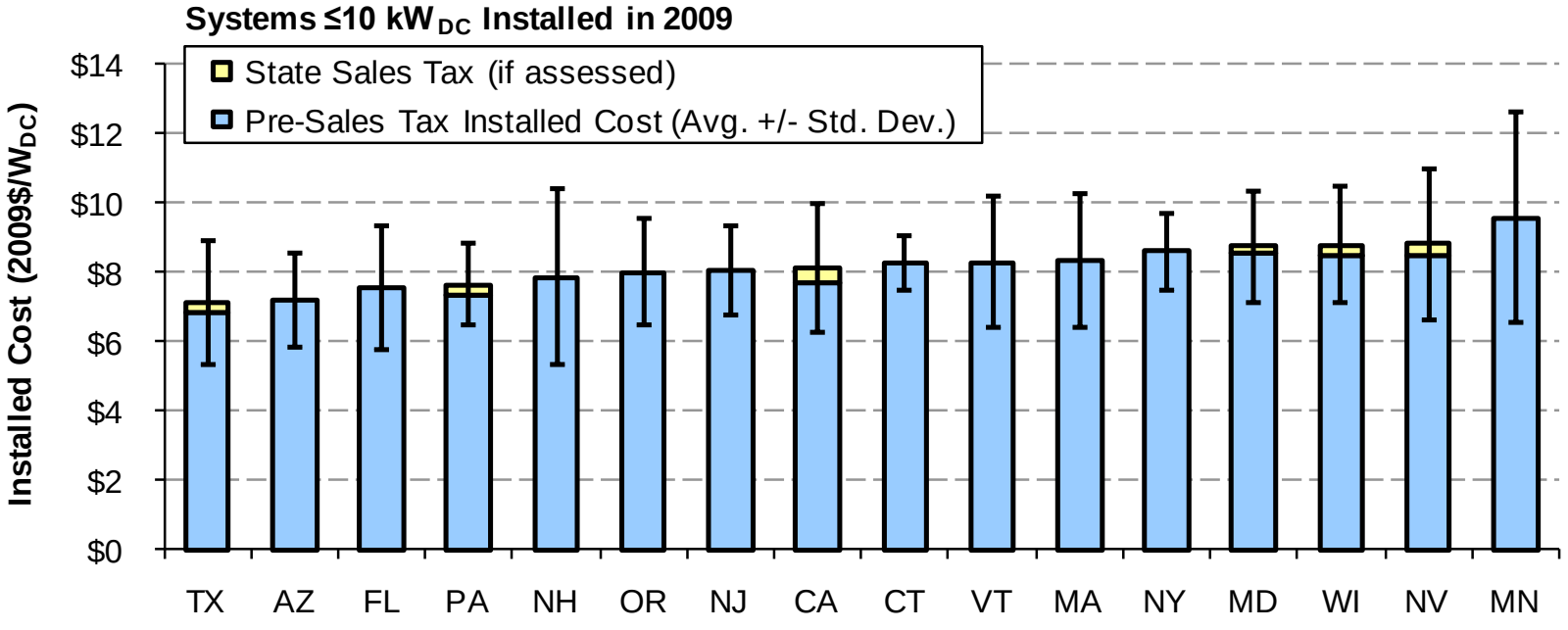
Lower costs in Germany and Japan may be partly attributable to greater deployment scale; highlights potential for further near-term cost reductions in the U.S.



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 kW_{DC} systems may partially reflect differences in market size and maturity, but other local factors are evidently also important



A small portion of cost difference reflects varying sales tax incentives

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.

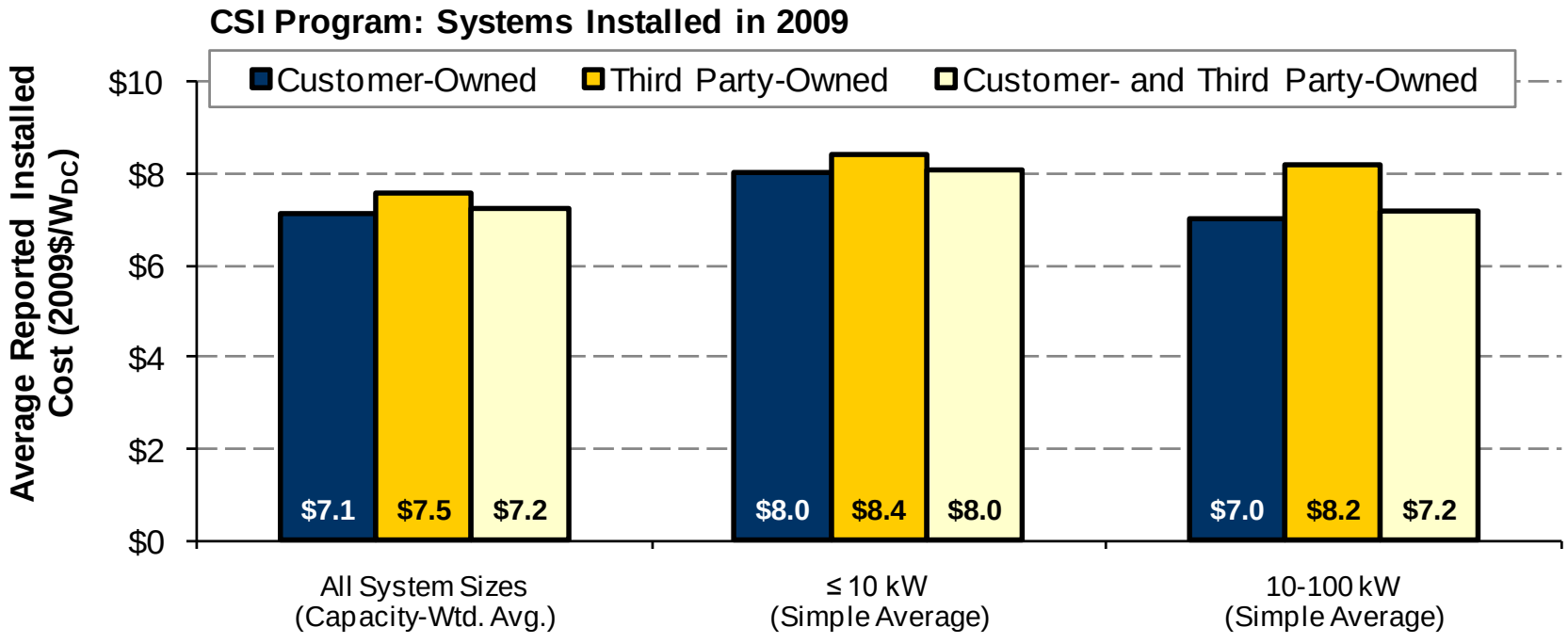
Cost Differences Among States Persists Across System Sizes

Average Installed Cost ($/$W_{DC}$) by State and PV System Size Range

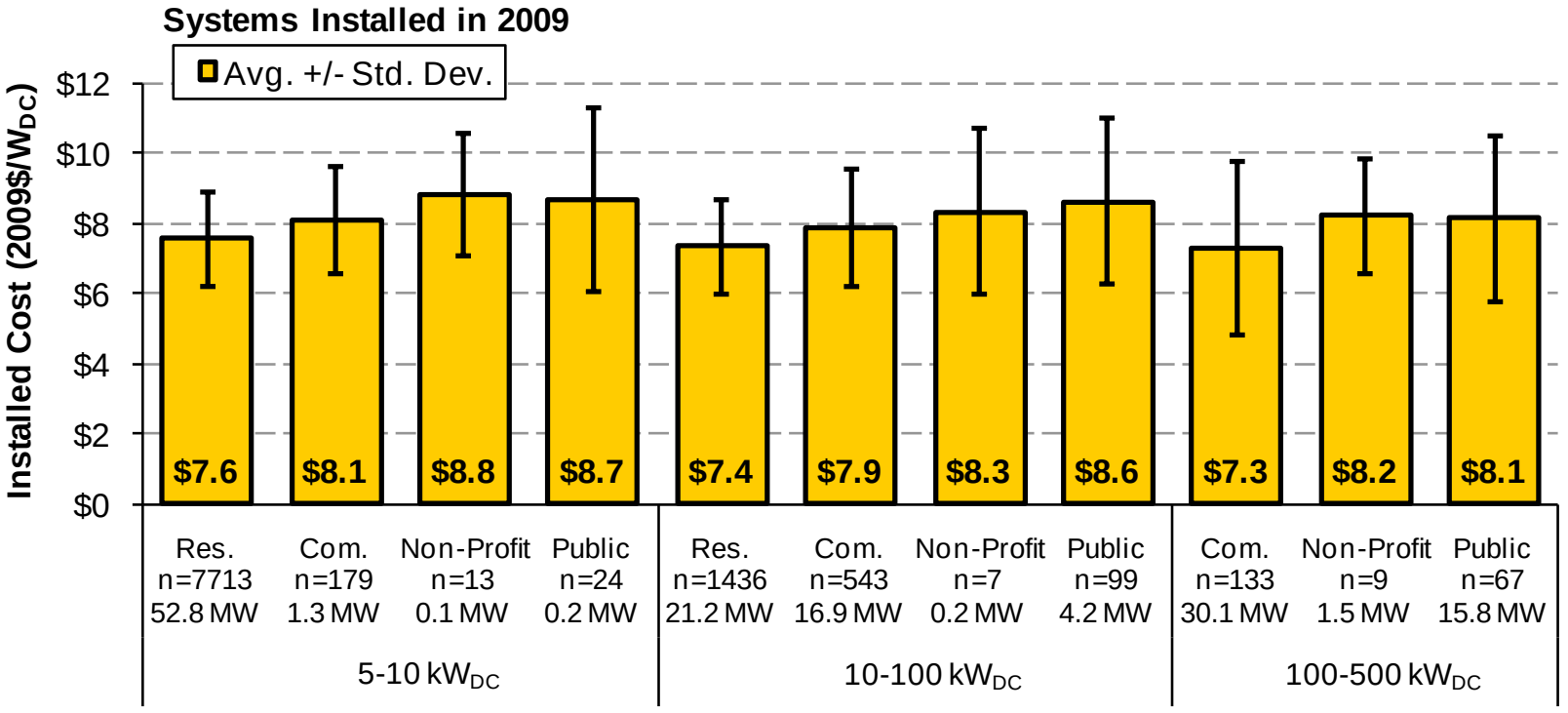
State	All Reported Yrs. Capacity-Weighted Average Cost (all sizes)		2009 Systems									
			Capacity-Weighted Average Cost (all sizes)		Simple Average Cost							
					0 - 10 kW_{DC}		10 - 100 kW_{DC}		100 - 500 kW_{DC}		>500 kW_{DC}	
AZ	$7.2	(n=3330)	$7.1	(n=2048)	$7.2	(n=1858)	$6.9	(n=187)	*	(n=3)	*	(n=0)
CA	$7.7	(n=58991)	$7.6	(n=15376)	$8.1	(n=13882)	$7.5	(n=1326)	$8.1	(n=106)	$7.2	(n=62)
CT	$7.9	(n=946)	$7.6	(n=306)	$8.3	(n=226)	$8.1	(n=61)	$7.3	(n=19)	*	(n=0)
FL	$7.5	(n=577)	$7.5	(n=575)	$7.6	(n=536)	$7.3	(n=38)	*	(n=0)	*	(n=1)
MA	$8.1	(n=1990)	$7.4	(n=860)	$8.4	(n=740)	$8.0	(n=92)	$6.8	(n=26)	*	(n=2)
MD	$9.0	(n=546)	$8.6	(n=316)	$8.8	(n=307)	$8.4	(n=9)	*	(n=0)	*	(n=0)
MN	$9.1	(n=198)	$9.3	(n=54)	$9.6	(n=49)	$9.6	(n=5)	*	(n=0)	*	(n=0)
NH	$7.6	(n=189)	$7.5	(n=157)	$7.9	(n=157)	*	(n=0)	*	(n=0)	*	(n=0)
NJ	$7.7	(n=4634)	$7.4	(n=1292)	$8.1	(n=964)	$7.9	(n=253)	$7.5	(n=62)	$7.2	(n=13)
NV	$8.7	(n=499)	$8.2	(n=183)	$8.8	(n=167)	$8.8	(n=16)	*	(n=0)	*	(n=0)
NY	$8.7	(n=1990)	$8.4	(n=779)	$8.6	(n=654)	$8.3	(n=125)	*	(n=0)	*	(n=0)
OR	$7.9	(n=1321)	$7.3	(n=473)	$8.0	(n=385)	$7.7	(n=76)	$6.9	(n=11)	*	(n=1)
PA	$7.9	(n=536)	$7.4	(n=372)	$7.7	(n=305)	$7.4	(n=66)	*	(n=1)	*	(n=0)
TX	$7.0	(n=1226)	$6.7	(n=459)	$7.1	(n=406)	$6.4	(n=51)	*	(n=2)	*	(n=0)
VT	$8.4	(n=365)	$7.9	(n=139)	$8.3	(n=134)	$7.2	(n=5)	*	(n=0)	*	(n=0)
WI	$8.7	(n=614)	$8.6	(n=264)	$8.8	(n=225)	$8.6	(n=39)	*	(n=0)	*	(n=0)

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



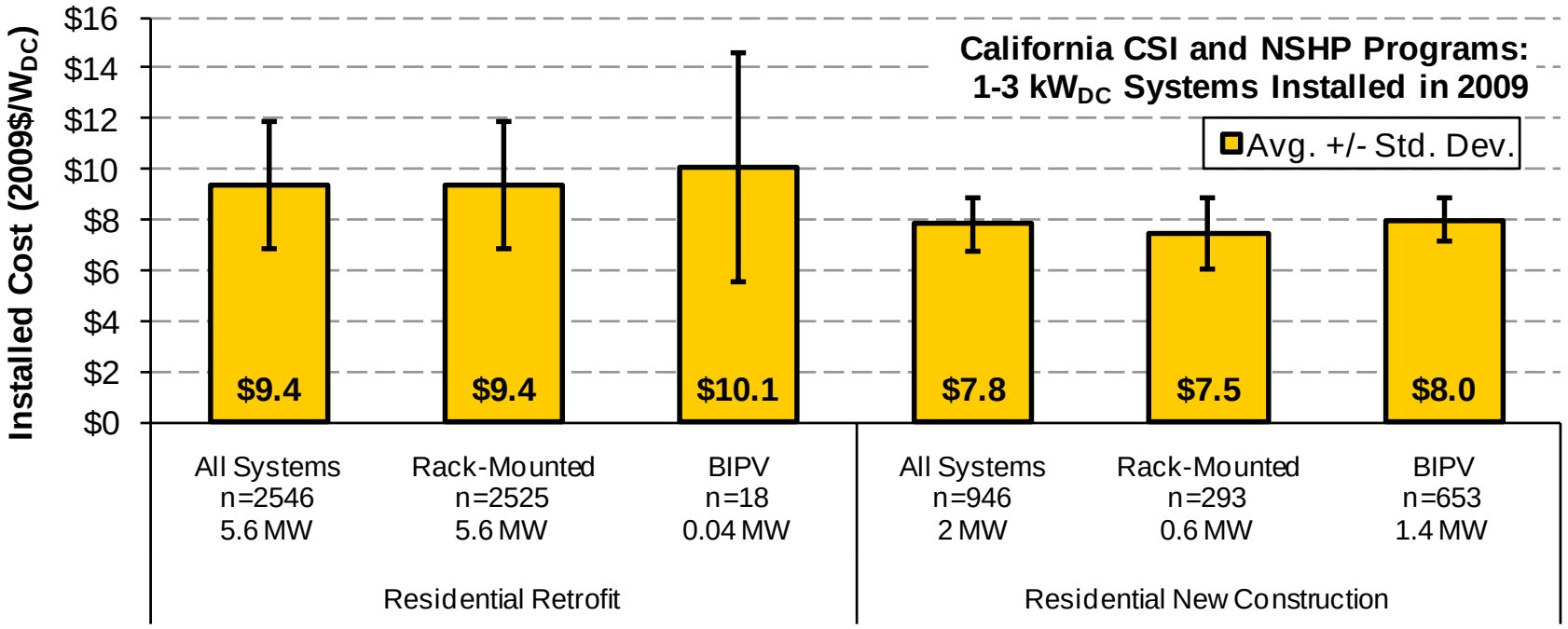
Residential PV Had Lower Costs than Other Similarly Sized Systems



- 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

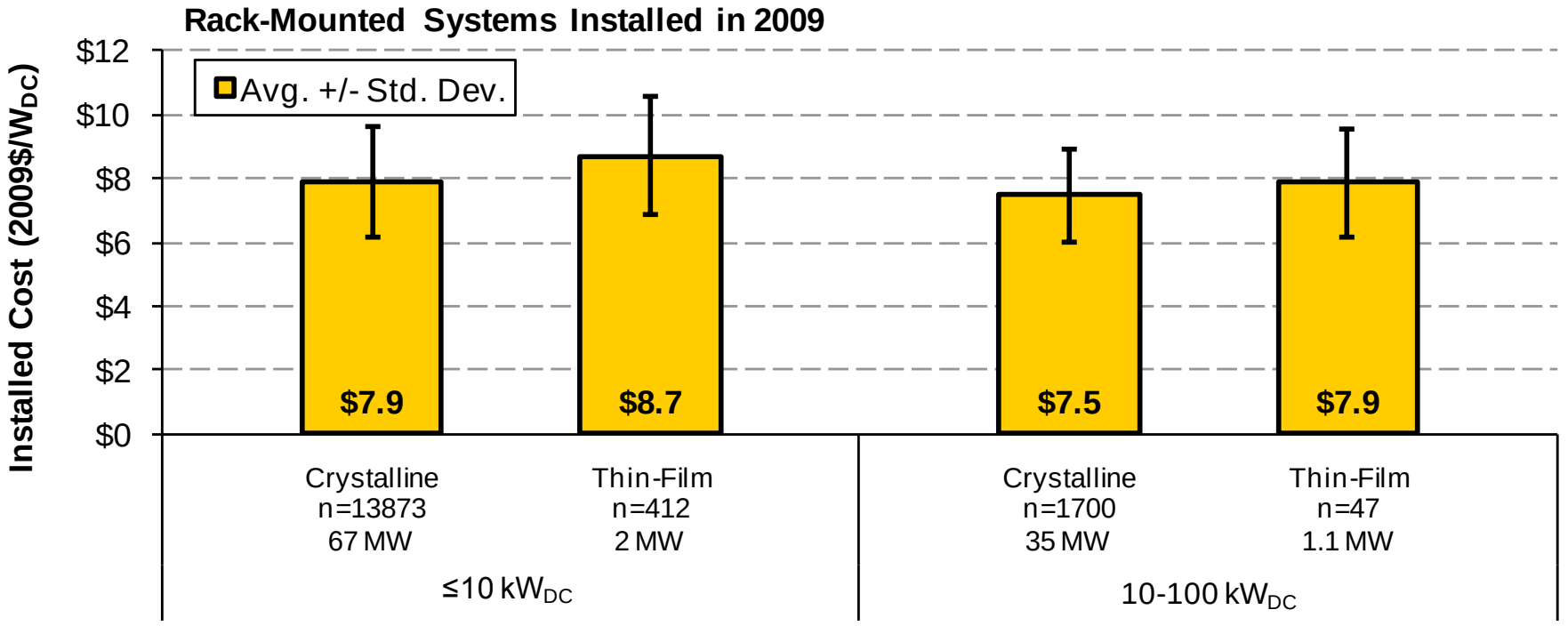
In 2009, residential new construction systems cost **$1.6/$W_{DC}$** less, on average, than similarly sized retrofit systems (or **$1.9/$W_{DC}$** less if comparing only rack-mounted systems)



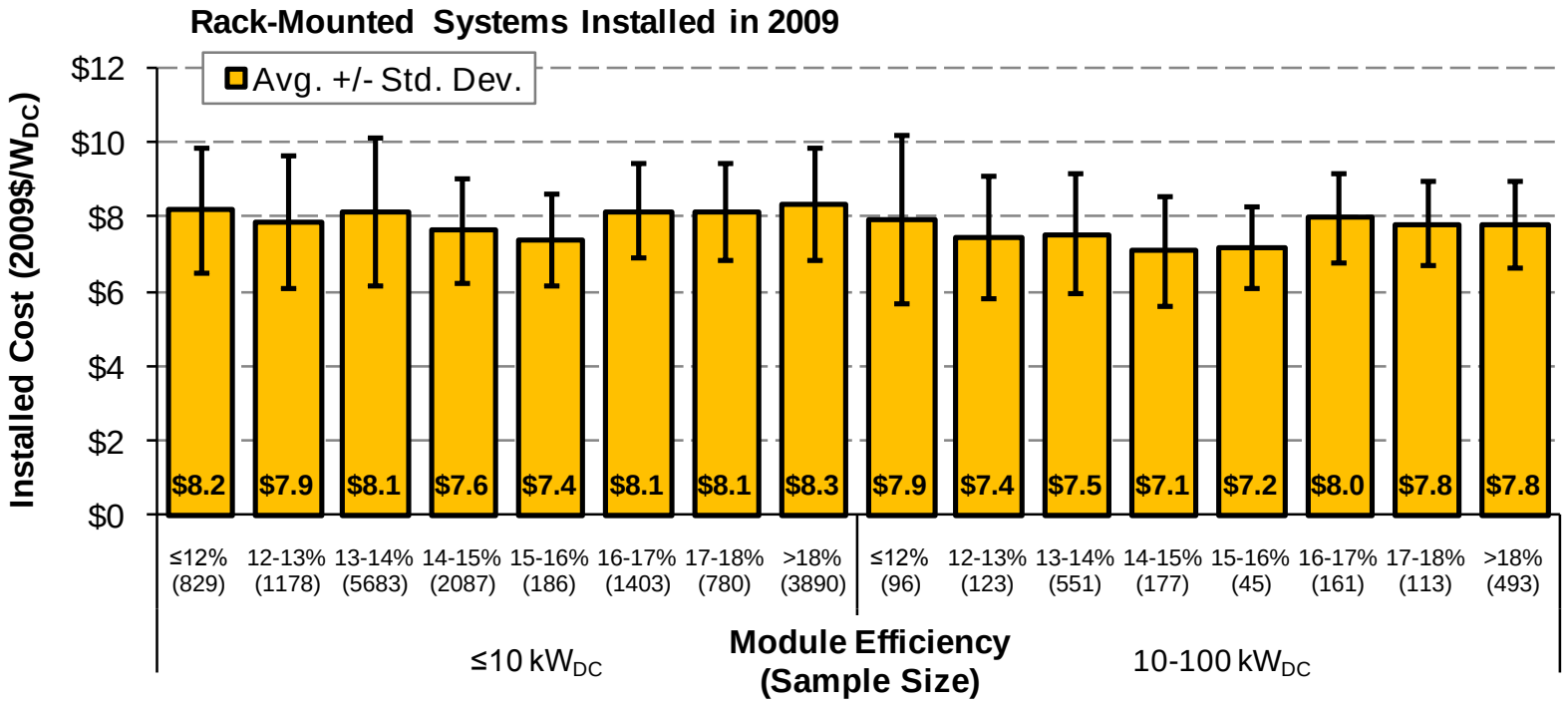
Note : The number of rack-mounted systems plus BIPV systems may not sum to the total number of systems, as some systems could not be identified as either rack-mounted or BIPV.

Thin-Film Systems Had Higher Installed Costs than Crystalline Systems

In 2009, rack-mounted thin-film systems ≤10 kW_{DC} cost **$0.8/$W_{DC}$** more, on average, than similarly sized crystalline systems

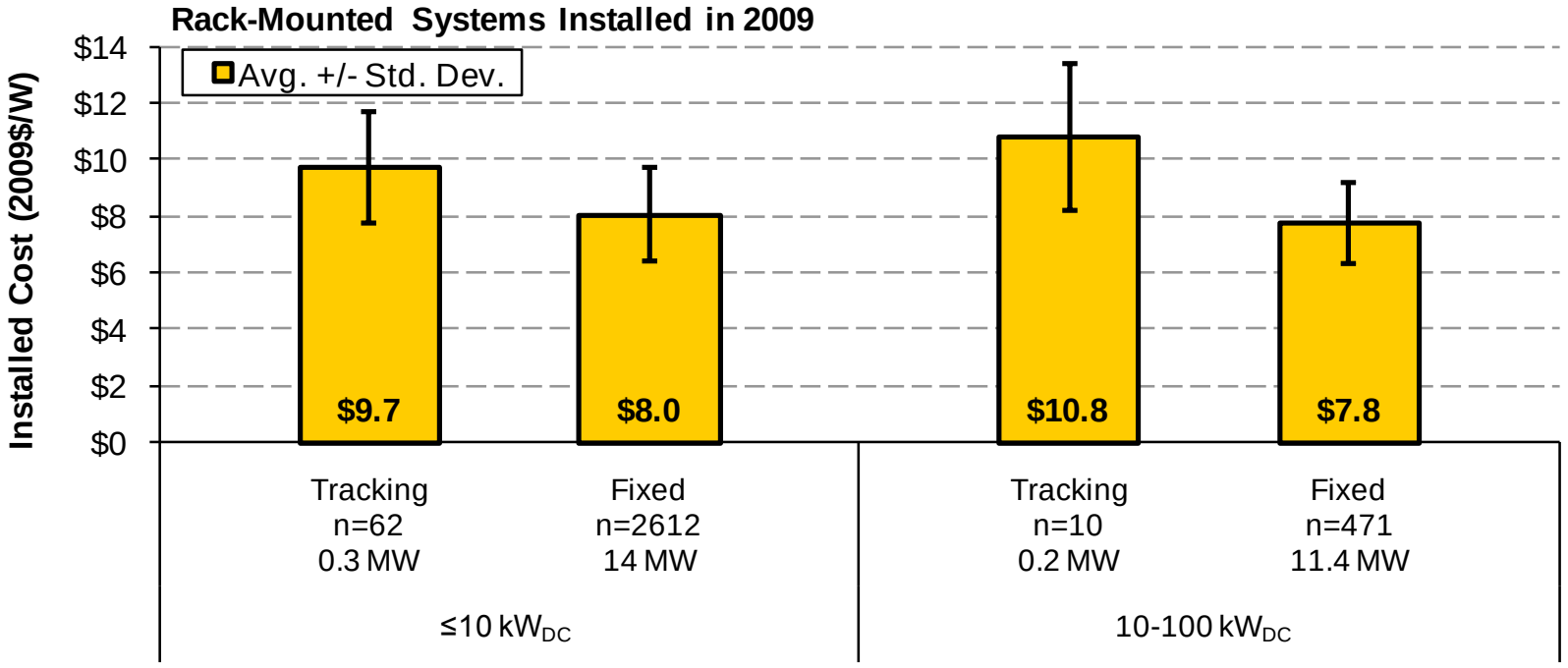


Systems with Mid-Range Module Efficiencies Had the Lowest Average Cost in 2009



- 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 ≤10 kW_{DC} size range, systems with tracking had an average cost \$1.7/W_{DC} (or 21%) greater than fixed-axis systems, reflecting added cost of tracking equipment and ground-mounting
- In the10-100 kW_{DC} size range, tracking systems also had higher installed costs, though the sample size is quite limited

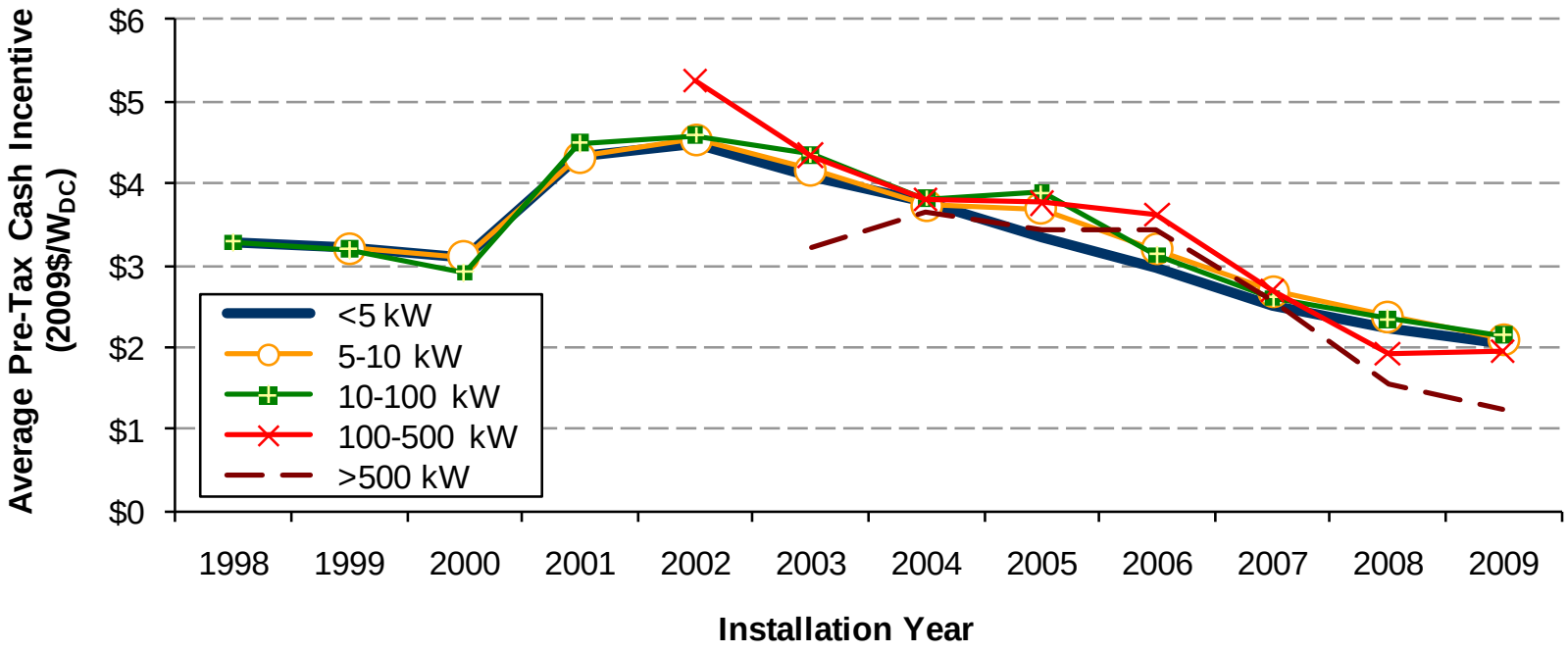
PV Incentive and Net Installed Cost Trends

Key Assumptions Used to Derive Incentive Trends and Net Installed Costs

- Incentives and net installed costs (i.e., customer cost after receipt of incentives) are calculated and account for:
  - Cash incentives provided by the PV incentive programs in the data sample
  - State and federal investment tax credits (ITCs)
- But do not account for:
  - Cash incentives potentially provided by other PV incentive programs
  - Revenue from *future* sales of renewable energy certificates (RECs)
  - The value of accelerated depreciation (applicable to commercial PV only)
- NJ SREC Registration Program is excluded (as the incentive is provided solely in the form of uncertain future REC payments)
- 10 kW was used to delineate between residential and commercial PV if no other information was available on customer type

State/Utility Cash Incentives Have Declined since 2002

Figure shows the average **cash incentive** on a pre-tax basis



- Average pre-tax cash incentives received by projects installed in 2009 ranged from \$1.2/W_{DC} to \$2.2/W_{DC} across the system size ranges shown, down by 37% to 47% from their peak in 2002
- Trends largely reflect incentive levels under the CA and NJ programs

REC Revenues Add to Overall Incentives, But Impact Varies Widely

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

1. **Voluntary REC Markets**: prices averaged about $1.4/MWh in 2009, which, extrapolated over a 20-year period, are equivalent to **$0.02/$W_{DC}$** on a pre-tax present-value basis
2. **Traditional RPS Markets** (no solar set-aside): the highest prices in 2009 occurred in Massachusetts, where Class I RECs averaged $30/MWh, equivalent to **$0.4/W_{DC}** (if extrapolated over a 20-year period)
3. **RPS Solar Set-Aside Markets**: Solar REC prices in New Jersey averaged $542/MWh in 2009, equivalent to **$6.4/$W_{DC}$** (if extrapolated over a 15-year period)

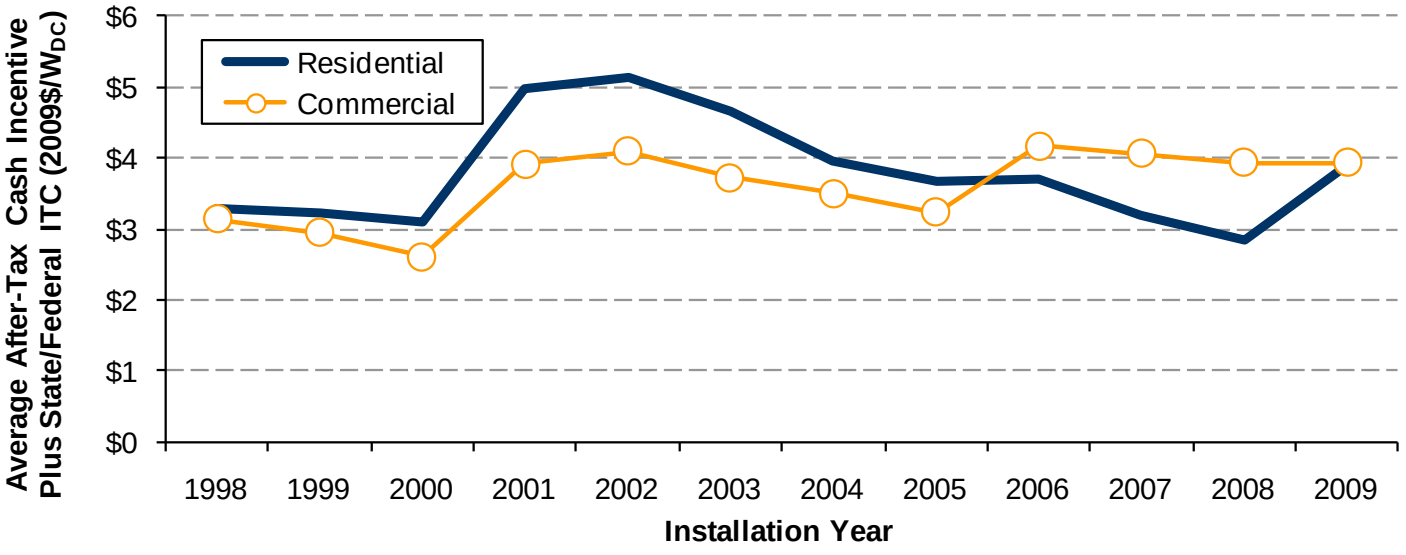
** Source of historical REC price data: Spectron and PJM-GATS*

*** $/$W_{DC}$ estimates calculated assuming 10% nominal discount rate and 14% capacity factor*

Because the revenue from future REC sales is uncertain, it is **not** included in the slides that follow

Including Federal & State ITCs, Incentives Were at a Near-All-Time High for Commercial PV in 2009 and Up Significantly for Residential PV

Figure shows the combined value, on an after-tax basis, of direct **cash incentives** plus **state/Federal ITCs** (excludes RECs and accelerated depreciation)

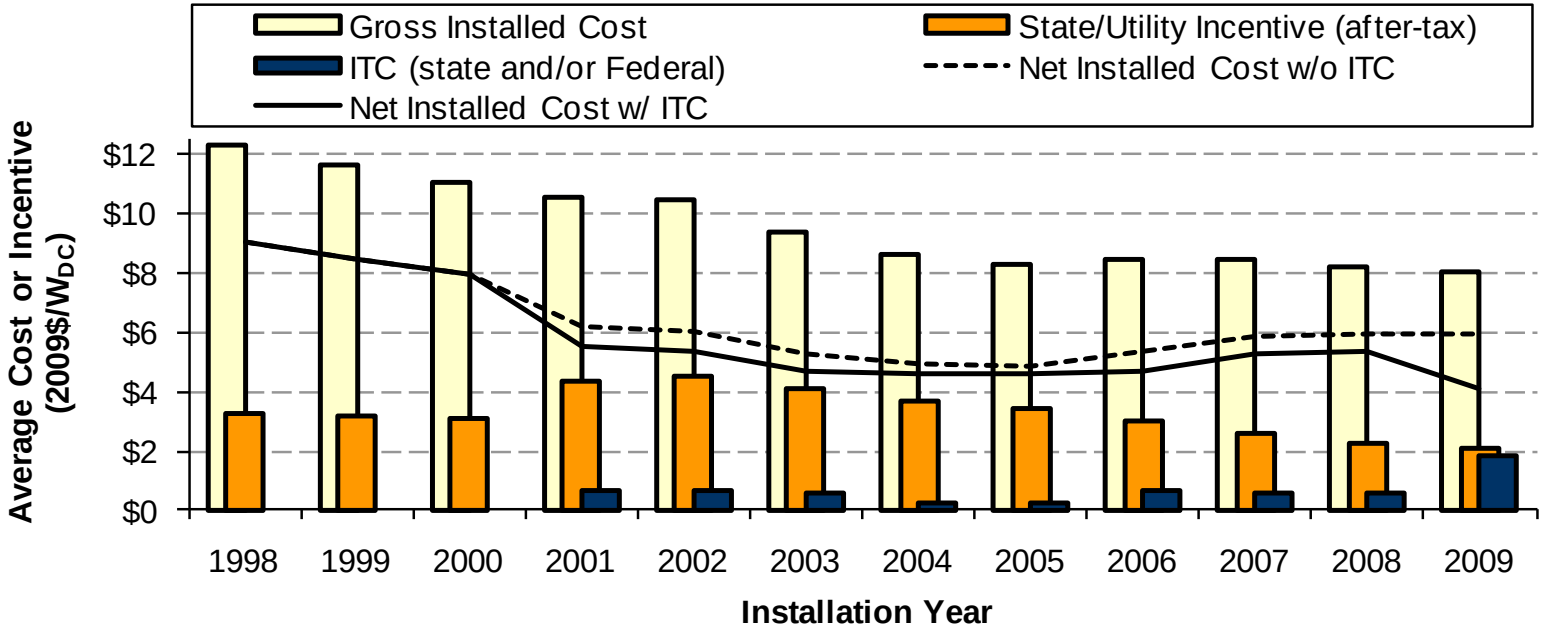


Residential PV received a large boost in 2009, as a result of the lifting of the $2,000 cap on the Federal ITC for residential PV

- The average combined after-tax incentive was $3.9/W$_{DC}$ for residential PV in 2009, up 37% from 2008
- For commercial PV, the combined after-tax incentive in 2009 also averaged $3.9/W$_{DC}$, virtually unchanged from 2008

The Net Installed Cost of Residential PV Dropped Significantly from 2008 to 2009

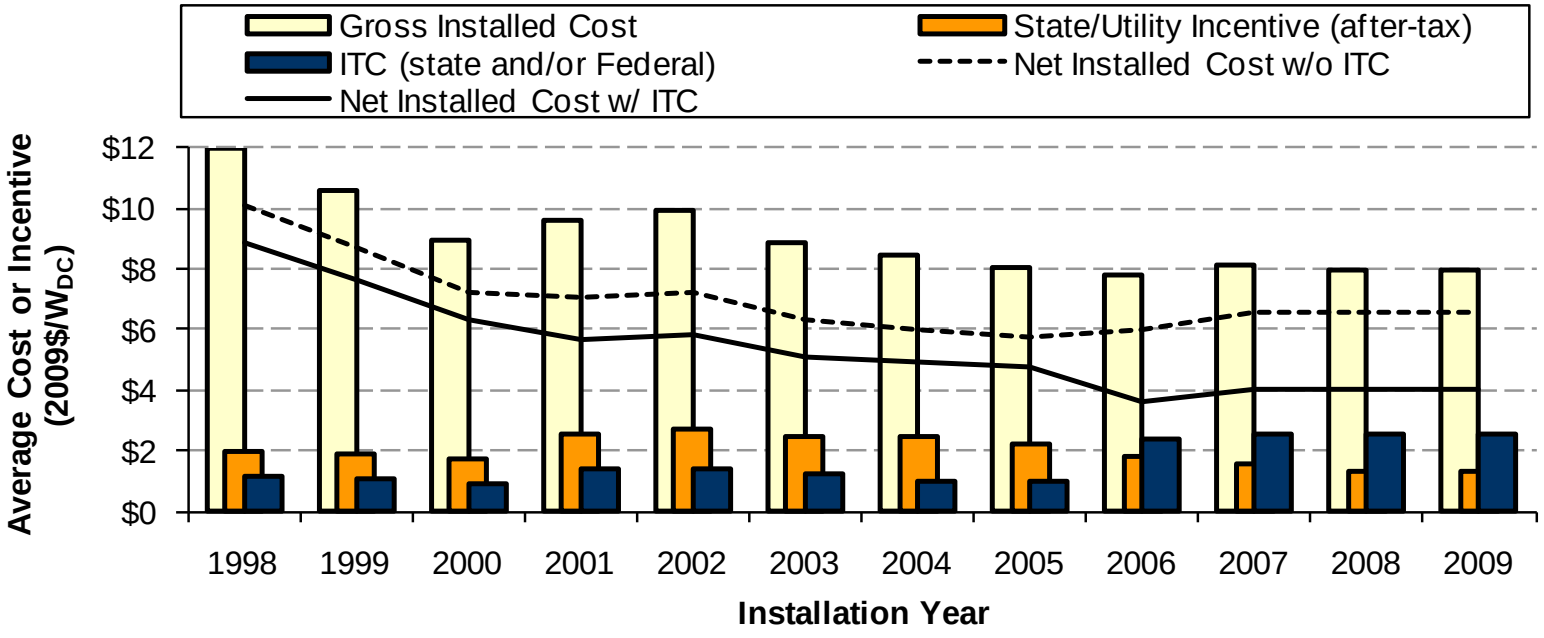
Calculated Net Installed Cost of Residential PV



- The net installed cost of residential PV was **$4.1/W$_{DC}$** in 2009, an all-time low and 24% below 2008; the result of the elimination of the dollar cap on the federal ITC
- From 2006-2008, net installed costs increased as reductions in cash incentives outpaced the decline in pre-incentive installed costs

…While Remaining Unchanged for Commercial PV

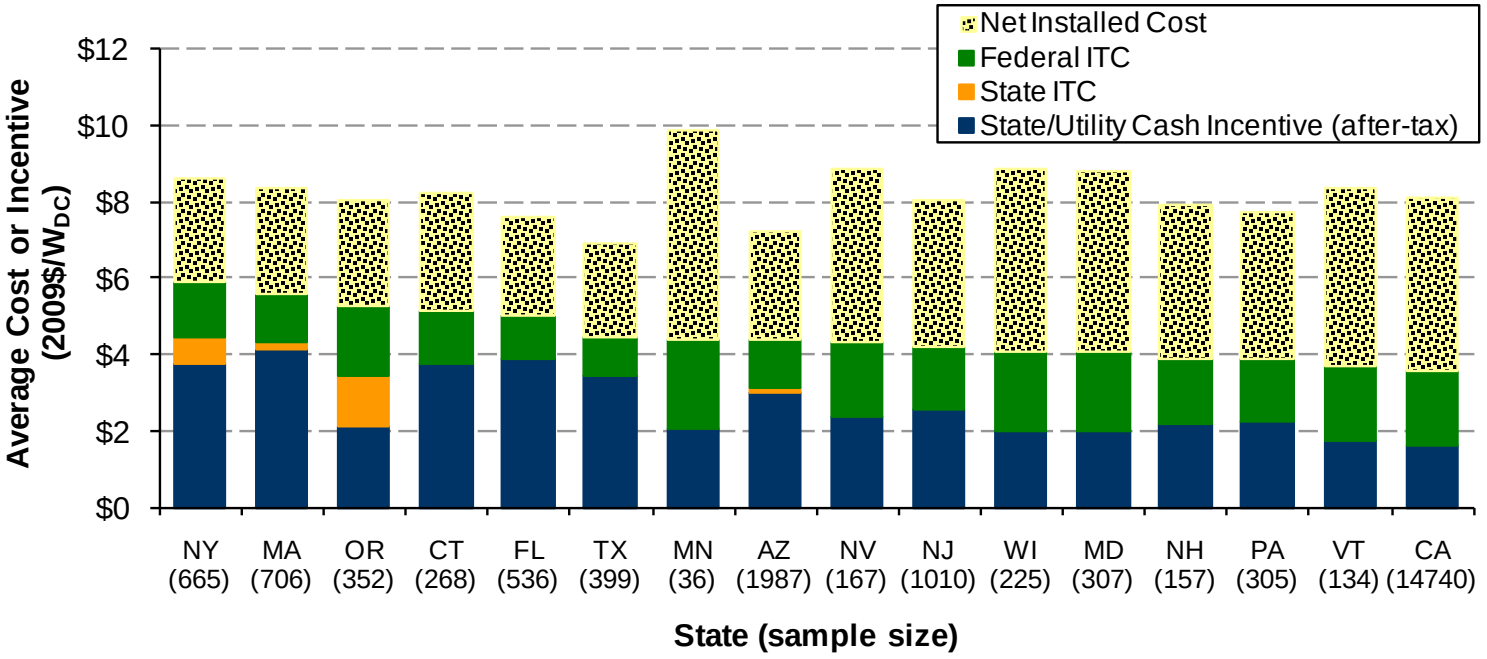
Calculated Net Installed Cost of Commercial PV



- The net installed cost of commercial PV was **$4.0/W$_{DC}$** in 2009, virtually unchanged from the preceding two years and up 11% from its all-time low in 2006 ($3.7/W$_{DC}$)
- Potential impact of incentive levels on gross installed costs illustrated by trends from 2000-02, when gross costs rose with average incentive levels

Incentives Have Diverged Widely Across States for Residential Systems...

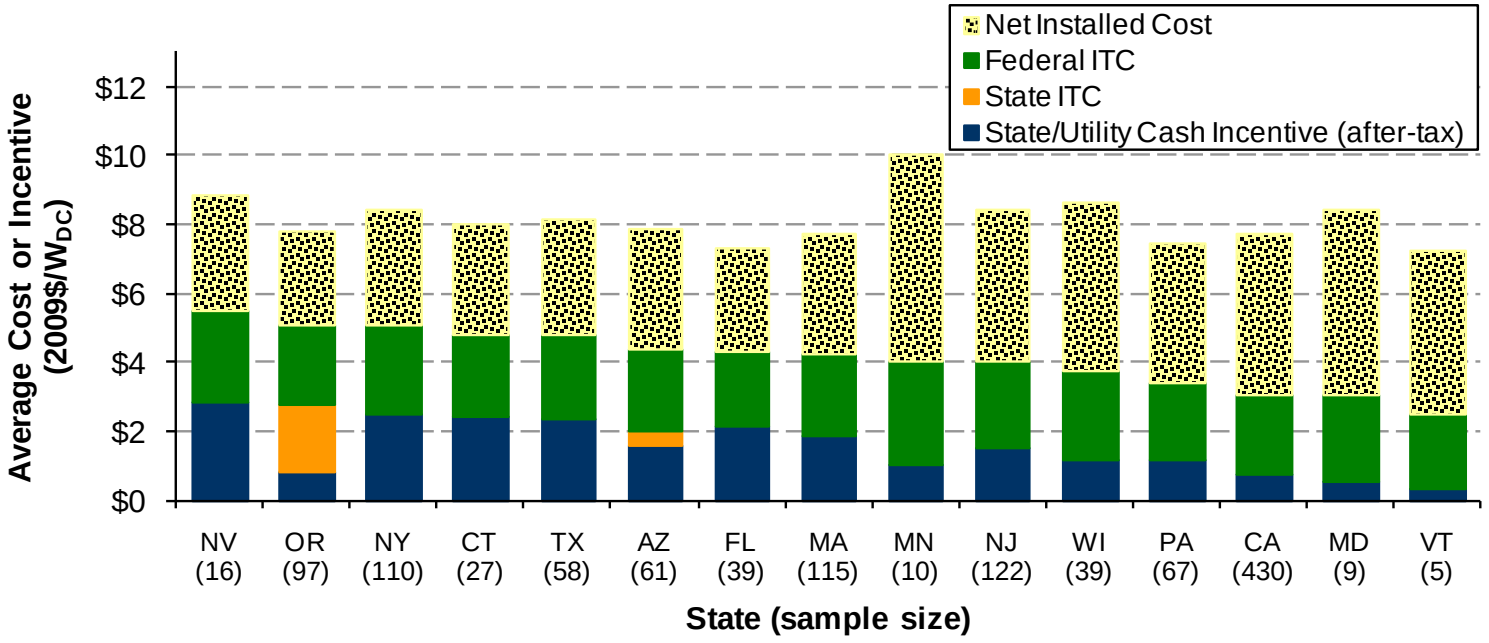
After-Tax Incentives and Net Installed Cost of Residential PV Systems Installed in 2009



- Average combined after-tax incentive (cash incentives plus ITCs) for residential PV ranged from \$3.5/W_{DC} in CA to \$5.9/W_{DC} in NY in 2009
- Net installed costs were lowest in Texas (\$2.4/W_{DC}) and highest in Minnesota (\$5.5/W_{DC})

...And Also for Commercial Systems

After-Tax Incentives and Net Installed Cost of Commercial PV Systems Installed in 2009



- Average combined after-tax incentives (cash incentives plus ITCs) ranged from \$2.5/W_{DC} in Vermont to \$5.5/W_{DC} in Nevada
- Net installed costs ranged from a low of \$2.1/W_{DC} in OR (though NJ would likely be lowest if SRECs were included) to a high of \$6.1/W_{DC} in MN

Conclusions and Outlook

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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Thanks to the U.S. DOE's Solar Energy Technologies Program and to the Clean Energy States Alliance for supporting this work