

# Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections *2013 Edition*



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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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- Historical and Recent Reported Prices
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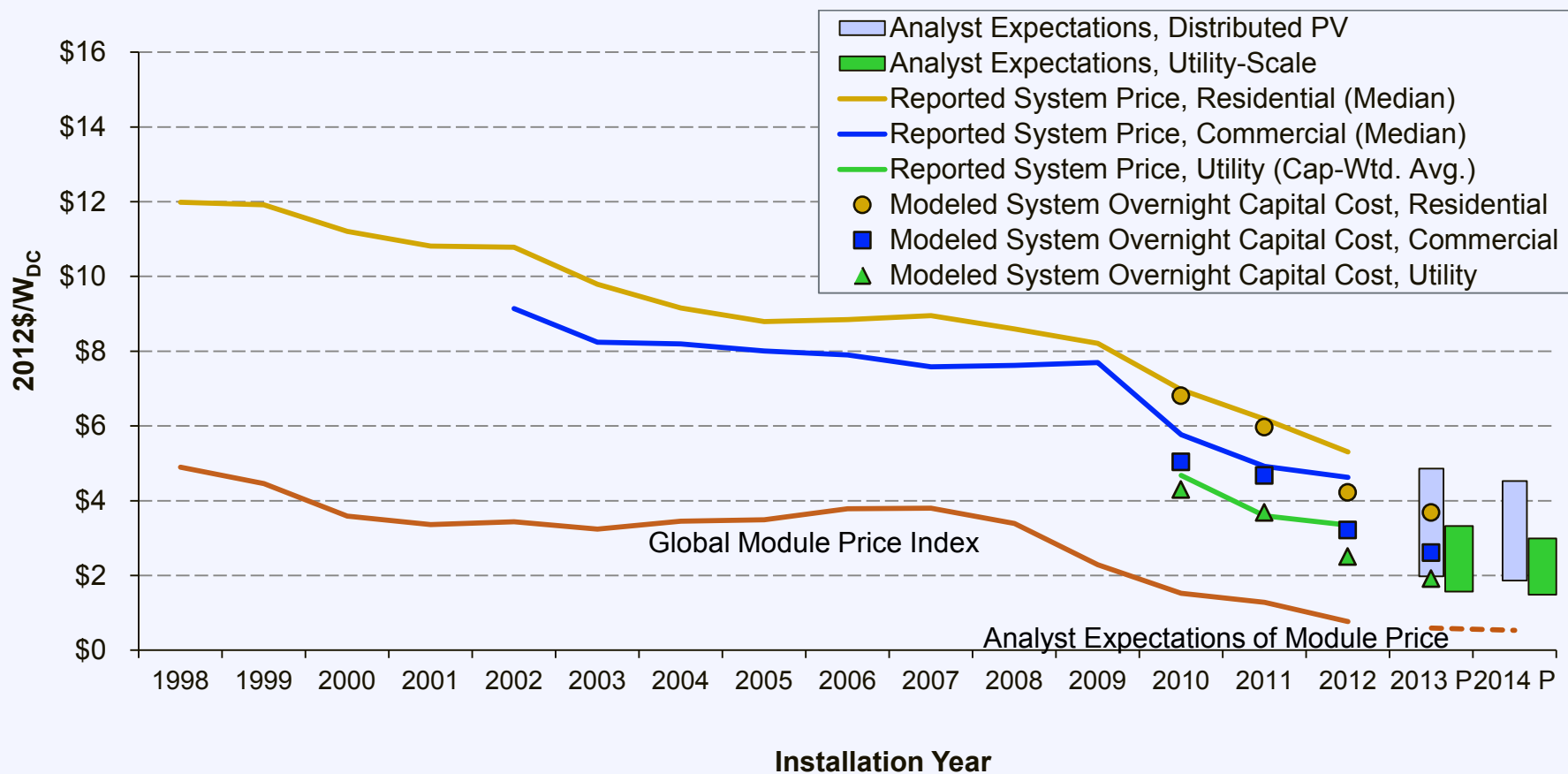
# Introduction

- **There exists a need for reliable and comprehensive information on PV system pricing**
  - Rapid market growth and changes to PV system pricing in recent years
  - Policy support for PV deployment premised on stimulating cost reductions through market scale and development
  - DOE SunShot Initiative seeks to reduce PV system prices 75% over the 2010-2020 period.
- **This briefing provides a high-level overview of historical, recent, and projected near-term PV system pricing trends in the United States, drawing on several ongoing research activities at LBNL and NREL:**
  - LBNL's annual Tracking the Sun report series
  - NREL's bottom-up PV cost modeling
  - NREL's synthesis of PV market data and projections.

# Executive Summary

- Reported pricing data that, among ~50,000 PV systems installed in 2012:
  - Res. and small com. ( $\leq 10$  kW) was **\$5.30/W** (median)
  - Large com. ( $> 100$  kW) was **\$4.62/W** (median)
  - Utility-scale (crystalline, fixed-tilt,  $> 2$  MW) was **\$3.35/W** (capacity weighted average).
- Modeled overnight capital cost for systems quoted in Q4 2011 (expected to be installed in 2012):
  - Residential (5.1 kW) was **\$4.22/W**
  - Commercial (221 kW) was **\$3.22/W**
  - Utility-scale (191.5 MW) was **\$2.50/W**.
- Delta between reported pricing and modeled cost is due to various factors, such as inefficient pricing, timing, geographic location, and project specifics.
- Reported installed prices of residential and commercial PV systems declined 6%–7% per year, on average, from 1998–2012, and by 6%–14% from 2011–2012, depending on system size.
- In near future analysts expect system prices to continue to fall, but for module prices to stabilize (Module ASP projected to be between \$0.50/W - \$0.75/W by 2014 ).
- Modeled overnight capital cost for systems quoted in Q4 2012 (expected to be installed in 2013):
  - Residential (5.1 kW) was **\$3.69/W**, a reduction of 13% from Q4 2011
  - Commercial (222.5 kW) was **\$2.61/W**, a reduction of 19% from Q4 2011
  - Utility-scale (192.8 MW) was **\$1.92/W**, a reduction of 23% from Q4 2011.

# Reported, Bottom-Up, and Analyst-Projected Average U.S. PV System Prices over Time



Note: The reported system price for the residential market is representative of the median price reported for systems less than or equal to 10 kW in size. The modeled residential system price represents a ~5 kW system. The reported system price for the commercial market is representative of the median price reported for systems greater than 100 kW in size. The modeled commercial system price represents a ~220 kW rooftop system. The reported system price for the utility-scale market represents the capacity-weighted average reported price for ground-mounted systems greater than 2 MW in size, with an average project size of 16.4 MW. The modeled system price of utility-scale systems represents a ~190 MW fixed-tilt ground-mounted system. Bottom-up system prices are representative of bids by an installer in the fourth quarter of the previous year. The Global Module Price Index is the average module selling price for the first buyer (P Mints SPV Market Research).

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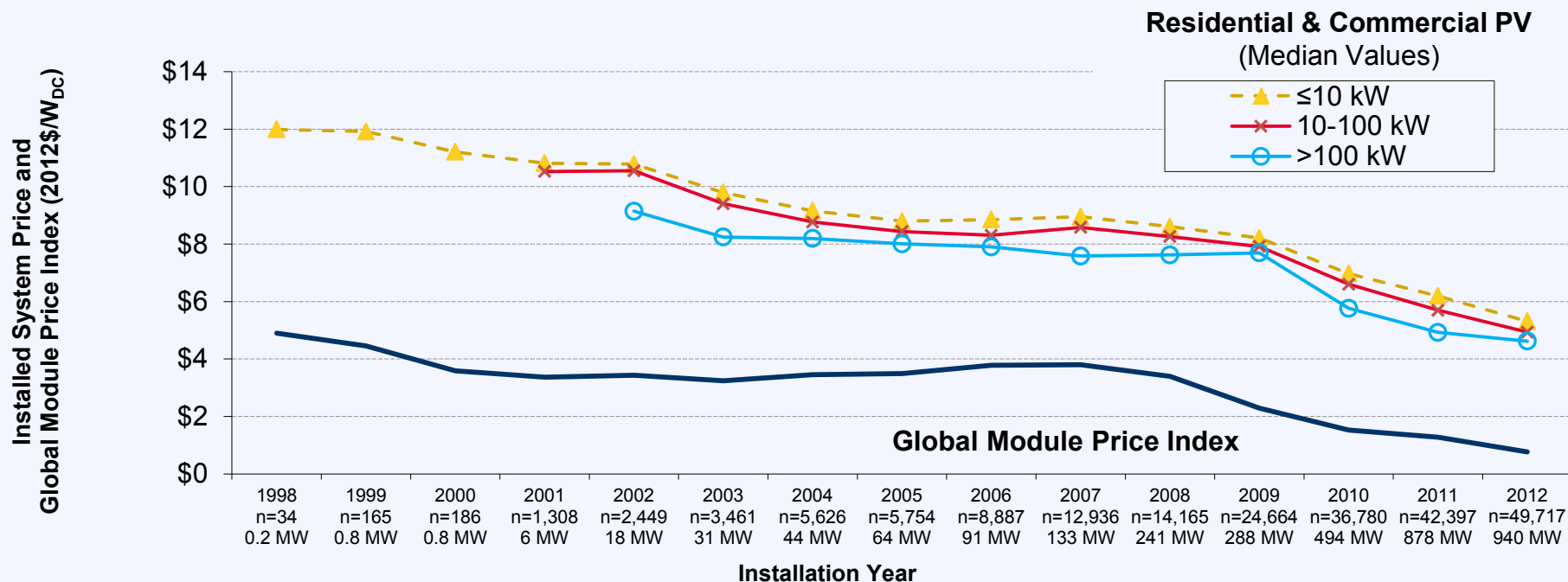
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# Data Sources and Methodology for Reported Installed Prices

- Derived from project-level data reported for residential, commercial, and utility-scale PV systems installed through year-end 2012, with a limited set of results presented for the first half of 2013
- Distributed PV: 47 PV incentive programs spanning 24 states provided project-level installed price data for PV systems funded through current and previous programs
- Utility-scale PV: Data sourced from Section 1603 Grant Program, FERC Form 1, SEC filings, company presentations, trade press articles
- All projects for which the reported installed price was deemed likely to represent an *appraised value* rather than an actual transaction price were eliminated from the data sample
- Final cleaned data sample consists of >200,000 PV systems totaling 4.7 GW of installed capacity; represents approximately 65% of all grid-connected PV capacity installed in the United States through 2012 and about 50% of all 2012 capacity additions.

# Median Reported Installed Price of Residential and Commercial PV Systems over Time

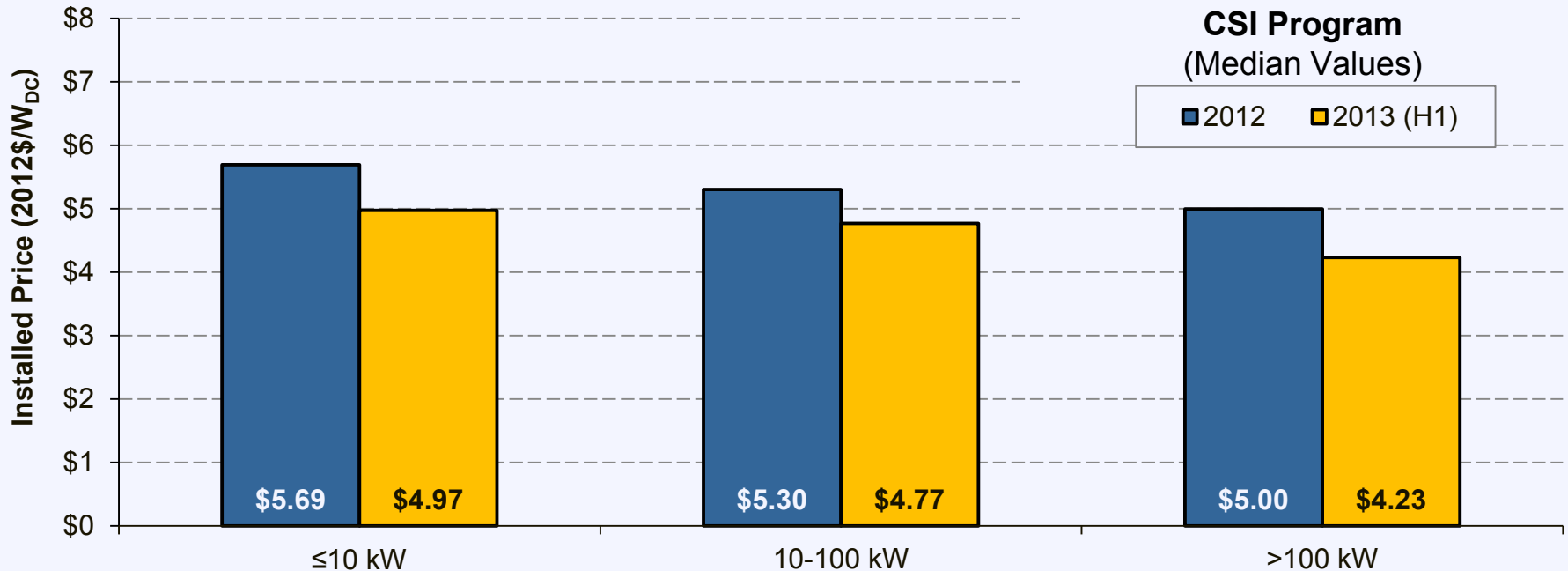


Note: Median installed prices are shown only if 15 or more observations are available for the individual size range. The Global Module Price Index is the average module selling price for the first buyer (P Mints SPV Market Research).

- Since 1998, installed PV system prices have fallen by 6-7% per year on average
- From 2011 to 2012, installed prices fell by \$0.88/W (14%) for systems ≤10 kW and by \$0.30/W (6%) for systems >100 kW
- By comparison, global annual average module prices fell by \$0.52/W from 2011-2012.

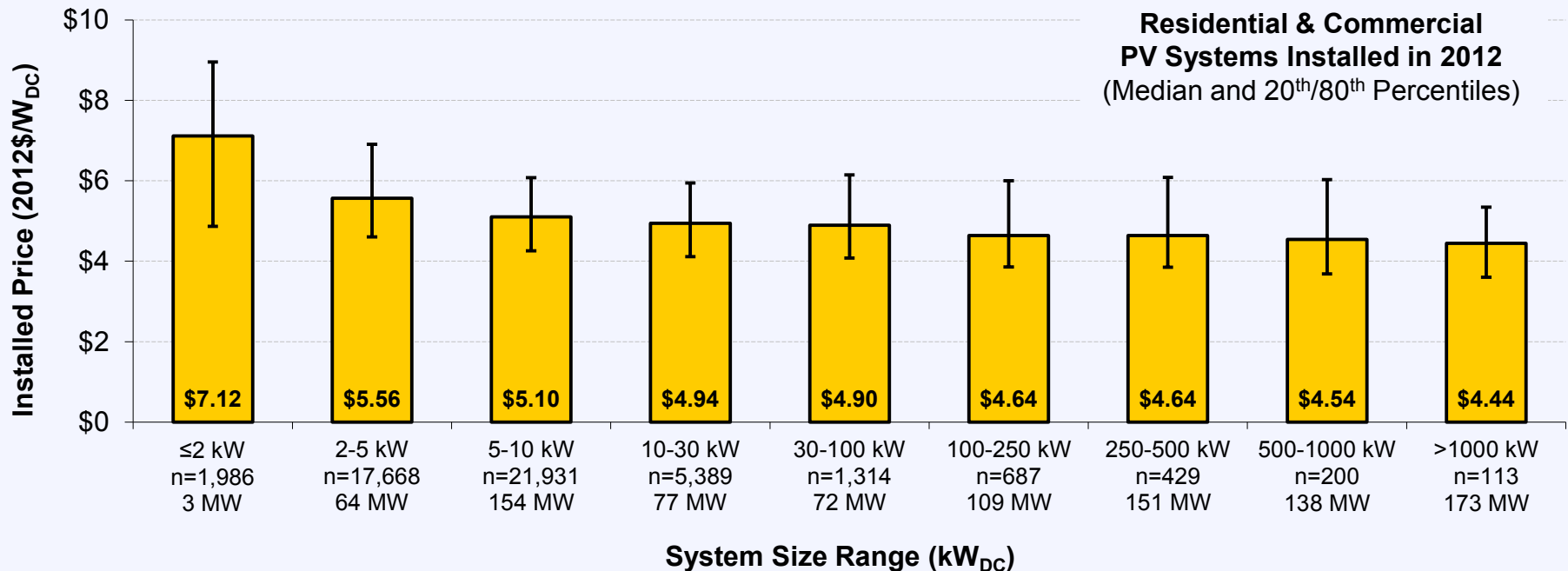


# Preliminary Price Trends for Systems Installed in 2013: A Focus on California



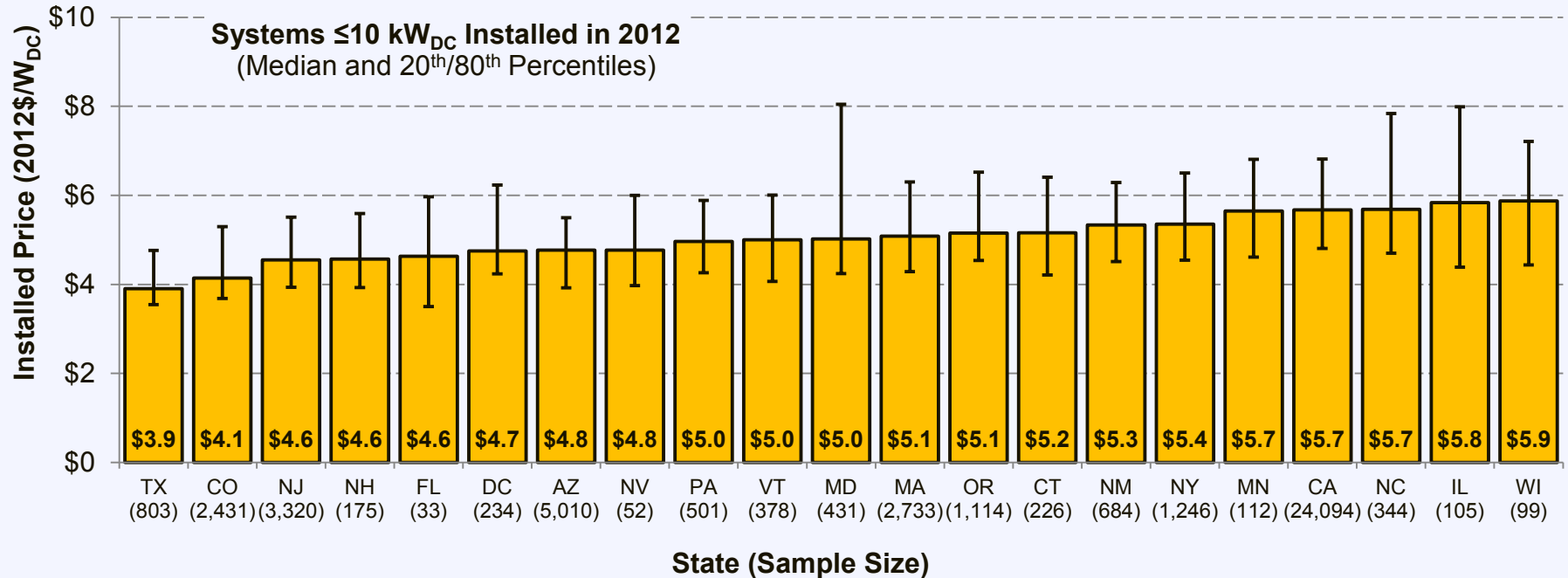
- Data from the California Solar Initiative (CSI) program show that installed prices have continued to fall into 2013
- Median installed prices in CSI fell by roughly \$0.53-0.77/W (10-15%) during the first half of 2013, relative to 2012, across the three size ranges shown.

# Variation in Installed Price by System Size: Residential and Commercial PV Systems in 2012



- Installed prices exhibit clear economies of scale, with the median installed price for the largest commercial systems 38% lower than for the smallest residential systems (and lower installed prices for utility-scale PV, as shown on later slides)
- Scale economies are especially pronounced at the small end of the size spectrum
- Substantial variability in installed prices exists within each size range, reflecting regional, local, project/site-specific, and installer-specific drivers.

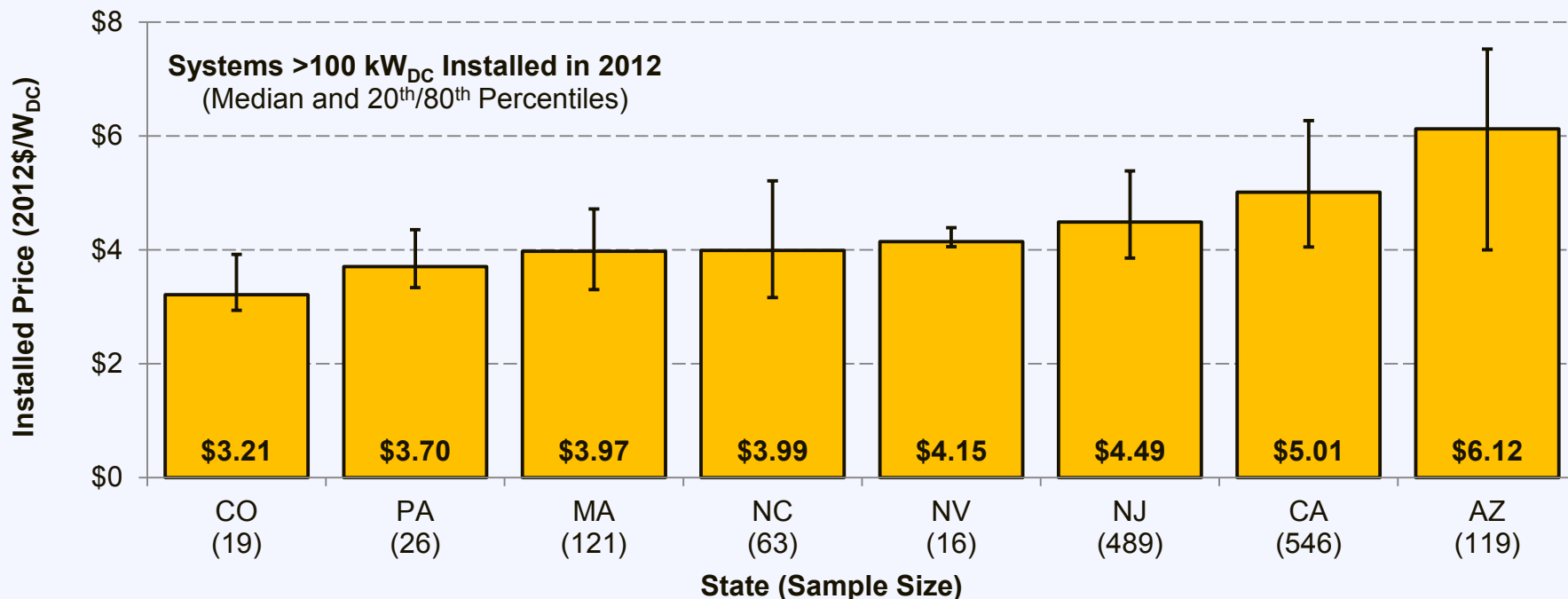
# Variation in Installed Price by State: Residential and Small Commercial ( $\leq 10$ kW) PV in 2012



Note: Numbers in parentheses below each state indicate the number of observations; median installed prices are shown only if 15 or more observations are available for a given state. CO and MN data are based on aggregated statistics provided the PV program administrator rather than project-level data.

- The median installed price differs by roughly \$2.0/W between the lowest- and highest-priced states, though similar variability also exists *within* individual states
- California, a relatively high cost state, pulls the overall sample median upward
- Installed price differentials across states reflect a wide array of potential factors: market size and maturity, incentive levels, regulatory costs, sales tax, and others.

# Variation in Installed Price by State: Large Commercial (>100 kW) PV Systems in 2012



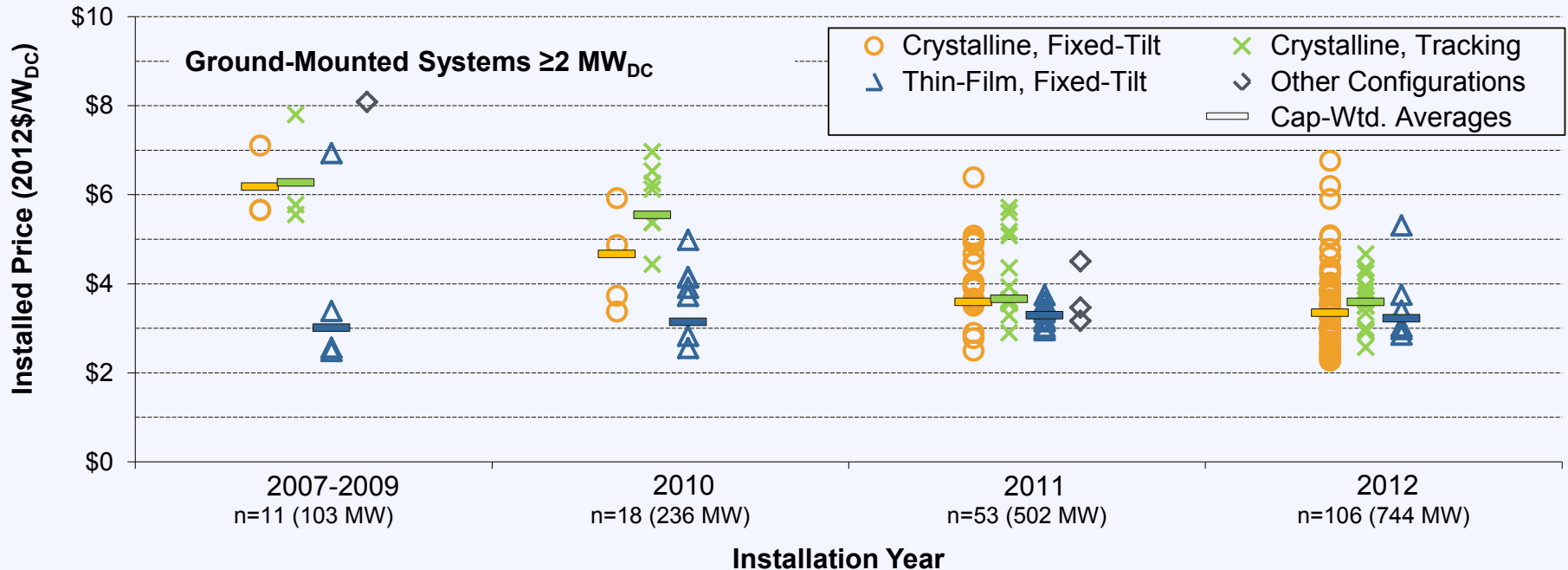
Note: Numbers in parentheses below each state indicate the number of observations; median installed prices are shown only if 15 or more observations are available for a given state. CO data are based on aggregated statistics provided by the PV program administrator rather than project-level data.

- A large disparity in median installed price (\$2.9/W) between the lowest- and highest-priced states also exists among large commercial systems (though some caution is warranted, given small sample sizes)
- Partly reflects differences across states in customer segments (e.g., roughly 2/3<sup>rd</sup>s of CA large commercial projects in 2012 were government/non-profit).

# Installed Price Data for Utility-Scale PV: Important Notes and Caveats

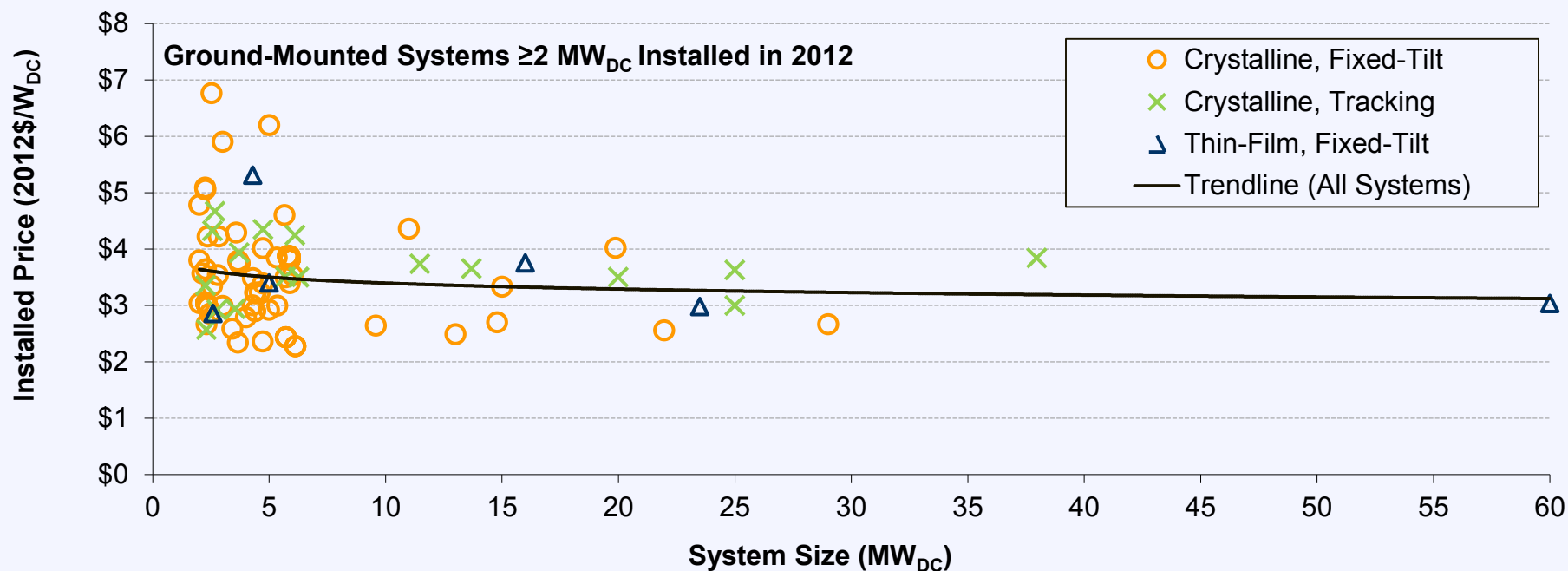
- Utility-scale PV is defined as ground-mounted systems  $\geq 2$  MW, regardless of whether electricity is delivered to utility or customer
- Analysis considers only entire projects (not individual phases)
- Project sample consists of 191 fully operational projects installed through year-end 2012, totaling roughly 1,600 MW (~70% of U.S. total)
- A few important caveats:
  - Small sample size that includes many 2-10 MW systems as well as a number of larger “one-off” projects with atypical characteristics
  - Lag in component pricing and market conditions between the time that a project was contracted and when it was installed
  - Data reliability is somewhat mixed depending on the data source available for any individual project
  - Focus is on installed price rather than levelized cost of electricity, and thus ignores performance differences across system configurations.

# Installed Price of Utility-Scale PV Projects Over Time



- Capacity-weighted average installed price was \$3.35/W for crystalline, fixed-tilt projects installed in 2012, down from \$3.59/W in 2011, a 7% decline YoY
- Capacity-weighted average installed price was \$3.60/W for crystalline tracking systems and \$3.23/W for thin-film, fixed-tilt systems completed in 2012
- A wide distribution in installed prices is observed, partially reflecting variation in system size (shown on following slide) and other project characteristics.

# Variation in Installed Price of 2012 Utility-Scale PV Projects by Size and Configuration



- Larger ( $>10$  MW) utility-scale systems vary in price within a relatively narrow range from roughly \$2.50/W to \$4.00/W, while smaller utility-scale projects span a much broader range that includes a number of high-priced systems ( $> \$5/W$ )
- Among the relatively small number of  $>10$  MW systems, capacity-weighted average prices were \$3.08/W for crystalline, fixed-tilt; \$3.56/W for crystalline with tracking; and \$3.14/W for thin-film, fixed tilt systems.

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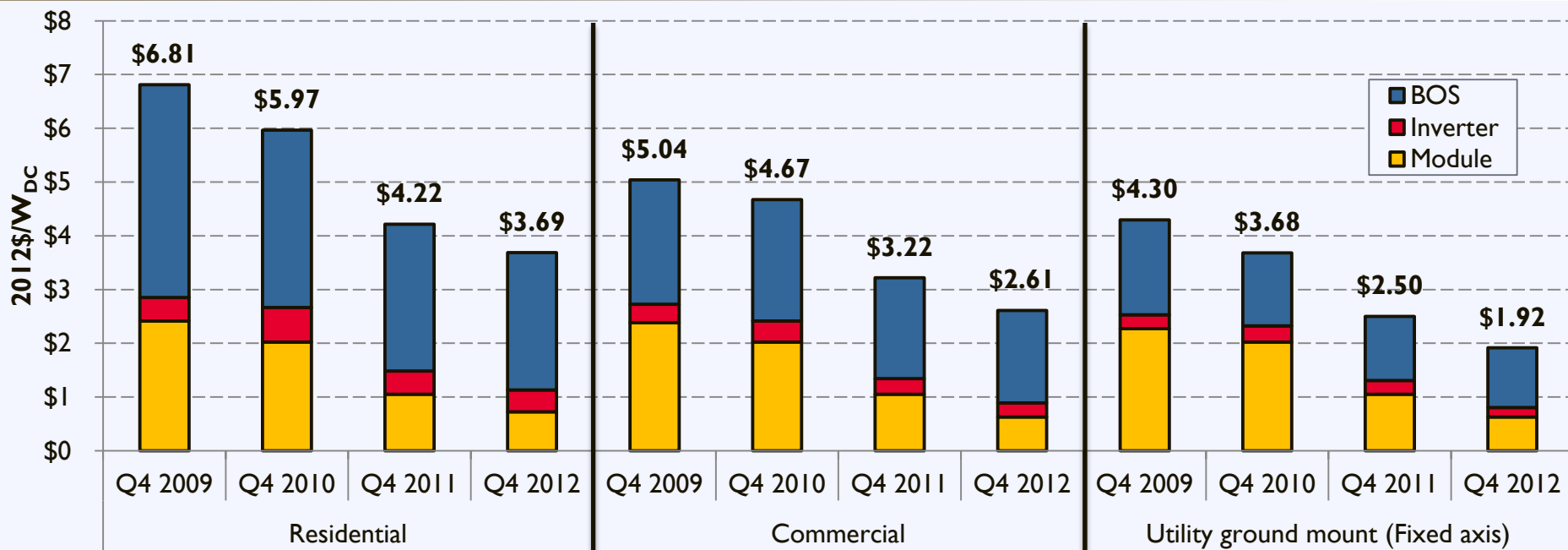
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# Methodology for Bottom-Up Modeling

- Detailed cost models for specific PV system designs account for all materials, labor, overhead and profit, land acquisition and preparation costs, and regulatory costs for a PV system up to the point of grid tie-in
  - Better able to determine individual components' contributions to total system cost
- NREL cost models are compiled from numerous industry and primary sources, for each component of a system incurred by a manufacturer and/or installer, and validated with manufacturers and installers
  - Dialogue created differentiates the interview method from the survey method by allowing for greater specificity and feedback of results
- The area of each modeled system is kept constant across years, but it increases in capacity based on improved module efficiencies.

# Bottom-up Modeled Overnight Capital Cost of PV Systems by Sector, Q4 '09 - Q4 '12

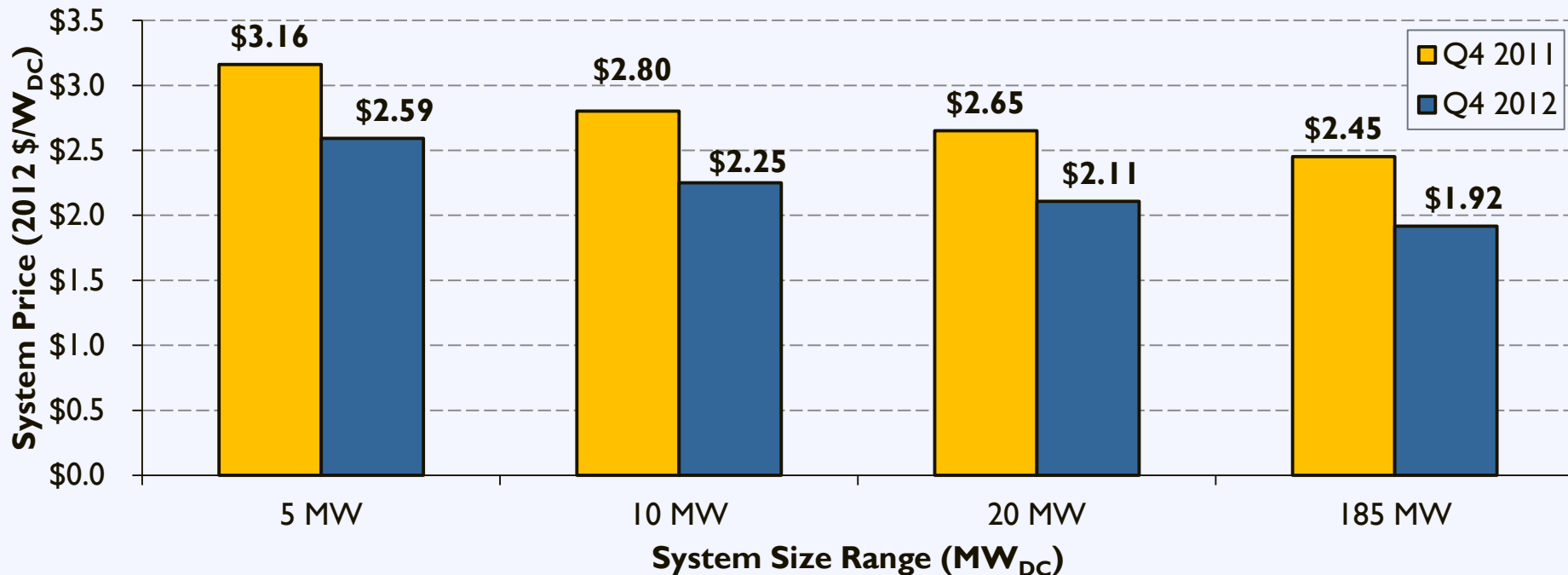


- Since Q4 2009, the overnight capital cost of systems has fallen between 14% – 18% per year
  - 50% - 75% of reduction attributed to module price reductions
- From Q4 '11 to Q4 '12, the overnight capital cost of systems fell between \$0.53/W - \$0.61/W, or 13% to 23%.

Note: Standard crystalline silicon modules (13.5% efficiency in Q4 2009 to 15.0% in Q4 2012). System size (residential: 4.6 kW in Q4 2009 to 5.1 kW in Q4 2012; commercial: 202.0 kW in Q4 2009 to 222.5 kW in Q4 2012; utility-scale: 174.6 MW in Q4 2009 to 192.8 MW to Q4 2012). The increase in module efficiency is the cause for increased system size. Modeled system sizes in the residential and commercial rooftop sectors

were chosen based on typical system sizes, then adjusted for optimal inverter configuration. System sizing for utility-scale benchmarks were chosen for comparison purposes against pricing reported from DOE's Energy Information Administration (2010).

# Bottom-up Modeled Overnight Capital Cost of Utility-Scale PV Systems by Size



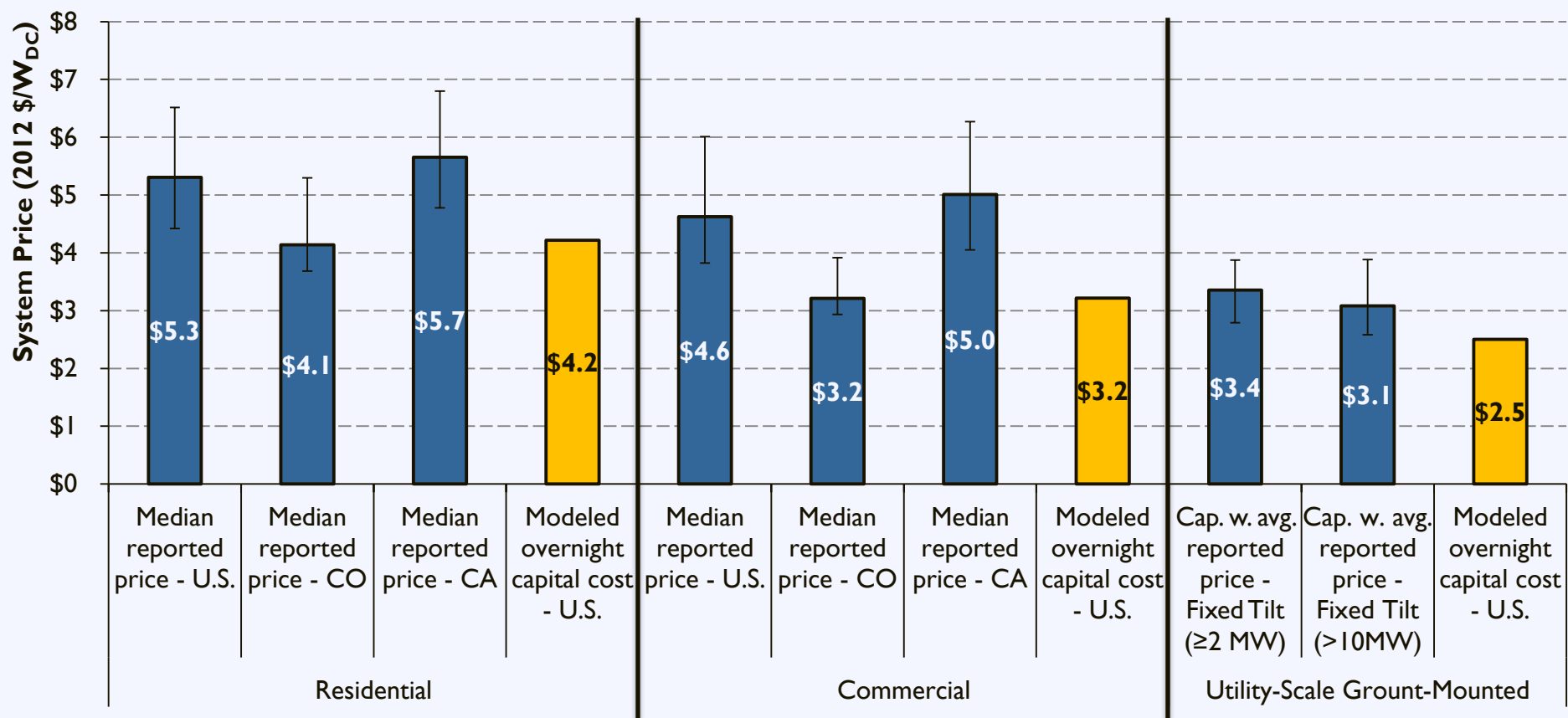
- Efficiencies of scale achieved in PV utility-scale bottom-up modeled overnight capital costs
  - 22-26% reduction in costs from 5 MW to 185 MW
    - Most of this cost reduction achieved by increasing size from 5MW to 20 MW (72%).

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# 2012 Reported Median (Residential/Commercial) and Capacity-Weighted Average (Utility-Scale) Prices vs. Q4 2011 Bottom-Up Benchmark Overnight Capital Cost



Note: Many factors contribute to the reported price and overnight capital cost differing values including the additional costs above and beyond the overnight capital cost of a project, such as third-party financing; different system sizing; installation time lag; and various methods for calculating system sales price. Error bars for reported price data represent 20/80 percentile of datasets. The costs included in the bottom-up benchmarks represent national averages; there is significant cost variation for each component, depending on the installer, market, or time frame. The above data is representative of the following system sizing: median residential reported size= 5.1 kW; residential bottom-up benchmark overnight capital cost = 5.1 kW; median commercial reported size (> 100 kW) = 258 kW; commercial bottom-up benchmark overnight capital cost = 221 kW; cap.-weighted average ground-mounted system (≥2 MW) reported size= 16 MW; utility-scale bottom-up benchmark overnight cap. cost = 191.5 MW.

# Reasons for Deviations Between Reported Price and Bottom-Up Benchmark Overnight Capital Cost

- Price vs. cost
  - Reported pricing reflects what a customer will pay for a system (i.e., what the market will bear). A customer's purchase price may be significantly higher than it would be elsewhere, regardless of the underlying cost to the installer, due to:
    - Higher electricity rates (e.g., CA)
    - Greater incentive programs (which may lower a customer's upfront cash outlay, though not the price paid to the installer)
    - Barriers to entry within specific markets, etc.
  - The bottom-up benchmarks are reflective of consistent, transparent assumptions of the cost and representative margins of each subcomponent to an installer, regardless of market conditions or incentives.
- Timing
  - Reported pricing generally reflects module and other component pricing at the time that installation contracts were signed (could precede installation date by more than a year for large projects)

# Reasons for Deviations Between Reported Price and Bottom-Up Benchmark Overnight Capital Cost (cont'd.)

- Bottom-up benchmark costs are contemporaneous with time subcomponent pricing estimates. Q4 benchmarks are compared with the following year, but may not fully capture lag between price quote and installation date.
- Geographic location
  - Reported price is weighted heavily toward California and New Jersey
  - Bottom-up benchmark based on national averages.
- Project specifics
  - Projects within dataset of report pricing includes systems not currently modeled in bottom-up benchmark, such as those using high-efficiency panels, high proportion of government facilities, and relatively small utility-scale projects.

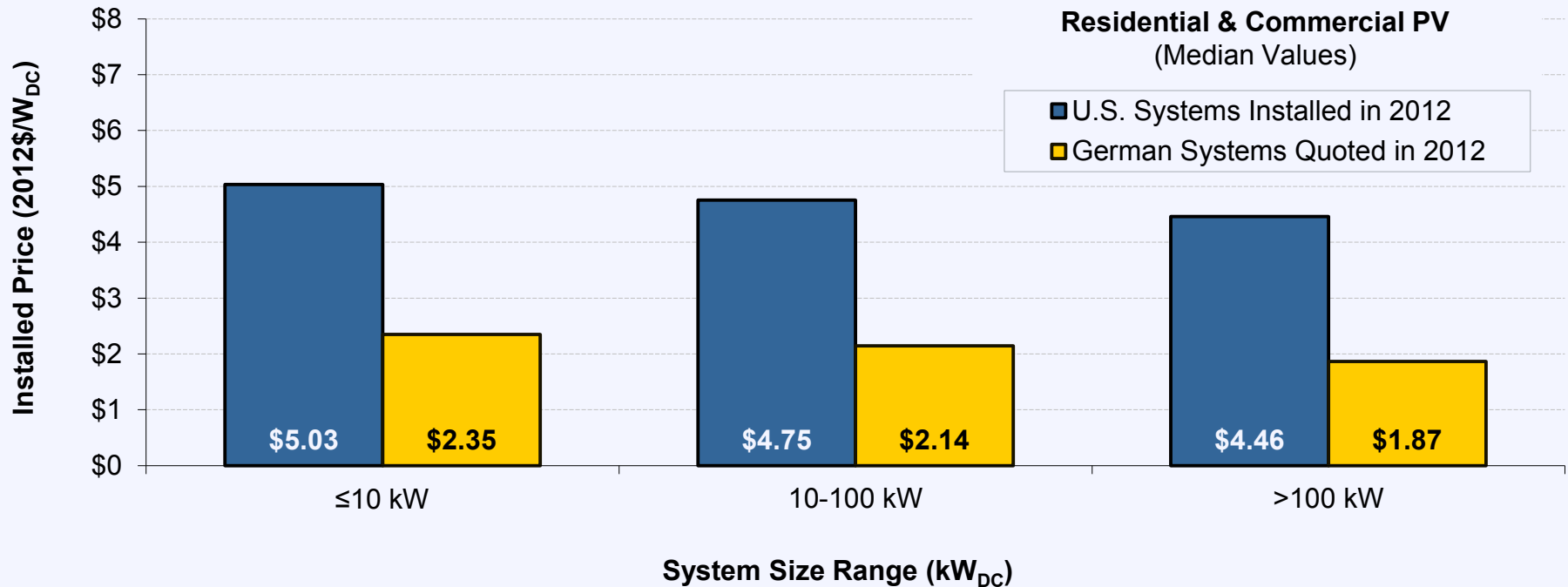
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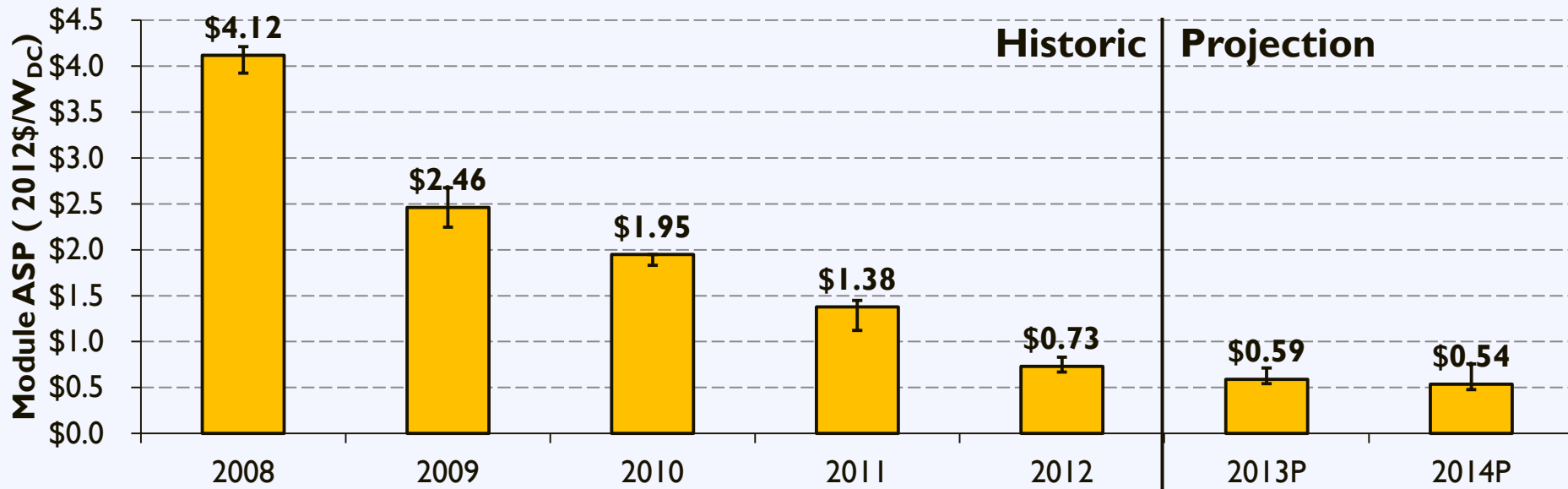


# Installed Price of Residential & Commercial PV Systems: U.S. Systems Installed in 2012 vs. German Systems Quoted in 2012



- Installed prices in the United States are high compared to most other major international PV markets, due largely to differences in soft costs
- The disparity is particularly stark in comparison to Germany, where installed prices are \$2.61-2.68/W (51-56%) lower across the three size ranges shown (on a pre-tax/VAT basis)
- Suggestive of potential for near-term cost savings in the United States.

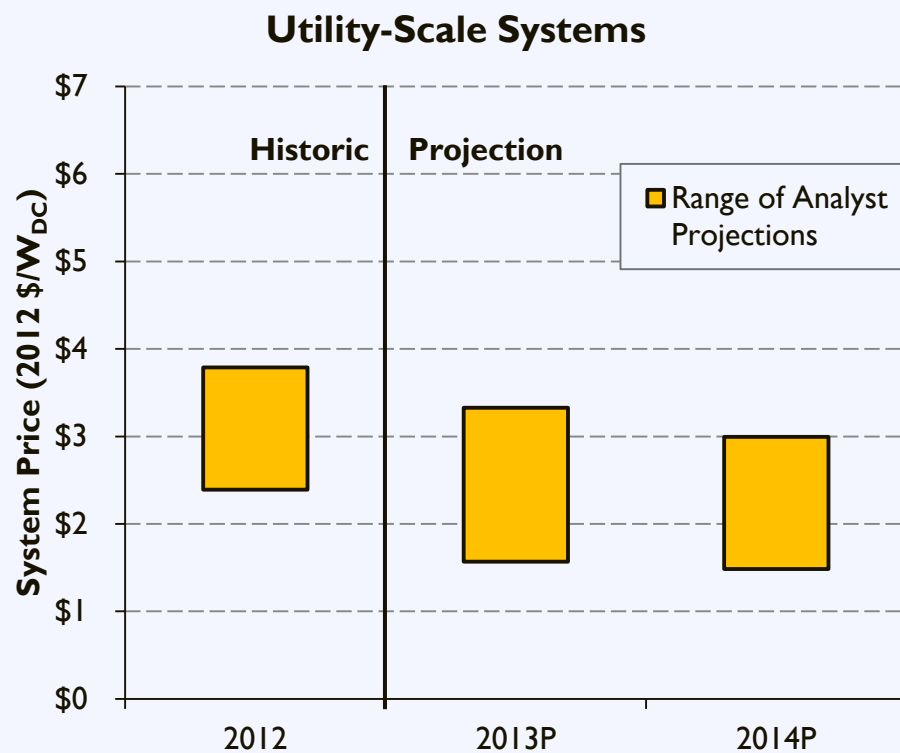
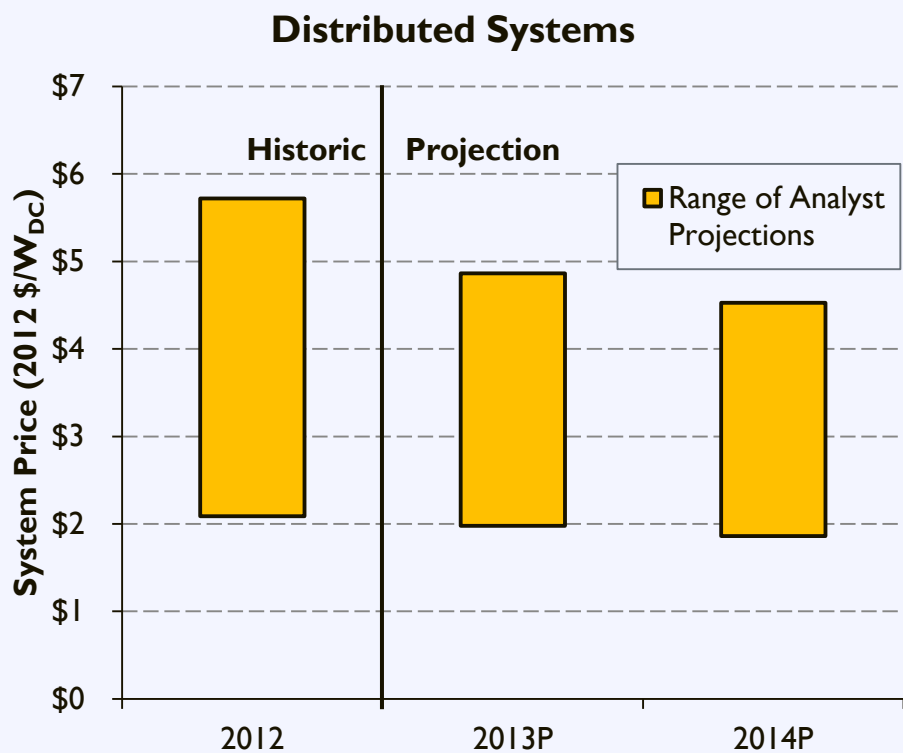
# Median and Range of Analyst Expectations of Module Average Selling Price



- Module prices in 2012 continued recent trend of dramatic reductions
  - Since 2008 has fallen on average 35% per year
- Mixed forecasts on future module ASP
  - However, not expected to increase or decrease dramatically in price
  - By 2014 ASP projected to be between \$0.50/W - \$0.75/W
- Major system price reductions are not expected to come from PV module price alone, as was the case in previous years.

Note: P = projection. Data represent the median, max., and min. figures from: BNEF (02/08/13, 03/25/13); Goldman Sachs (01/03/13); GTM Research (Oct. 2010, Jan. 2013); Photon Consulting (Jan. 2011, March 2012, March 2013), UBS (03/10/13). Inflation adjusted 2008-2012: CPI; inflation adjusted 2013-14: EIA, AEO, Table 20, Gross Domestic Product, August 2012.

# Analyst Estimates (2012) and Projections (2013–2014) of Global Average System Price



- Analysts expect the system prices of both utility-scale and distributed systems to continue to fall in the near future
  - Distributed systems are expected to reach between \$2/W - \$4.75/W by 2014
  - Utility-scale systems are expected to reach between \$1.50 - \$3.15/W by 2014.

**Note:** P = projection. Data represent the max. and min. figures from: Bloomberg New Energy Finance (05/13/13); Cowen & Company (05/16/13); Deutsche Bank (03/14/13, 05/07/13, 05/16/13); GTM Research (Feb. 2013); Navigant Consulting (Q2 2013); Photon Consulting's The Wall (06/14/13); Stifel Nicolaus (05/07/13). Inflation adjusted 2013-14: EIA, AEO, Table 20, Gross Domestic Product, August 2012.

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# Conclusion

- Continued system price reductions in 2012; more expected in the near-term, despite tensions on trade issues
  - Reported system pricing fell 6-14% from 2011-2012
  - Modeled overnight capital costs fell 13-23% from Q4 2011 to Q4 2012.
- Despite general downward trend, large variation in reported pricing within market segment in 2012
  - A difference of roughly \$2/W in median installed price between the lowest- and highest-priced states for residential & commercial systems  $\leq 10$  kW, but similar variability also exists *within* individual states
  - Ground-mounted systems  $\geq 2$  MW ranged in price from \$2/W to above \$6/W.
- Difference between reported price and bottom-up benchmark overnight capital cost for similarly segmented systems in 2012
  - Residential (\$5.30/W reported price, \$4.22/W bottom-up benchmark overnight capital cost); commercial (\$4.62/W reported price, \$3.22/W bottom-up benchmark overnight capital cost); utility-scale (\$3.35/W reported price, \$2.50/W bottom-up benchmark overnight capital cost)
  - Delta between reported pricing and modeled cost is due to various factors, such as inefficient pricing, timing, geographic location, and project specifics.