Energy Technologies Area Lawrence Berkeley National Laboratory

Tracking the Sun VIII

The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States

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— Report Summary —
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trackingthesun.lbl.gov

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Report Overview

Summarize trends in the installed price of grid-connected residential and non-residential PV systems in the United States

- **Focus on projects installed through 2014 with preliminary data for the first half of 2015**
- **Describe:**
  - Historical trends in national median prices
  - Variability in pricing across projects
- **Including:**
  - Key drivers for decline in median prices
  - Summary and comparison to other PV system price and cost benchmarks
  - Comparison to international markets
  - Installed price variation with system size and design, location, installer, and sector

What's New in *Tracking the Sun VIII*

- **Focus on Residential and Non-Residential PV.** Data for utility-scale PV are published in LBNL's companion *Utility-Scale Solar* annual report series
- **Expanded Data Sources.** Includes installed price and cost data from a variety of other sources in order to supplement and benchmark the primary set of installed pricing trends
- **New Analyses** related to system size and module efficiency trends, variation in installer-level pricing, and more details on characteristics of PV systems in the data sample

Related National Lab Research Products

***Tracking the Sun* is produced in conjunction with several related and ongoing research activities by LBNL and NREL**

- ***Utility-Scale Solar:*** LBNL annual report on utility-scale solar (PV and CSP) describing trends related to project characteristics, installed prices, operating costs, capacity factors, and PPA pricing
- ***The Open PV Project:*** Online data visualization tool developed by NREL that incorporates data underlying the Tracking the Sun and Utility-Scale Solar reports
- ***Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections***: Annual briefing produced jointly by NREL and LBNL that provides a broad overview of PV pricing trends, drawing from Tracking the Sun and other ongoing research activities at both labs
- ***In-Depth Statistical Analyses*** of PV pricing data by researchers at LBNL and several academic institutions examining PV pricing dynamics and underlying drivers, using more-advanced statistical techniques

These and other solar energy publications are available at http://emp.lbl.gov/projects/solar

Outline

- **Data Sources, Methods, and Sample Description**
- **Historical Trends in Median Installed Prices**
- **Variation in Installed Prices**
- **Conclusions**

Key Definitions and Conventions

Installed price: The up-front $/W price paid by the PV system owner, prior to incentives (see next 2 slides for discussion of TPO and data limitations)

Customer Segments*:

- **Residential PV:** Single-family residences and, depending on the conventions of the data provider, also multi-family housing
- **Non-Residential PV:** Non-residential roof-mounted systems of any size, and non-residential ground-mounted systems up to 5 MW_{AC}
- **Utility-Scale PV** (**not** included in this report)**:** Ground-mounted systems ≥5 MW_{AC}

**These customer segment definitions may differ from other market reports*

Units:

- Monetary values expressed in real 2014 dollars
- System size and capacity data expressed in DC units (module nameplate)

Data Sources and Limitations

Installed price trends are based on project-level data:

- Derived primarily from state agencies and utilities that administer PV incentive programs, solar renewable energy credit registration systems, or interconnection processes (~50 entities in total)
- Supplemented with data from other public sources (FERC Form 1, U.S. Treasury Department's Section 1603 Grant Program, trade press, etc.)

Key Data Limitations

- Self-reported by PV installers and therefore susceptible to inconsistent reporting practices
- Differs from the underlying cost borne by the developer or installer (price ≠ cost)
- Historical and therefore may not be representative of systems installed more recently or current quotes for prospective projects
- Excludes a sub-set of third-party owned (TPO) systems, for which reported prices represent appraised values (see next slide)

Data Cleaning and Standardization

- Standardize spellings of installer, module, and inverter names
- Assign attributes based on equipment data: module efficiency and type, building integrated vs. rack-mounted, microinverter vs. standard inverter
- Infer system ownership (host-owned or TPO) if data not provided directly
- Remove systems from final data sample if:
  - Missing valid data for installed price, system size, or installation date
  - Battery back-up
  - Self-installed
  - Integrated TPO systems (see below)

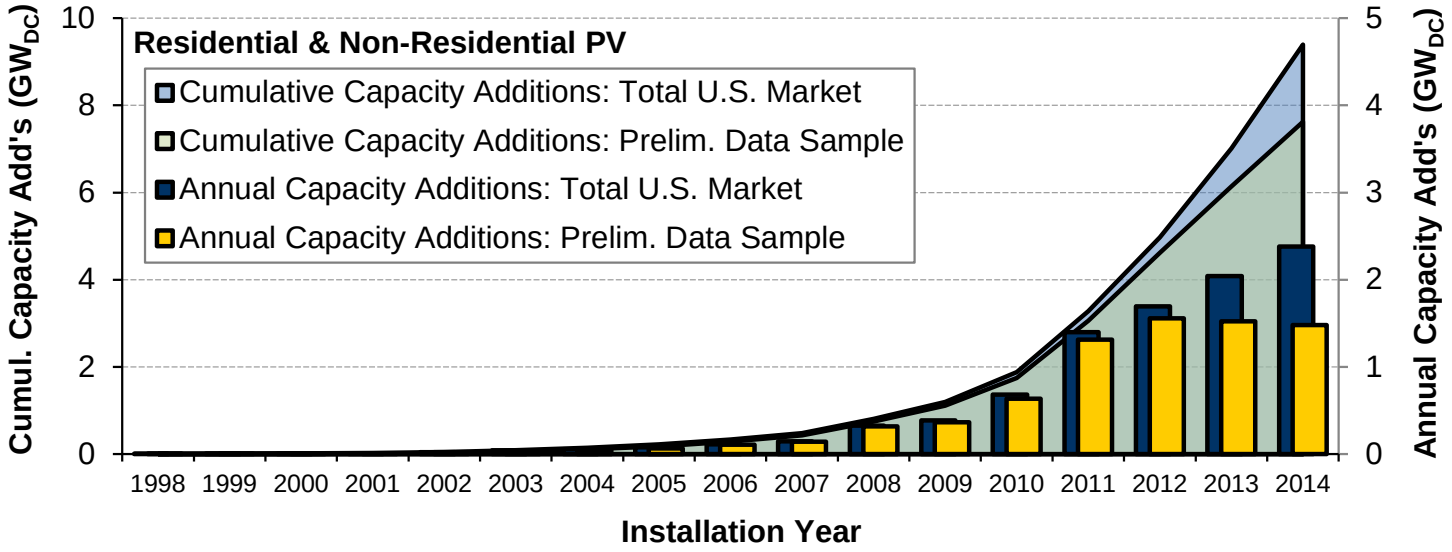
Treatment of Third-Party Owned (TPO) Systems in the Data Sample and Analysis

- **Integrated TPO.** A single company provides both the installation service and customer financing. Reported prices represent appraised values. ***Excluded from analysis***.
- **Non-Integrated TPO.** Customer finance provider purchases system from installation contractor. Reported prices represent sale price to customer finance provider. ***Retained in analysis***.

Sample Size Compared to Total U.S. Market

Preliminary data sample:

- >400,000 systems through 2014
- 81% of U.S. Res. + Non-Res. capacity through 2014
- 62% of 2014 U.S. capacity additions

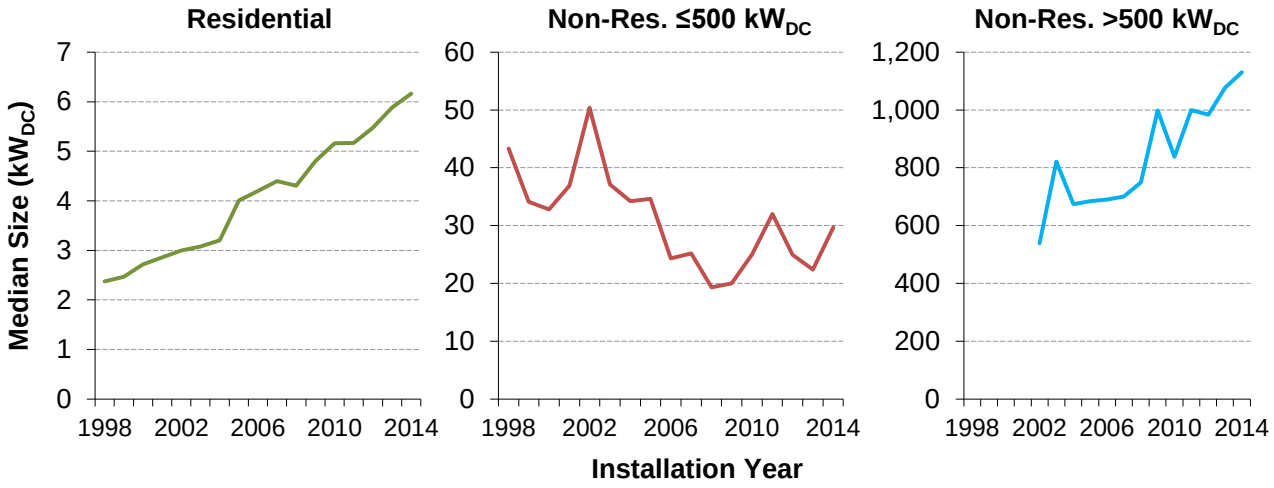


Total U.S. residential and non-residential PV capacity additions are based on GTM Research and SEIA (2015). LBNL adjusted those values to maintain consistency with how the non-residential sector is defined within this report, relying in part on data from GTM Research (2015a).

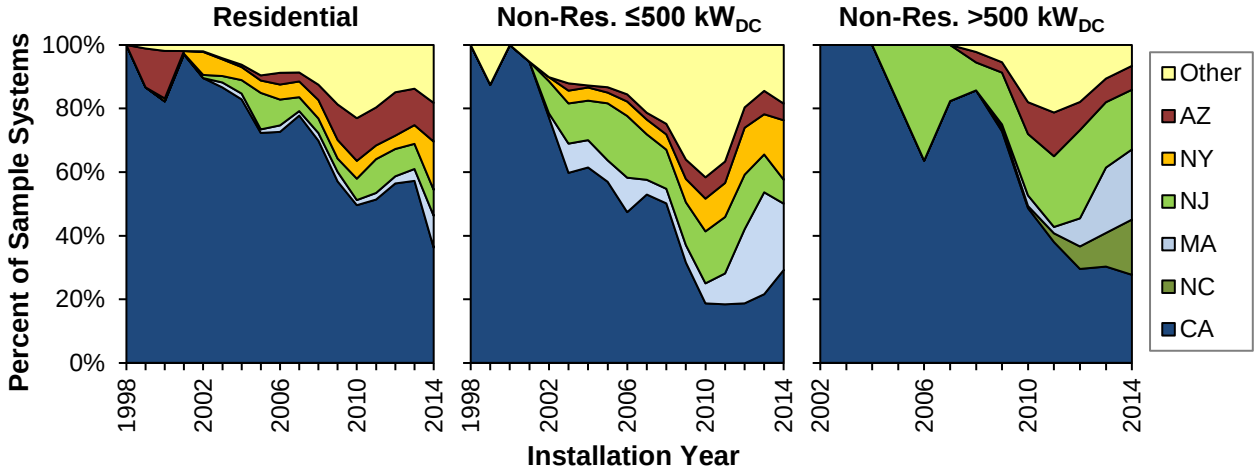
- Sample erosion in 2013/14 due primarily to transition issues in California (i.e., transfer of data collection from incentive program to utilities' net metering and interconnection processes)
- Most other major markets well represented, with the exception of Hawaii
- Removal of integrated TPO and other excluded systems reduces the final data sample to roughly 320,000 systems

Data Sample Characteristics:
System size trends and distribution among states

System Size Trends



Distribution Across States



- Residential system sizes growing steadily over time (6.2 kW in 2014)
- Non-Res. systems in the sub-500 kW class are generally small (20-30 kW)
- Non-Res. systems >500 kW also growing in size (1,100 MW in 2014)

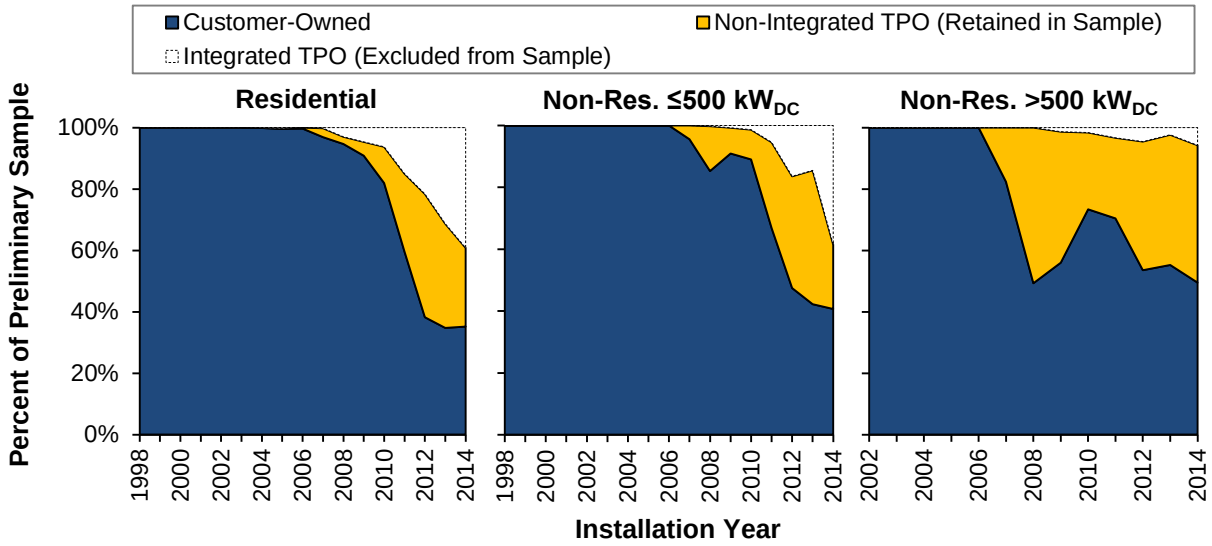
- Sample spans 42 states, though heavily weighted toward 6 states (CA , NC, MA, NJ, NY, AZ)
- Prominence of CA has declined over time, as in the broader market

Data Sample Characteristics:
Distribution by system ownership

Res & Non-Res ≤500 kW:

- Total TPO shares grew to ~60% of sample by 2012, remaining near that level through 2014
- Much higher TPO shares of sample for some states (80-90% in AZ, NJ)
- Integrated TPO shares have continued to grow; increasing percentage of systems excluded from final data sample
- Most pronounced for AZ (65% of 2014 residential sample is integrated TPO)

Distribution by System Ownership*



* *This figure is based on the preliminary data sample in order to illustrate consistency with the broader U.S. market and to show explicitly how exclusion of integrated TPO systems impacts the final data sample used for analysis; unless otherwise indicated, all other figures are based on the final data sample.*

Non-Res >500 kW:

- TPO emerged earlier than for other segments, but plateaued at somewhat lower level
- Negligible presence of integrated TPO

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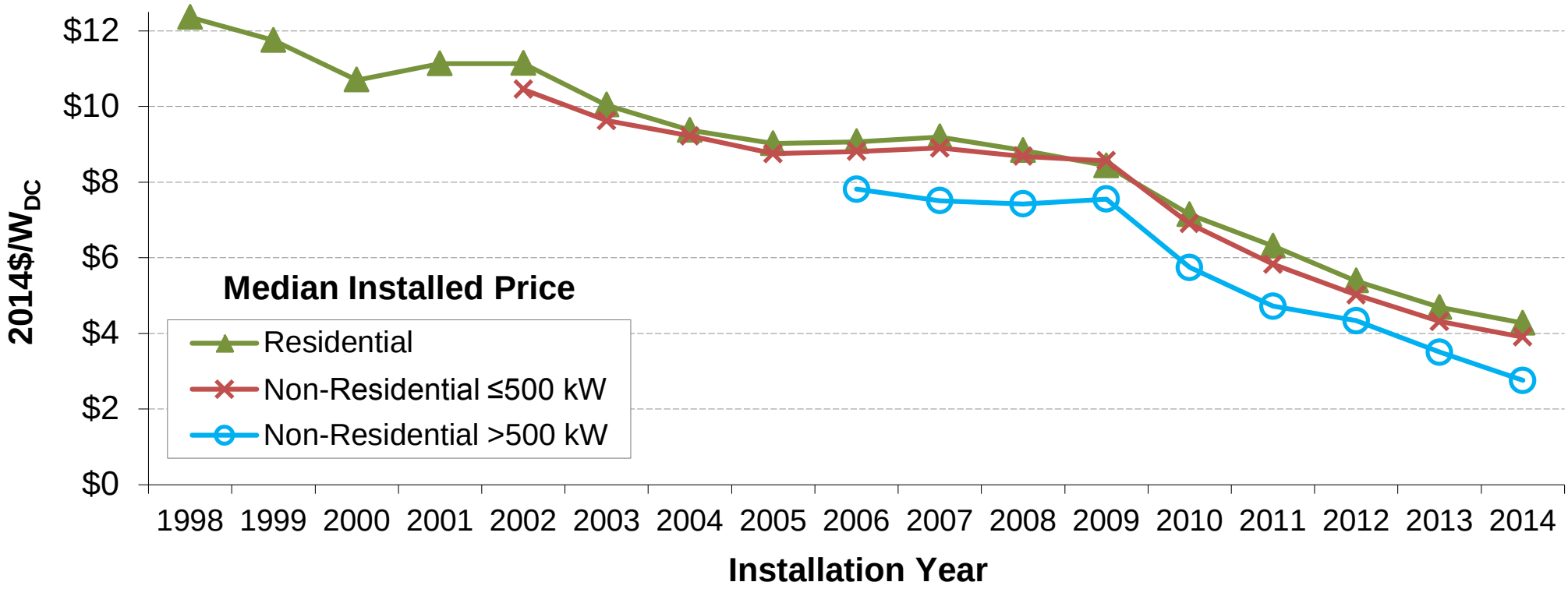
Installed Prices Continued their Rapid Descent through 2014

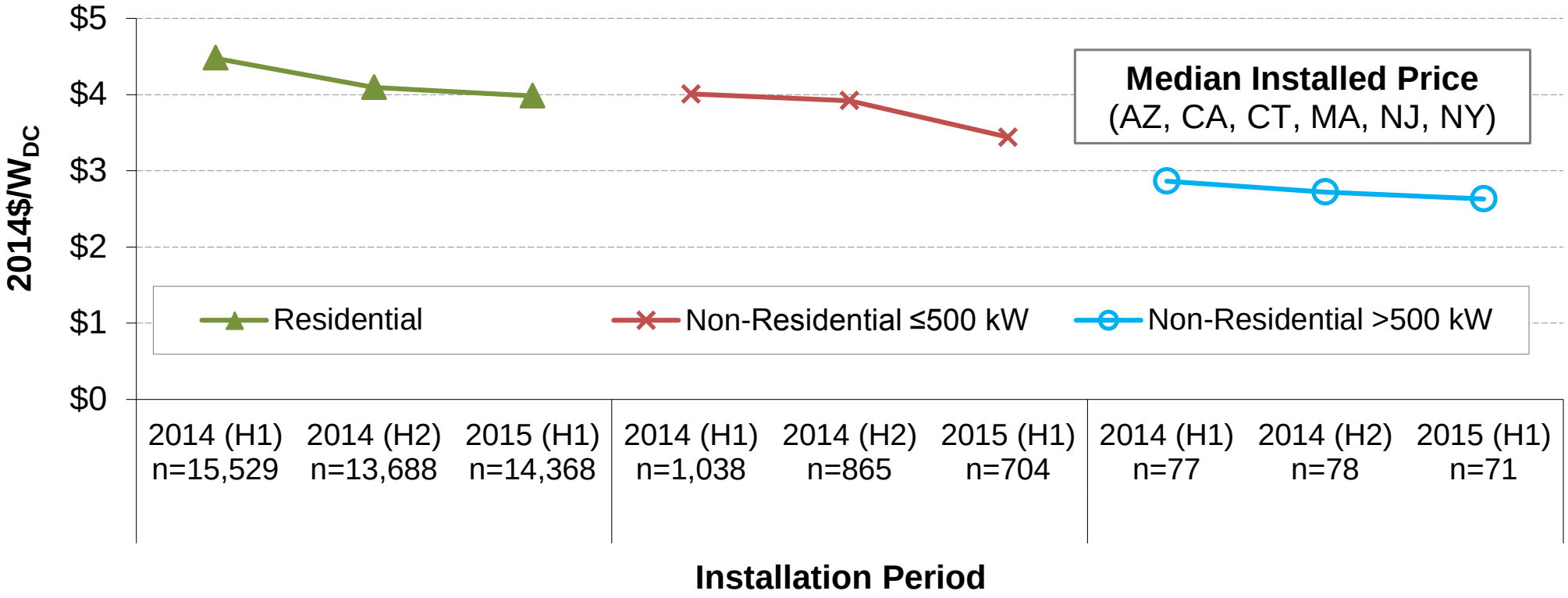
National median installed prices in 2014 declined YoY by $0.4/W (9%) for residential systems, by $0.4/W (10%) for non-residential systems ≤500 kW, and by $0.7/W (21%) for non-residential systems >500 kW



Note: Median installed prices are shown only if 20 or more observations are available for a given year and customer segment.

Preliminary Data for 2015 Show Installed Price Declines Are Keeping Pace with Recent Trends

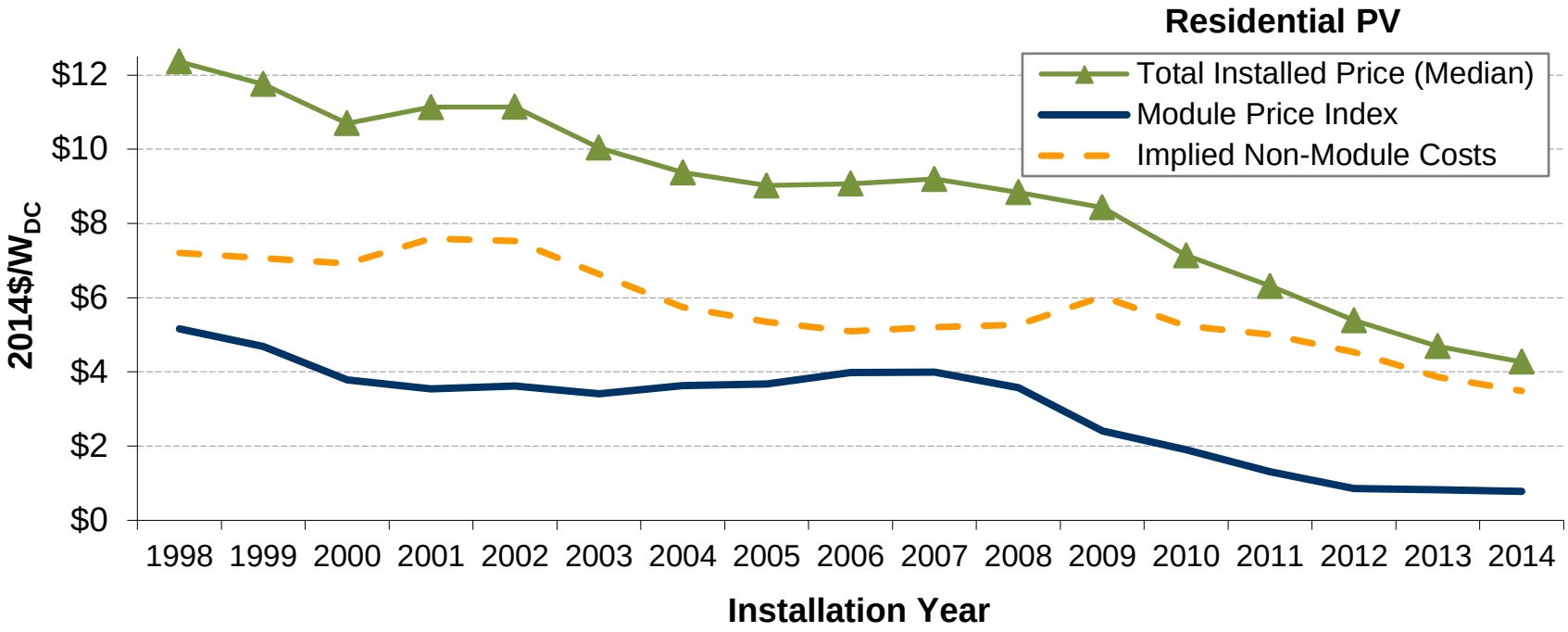
Compared to 2014, median installed prices in H1 2015 fell by $0.3/W (8%) for residential systems, $0.5/W (13%) for non-res. systems ≤500 kW, and $0.2/W (6%) for non-residential systems >500 kW



Note: The figure is based on data from only a subset of programs from the larger dataset, and therefore cannot be directly compared to other figures in the slide deck.

Installed Price Declines Have Continued Despite Flat Module Prices

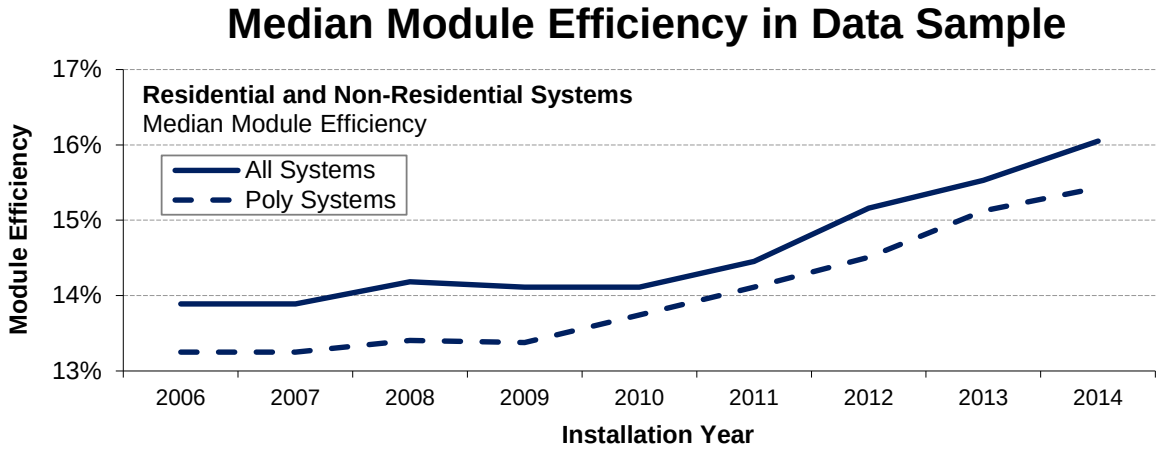
- Steep reductions in module prices were the primary driver for installed price reductions from 2008 to 2012 (~80% of the total installed price decline)
- Since 2012, however, module prices have remained relatively flat, and installed price declines have been driven primarily by reductions in non-module costs (including installer margins)



Notes: The Module Price Index is the U.S. module price index published by SPV Market Research (Mints 2015). Implied Non-Module Costs are calculated as the Total Installed Price minus the Module Price Index, and therefore include installer profit margin.

Recent Non-Module Cost Reductions Are Associated Primarily with Declining Soft Costs

- Hardware component prices (inverters and racking) have fallen significantly (GTM Research and SEIA 2015), though comprise only 10-20% of the total drop in non-module costs from 2013 to 2014
- Remainder is attributable mostly to soft costs reductions, stemming partly from technical factors (that can be readily quantified):
  - Increasing system size (~10% of total YoY non-module cost reduction)
  - Increasing module efficiency (~15% of total YoY non-module cost reduction)
- Soft cost reductions also associated with:
  - Widespread policy and industry efforts aimed at reducing soft costs
  - Steady reductions in incentives (next slide)

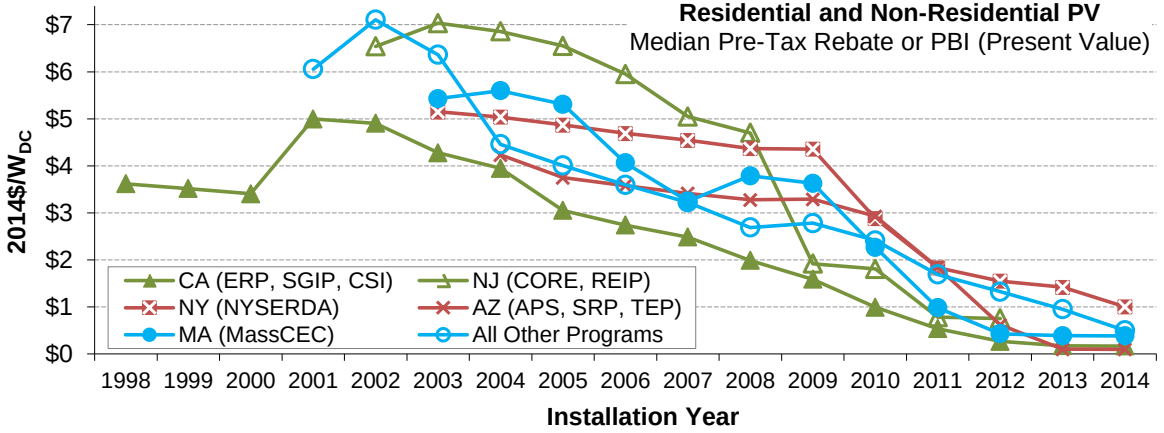


Notes: "All Systems" is based on all residential and non-residential systems in the data sample, regardless of module technology, while "Poly Systems" is based on only those systems with poly-crystalline modules. The figure is based on data from 200,930 systems installed over the 2006 to 2014 period, for which module efficiencies could be identified.

Installed Price Declines Have Been Partially Offset by Falling State and Utility Incentives

- Rebates and performance-based incentives (PBIs) have declined from $5-7/W at their peak to less than $1/W (or zero) in most major markets
- Incentive reductions partly a response to installed price declines and the emergence of other forms of incentives (SRECs, ITC, improved monetization of tax benefits)
- Ratcheting down of incentives also a deliberate strategy by some states to induce cost reductions

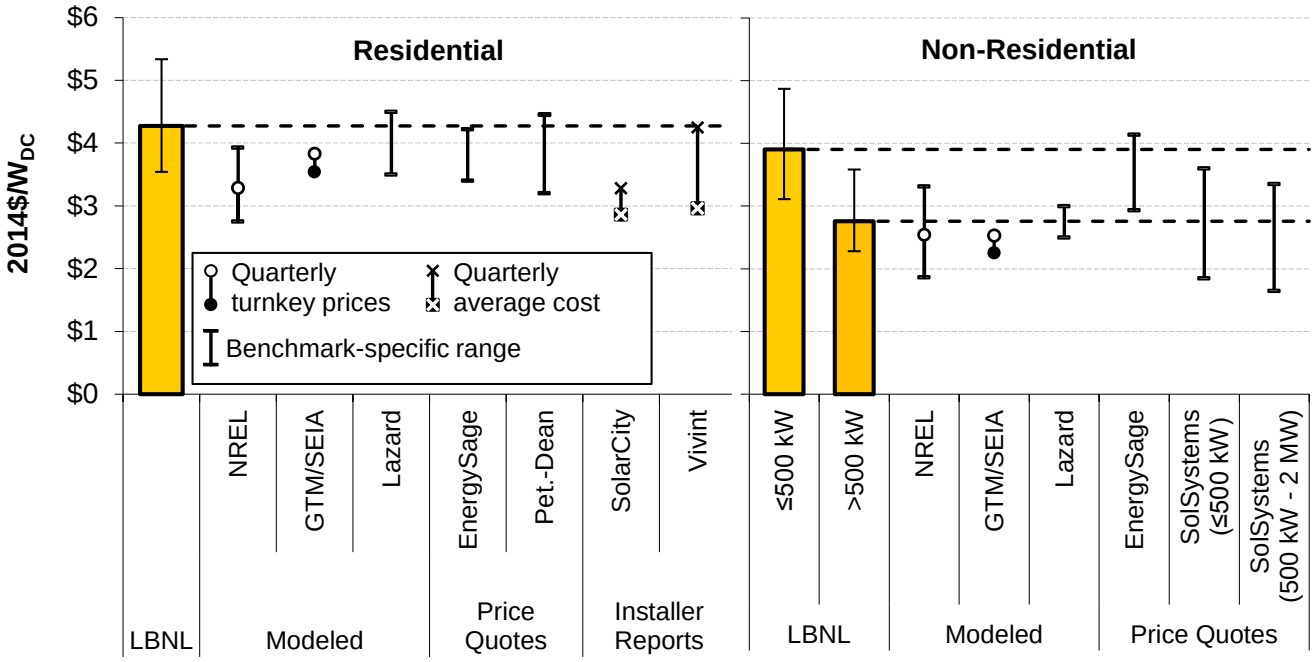
Reductions in rebates and PBIs since their peak equate to 70% to 120% of the corresponding drop in installed prices



Notes: The figure depicts the pre-tax value of rebates and PBI payments (calculated on a present-value basis) provided through state/utility PV incentive programs, among only those systems that received such incentives. Although not shown in the figure, a growing portion of the sample received no direct cash incentive. Also note that the data are organized according to the year of installation, not the year in which incentives were reserved.

National Median Installed Prices Are Relatively High Compared to Other Recent Benchmarks

National median prices for systems installed in 2014: $4.3/W (res.), **$3.9 /W** (sm. non-res.), **$2.8/W** (lg. non-res.)

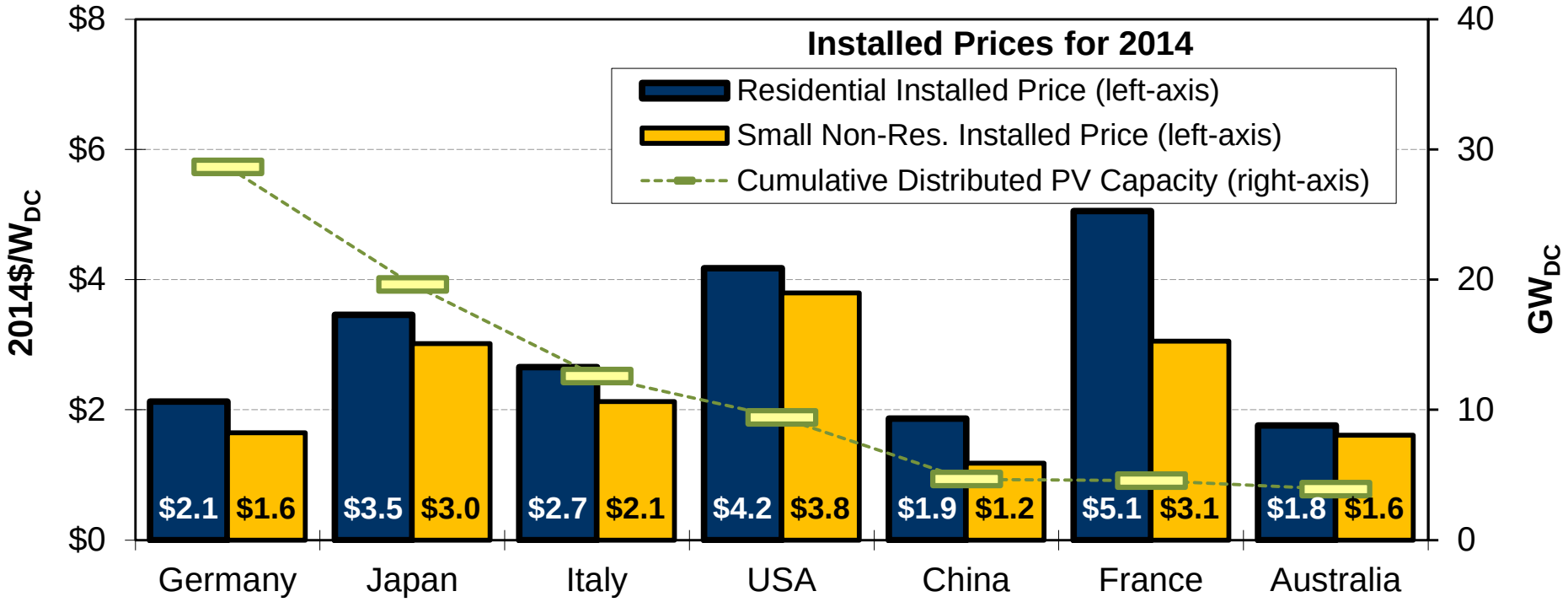


*Notes: **LBNL** data are the median and 20thand 80th percentile values among projects installed in 2014. **NREL** data are the median and 20thand 80th percentile ranges from Monte Carlo modeling of U.S. turnkey prices for 5 kW residential and 200 kW commercial systems, representative of bids issued circa Q4 2013 (Davidson et al. 2014, Feldman et al. 2014). **GTM/SEIA** data are modeled turnkey prices for Q1 and Q4 2014; residential price is for 5-10 kW system with standard crystalline modules installed by company with at least 600 systems per year, while commercial price is for a 300 kW "minimalist" flat-roof system, with further details available from the reference source (GTM Research and SEIA 2015). **Lazard** data are the range reported in their Sept. 2014 levelized cost of energy analysis (Lazard 2014). **EnergySage** data are the 20thand 80th percentile range among price quotes issued in 2014, calculated by LBNL from data provided by EnergySage. **Petersen-Dean** data are the minimum and maximum values from a series of online price quotes for turnkey systems across a range of sizes (3.3 to 8.3 kW) and states (AZ, CA, and TX), queried from the company website by LBNL in May 2015. **SolarCity** and **Vivint** data are the companies' reported average costs, inclusive of general administrative and sales costs, for Q1 and Q4 2014 (SolarCity 2015, Vivint Solar 2015). **SolSystems** data are the lowest and highest "developer all-in asking prices" among the company's monthly Sol Project Finance Journal reports issued in 2014 (e.g., SolSystems 2014).*

Medians differ from other benchmarks due to:

- Timing: Systems installed vs. quoted in 2014
- Location: Most systems in relatively high-cost states
- Price vs. cost: SolarCity and Vivint data represent costs
- Value-based pricing: Prices in some locations may reflect supra-normal margins
- System size/components: high-efficiency modules, microinverters, etc.
- Scope of costs included: loan origination fees, re-roofing costs, etc.
- Installer characteristics: size, experience, business model

Installed Prices in the United States Are Higher than in Most Other Major National PV Markets



Notes: Installed price data for all countries other than the U.S. are based on annual country reports submitted to the IEA Photovoltaic Power Systems Programme (IEA-PVPS 2015). Prices for all countries exclude sales or value-added tax (VAT). Data for cumulative distributed PV capacity additions are based on REN21 (2015), IEA-PVPS (2015), EPIA (2014), Shaw (2015).

- Installed prices differ across countries largely due to soft costs (Seel et al. 2014, Ardani et al. 2012, Friedman et al. 2014, RMI and GTRI 2014)
- Soft cost differences are driven partly by deployment scale, though a wide variety of other factors also likely play a role

Outline

- Data Sources, Methods, and Sample Description
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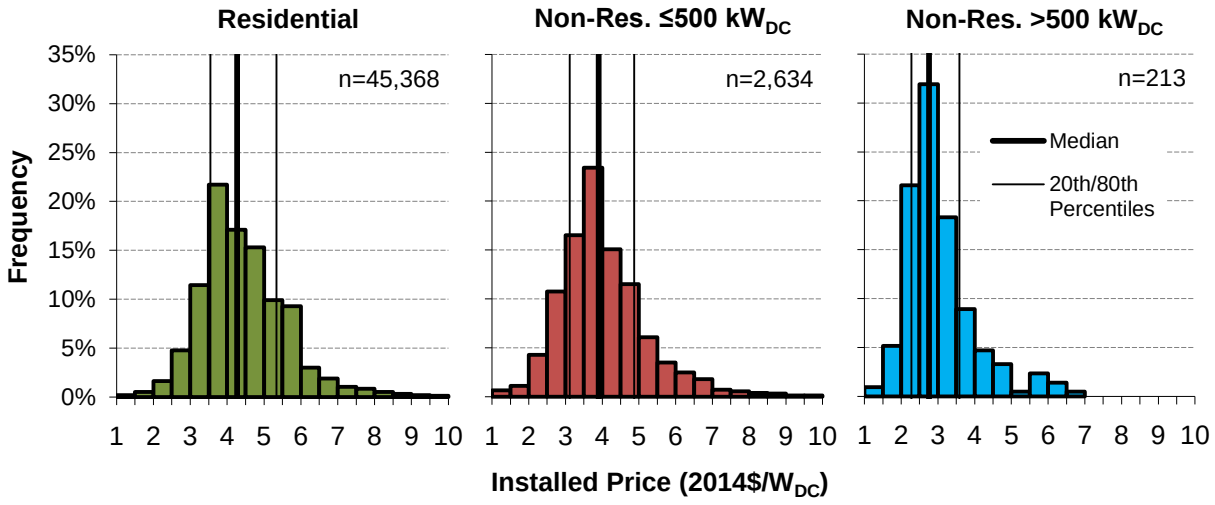
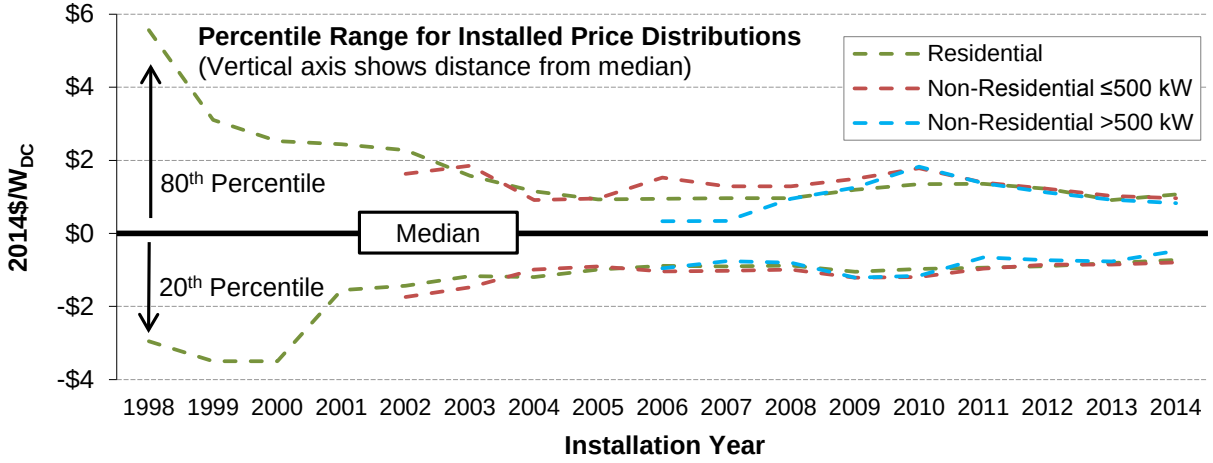
Installed Prices Vary Widely Across Projects

Though have narrowed over time

Installed Price Distributions for Systems Installed in 2014



Installed Price Percentile Ranges over Time



Note: Percentile bands are shown only if 20 or more observations are available for a given year and customer segment.

Wide distributions in system pricing reflect variation in:

- Project characteristics
- Local market and regulatory environment
- Installer size, experience, business model
- Labor rates, taxes, permitting and interconnection processes

Narrowing is consistent with a maturing market characterized by increased competition and better-informed consumers

Recent Studies Shed Light on Installed Pricing Variation and Dynamics for Residential PV

LBNL and academic partners (Yale, U. of Wisconsin, U. of Texas) applied more-advanced statistical and econometric methods to the *Tracking the Sun* dataset, focusing on residential systems

Gillingham et al. (2014) estimated the effects of a broad set of drivers on residential PV pricing, including variation in system size ($1.5/W effect), density of installers ($0.5/W effect), consumer value of incentives and electricity bill savings ($0.4/W effect), and installer experience ($0.2/W effect)

Dong and Wiser (2013) found installed price differences of $0.3/W to $0.8/W between cities in California with the least- and most-onerous permitting practices

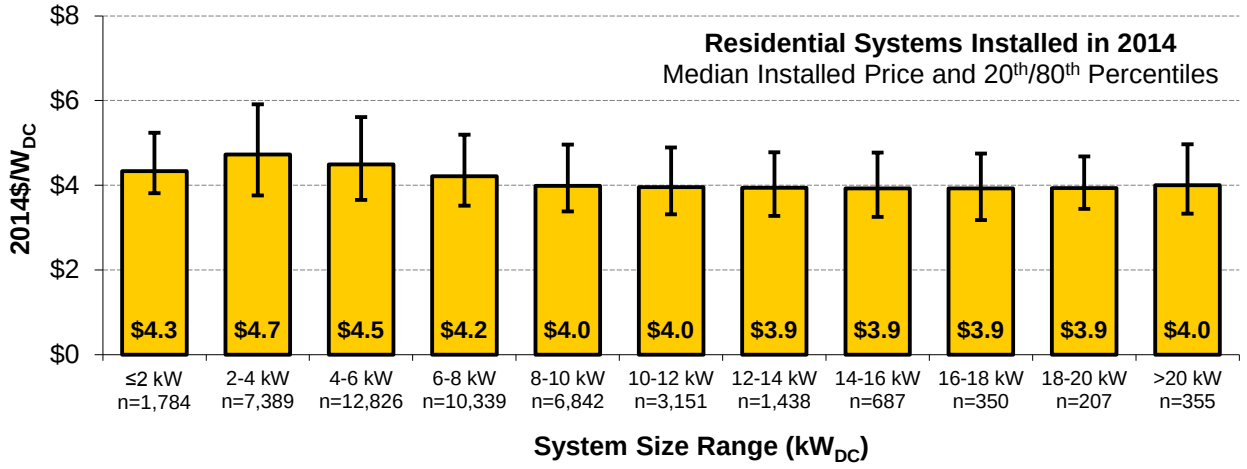
Burkhardt et al. (2014) found that local permitting procedures alone impact installed prices by $0.2/W, while the combination of permitting and other local regulatory procedures impacts prices by $0.6/W to $0.9/W

Dong et al. (2014) found that, historically, 95% to 99% of rebates in California were passed through to consumers, rather than retained as increased installer margins

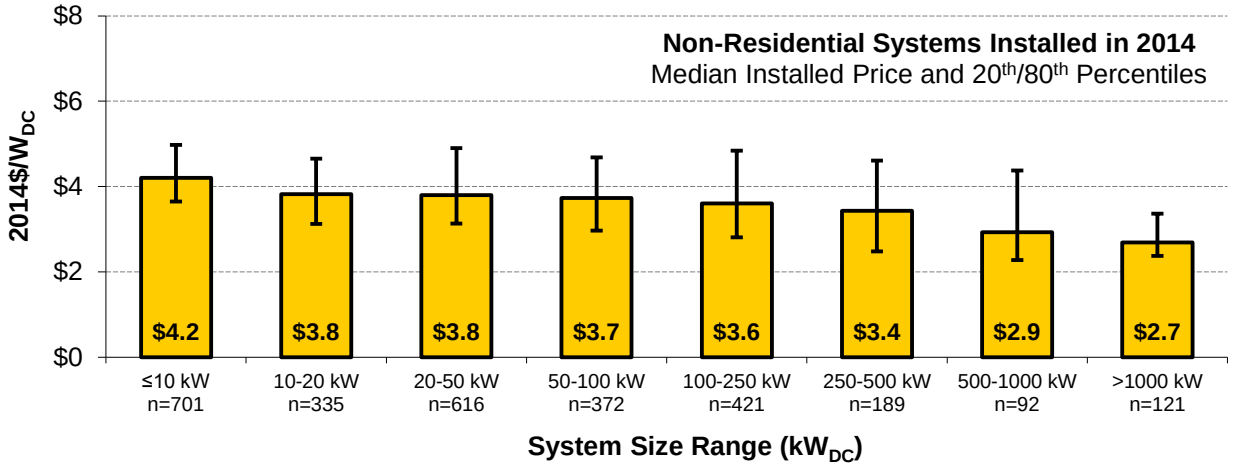
Studies available at http://emp.lbl.gov/projects/solar

Economies of Scale Occur Among Both Residential and Non-Residential Systems

Residential Systems



Non-Residential Systems



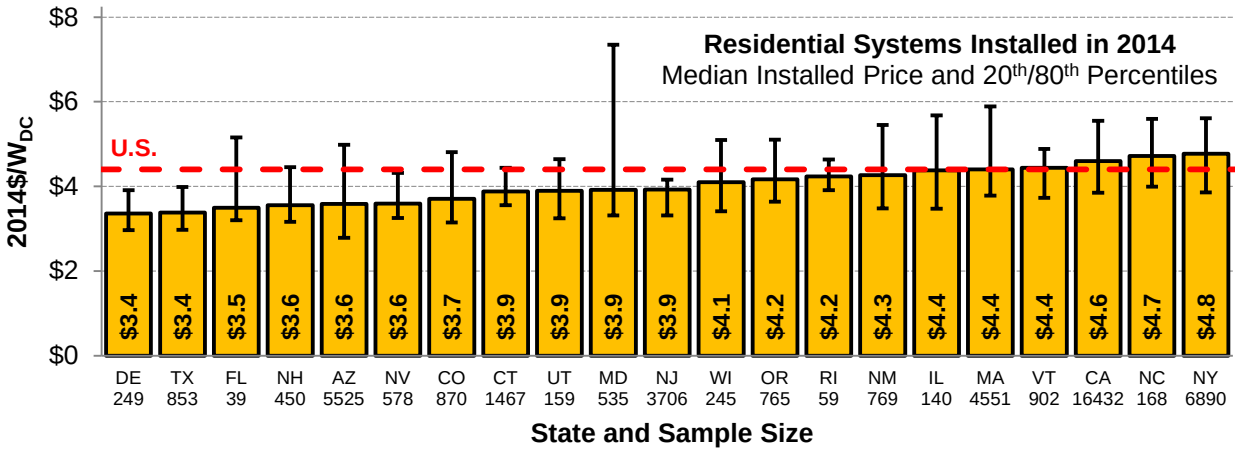
- For residential systems installed in 2014, median prices were roughly 15% lower for 8-10 kW systems than for 2-4 kW systems
- Among non-res. systems installed in 2014, median installed prices were 36% lower for the largest (>1,000 kW) than for the smallest (≤10 kW) non-res. systems
- Even greater economies of scale may arise when progressing to utility-scale systems, which are outside the scope of this report

Installed Prices Differ Among States

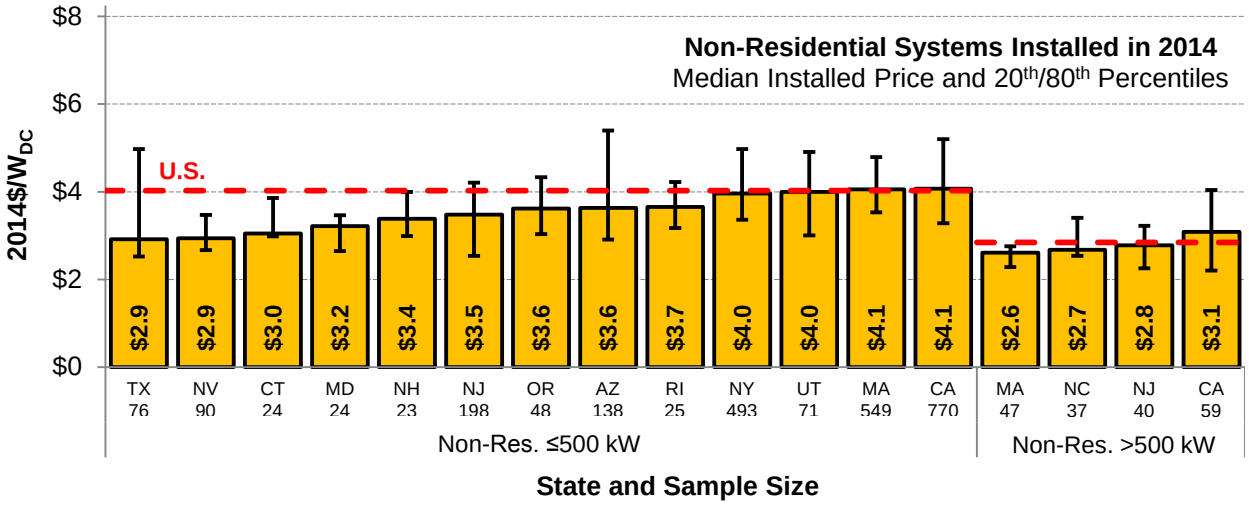
Relatively high prices in some large state markets

- Some of the largest markets (CA, MA, NY) are relatively high-priced, pulling overall U.S. median prices upward
- Pricing in most states is below the national median
- Cross-state variation may reflect differences in installer competition and experience, retail rates and incentive levels, project characteristics particular to each region, labor costs, sales tax, and permitting and administrative processes
- High degree of variability also occurs *within* states

Residential Systems



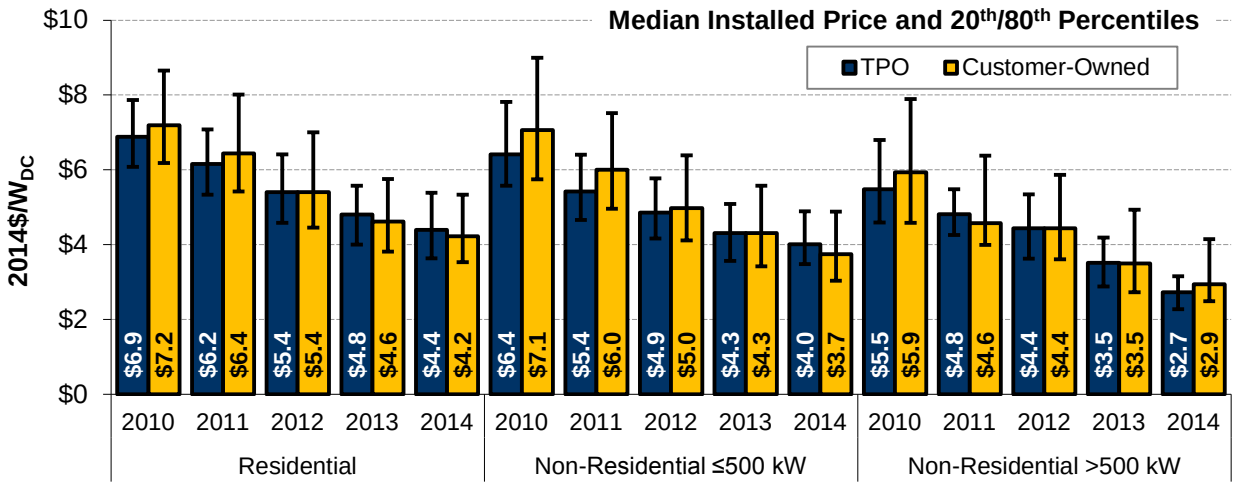
Non-Residential Systems

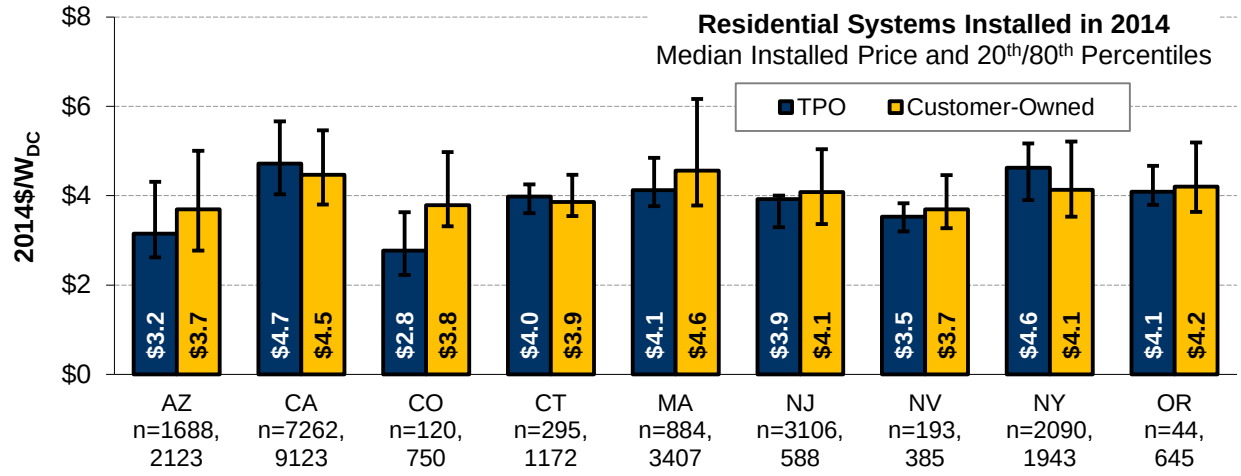


Note: Results shown only if 20 or more observations are available for the state

Installed Prices Reported for TPO Systems Are Generally Similar to Customer-Owned Systems

- At the *national* level, installed price differential between integrated TPO and customer-owned systems has inverted over time, but has generally been small (top figure)
- Implies that growth of TPO has not had a material impact on national median installed price trends
- In some states, installed prices differ more substantially between TPO and customer-owned residential systems, potentially contributing to cross-state price differences (bottom figure)

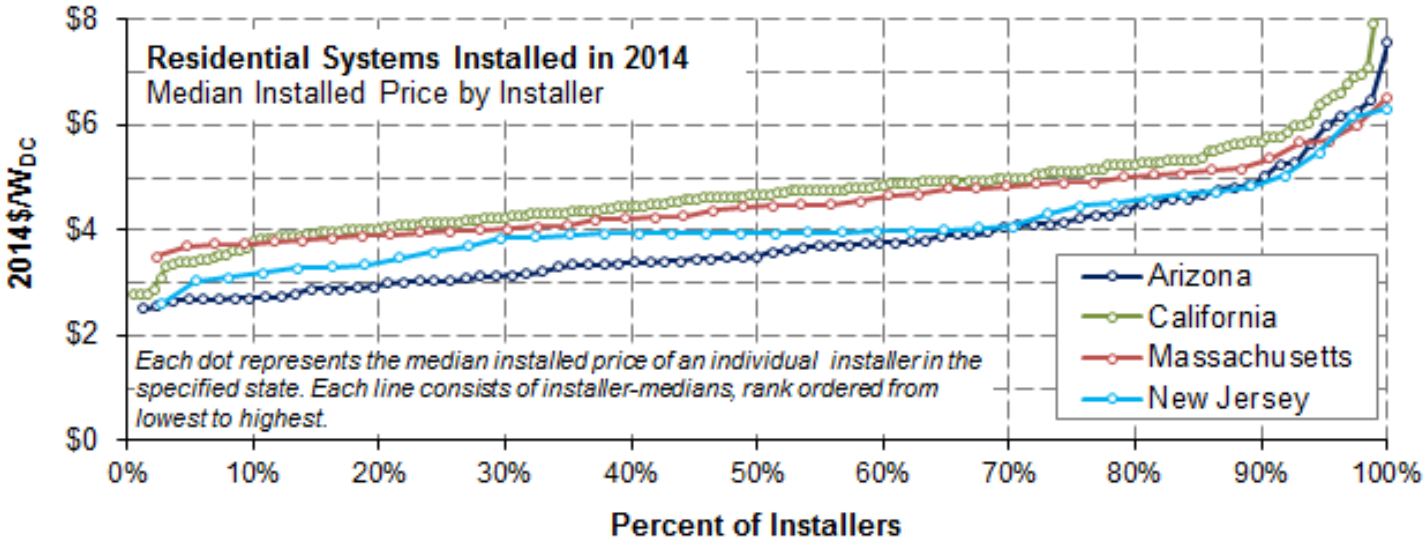




Notes: The values shown here for TPO systems are based on systems financed by non-integrated TPO providers, for which installed price data represent the sale price between the installation contractor and customer finance provider.

Prices Vary Considerably Across Residential Installers Operating within the Same State

Within each of the four states shown, ***installer-level median prices*** differ by $1.1/W to $1.4/W between the 20% and 80%iles (and by more across the full set of installers)



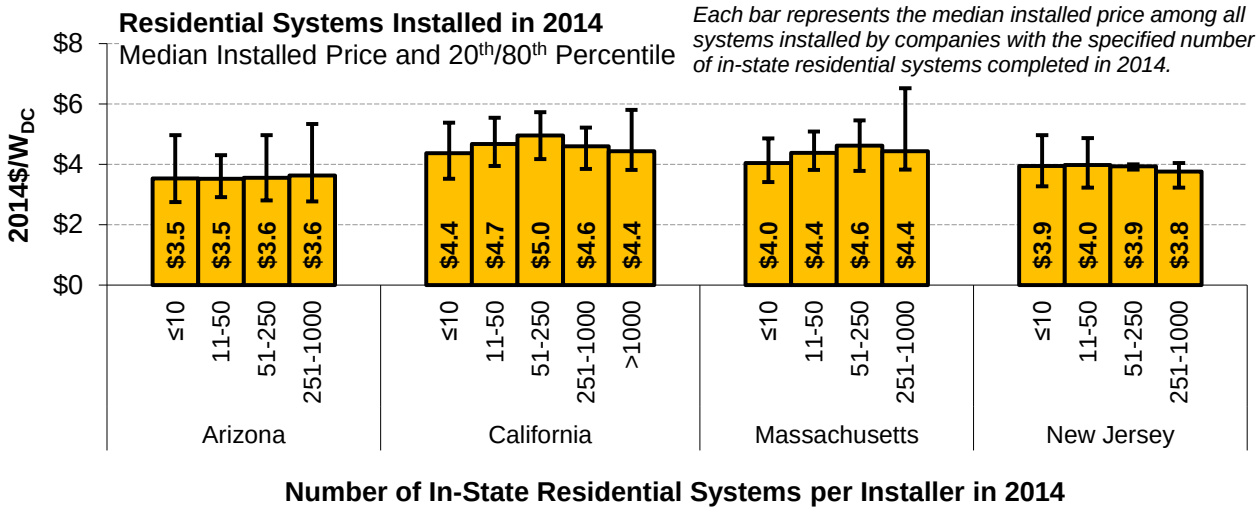
Notes: Each line includes only installers that completed at least 10 residential systems in the given state in 2014.

- "Low-price leaders" provide a benchmark for what may be achievable in terms of near-term installed price reductions within the broader market (e.g., 20% of installers in Arizona have median prices below $3.0/W)
- High-priced installers may specialize in "premium" systems or may include in their reported prices additional items beyond what is typically counted as part of the PV system (e.g., loan origination fees, re-roofing costs, etc.)

Larger Residential Installers *Seemingly* Do Not Have Lower Prices

The figure segments projects according the number of in-state systems the associated installer completed in 2014

- AZ and NJ: No clear relationship between price and installer volume
- CA and MA: Seemingly higher prices for mid-sized installers than for lower- or higher-volume companies



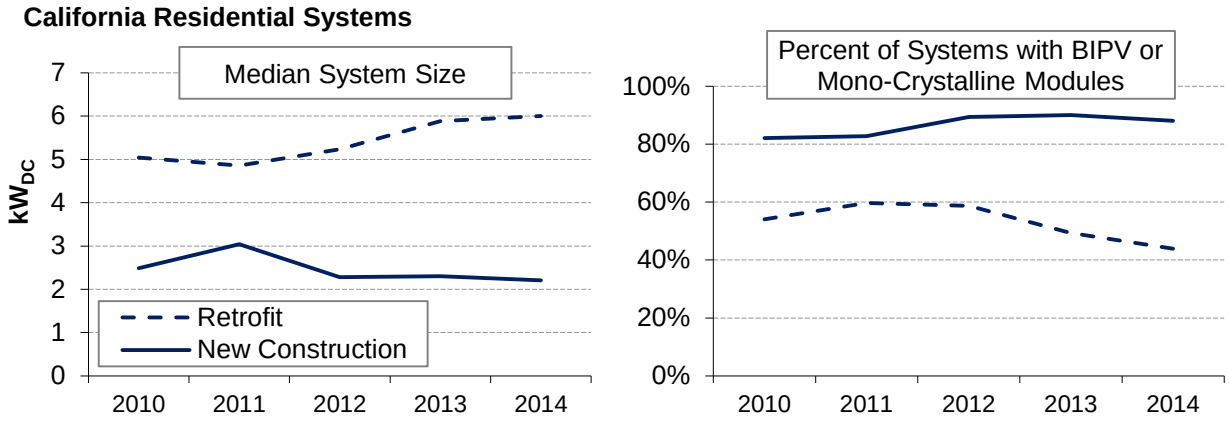
Notes: Each bin includes at least 3 installers and, with the exception of the ≤10 systems bin, at least 15% of all residential systems in the sample installed in-state in 2014. For California, installer volumes are based on market volumes from GTM's U.S. PV Leaderboard (GTM Research 2015b). For all other states, they are calculated from the preliminary data sample, and therefore include integrated TPO systems and other excluded systems not used for the purpose of calculating installed price statistics.

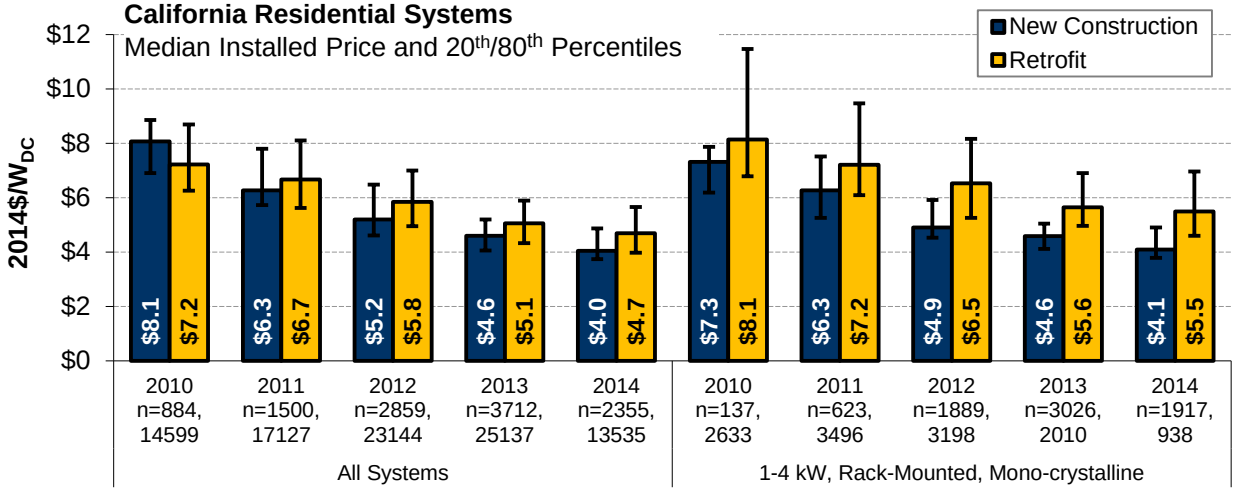
What to conclude?

- Installer size effects arise at geographical scales other than the state-level?
- Installer size effects are simply obscured by other unrelated factors?
- Installer size effects are offset by countervailing factors (e.g., higher customer acquisition costs for high-volume installers)?

Residential New Construction Offers Significant Installed Price Advantages Compared to Retrofit

- PV systems installed in new construction tend to be small and have high incidence of premium modules (top chart)
- Nevertheless, residential new construction systems in CA were $0.7/W less than retrofits in 2014 (bottom chart)
- Price advantage is even greater if comparing 1-4 kW systems with mono-crystalline modules
- Illustrates economies of scale and scope in new construction (particularly for large housing developments)

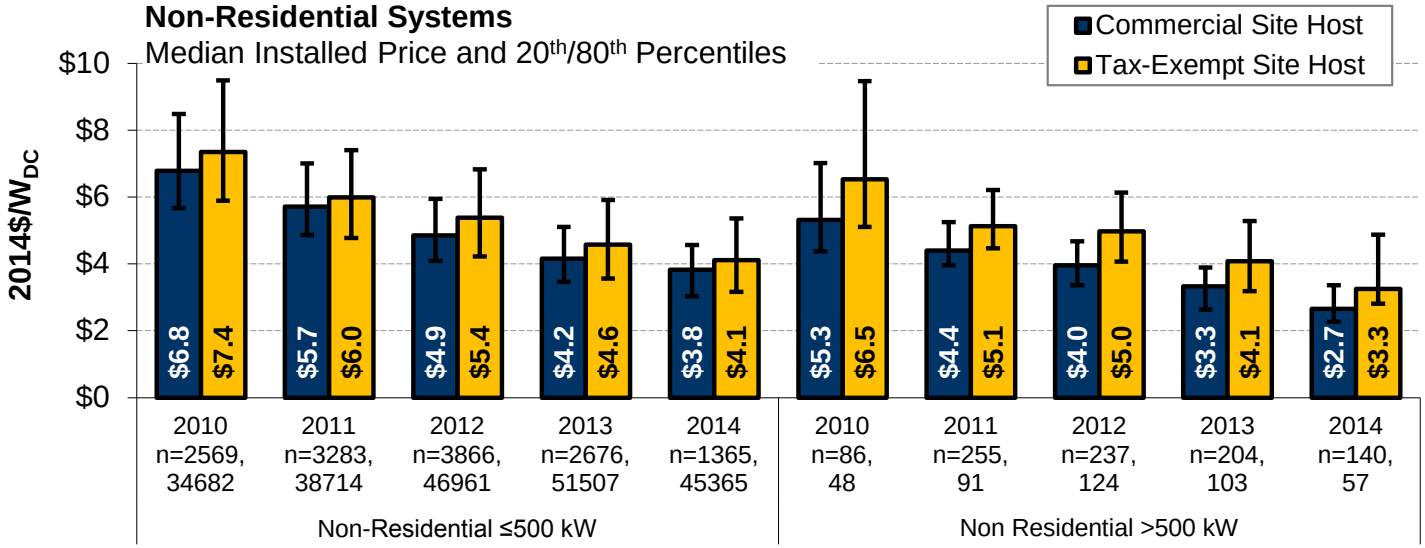




Installed Prices Are Higher for Systems at Tax-Exempt Customer Sites than at For-Profit Commercial Sites

Tax-exempt customers

- Schools, government facilities, non-profits, religious organizations
- Represent 10% of non-res. systems ≤500 kW and 30% of non-res. systems >500 kW in sample

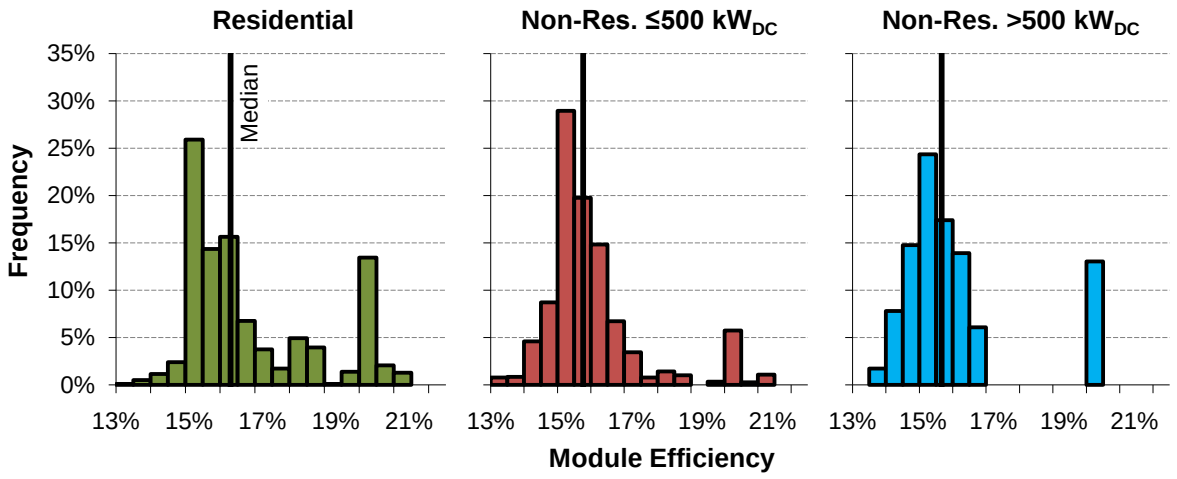


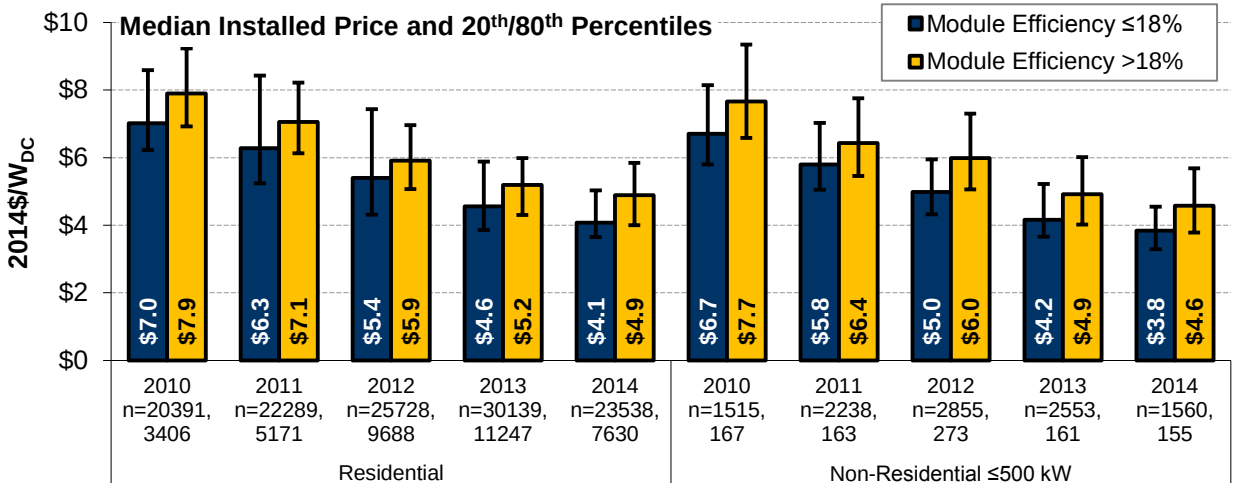
Compared to systems installed at for-profit commercial sites

- Median prices at tax-exempt sites in 2014 were $0.3/W higher for systems ≤500 kW and $0.6/W for systems >500 kW
- May reflect potentially lower negotiating power, more onerous permitting and procurement, and higher incidence of prevailing wage/union labor requirements, domestically manufactured components, and shade or parking structures

Installed Prices Are Substantially Higher for Systems with High-Efficiency Modules

- Roughly one-quarter of 2014 systems in the sample have module efficiencies >18% (top chart)
- Systems with >18% efficiency modules had a median installed price $0.8/W higher than systems with mid/low-efficiency modules in 2014
- Cost premium for high-efficiency modules appears to outweigh associated reduction in BOS costs (though tradeoffs between module technologies entail a broader set of considerations)

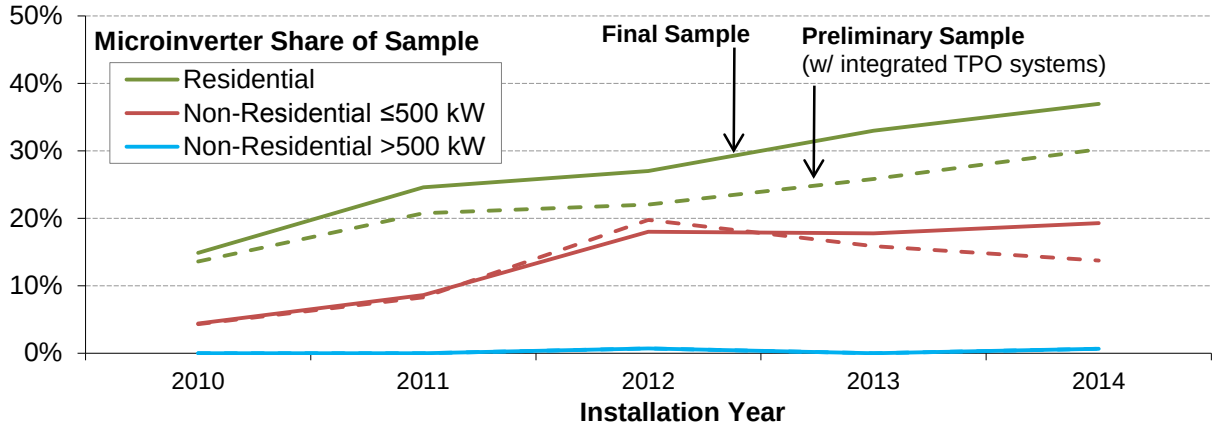


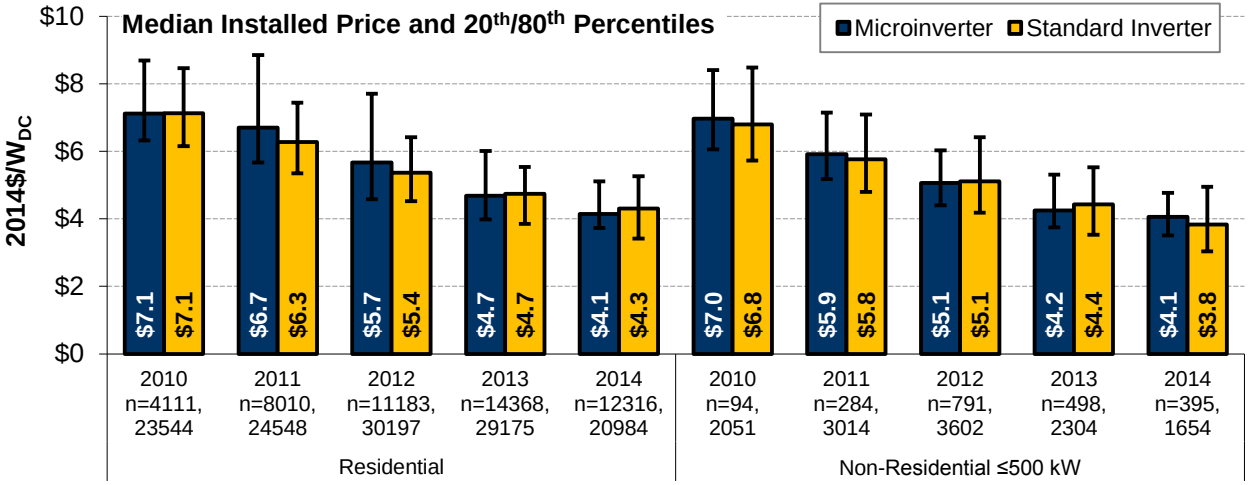


Notes: Module efficiencies were identified or estimated for the roughly 70% of systems in the 2014 sample for which data on module manufacturer and model were available.

Microinverters Have an Apparently Small Effect on Installed Prices

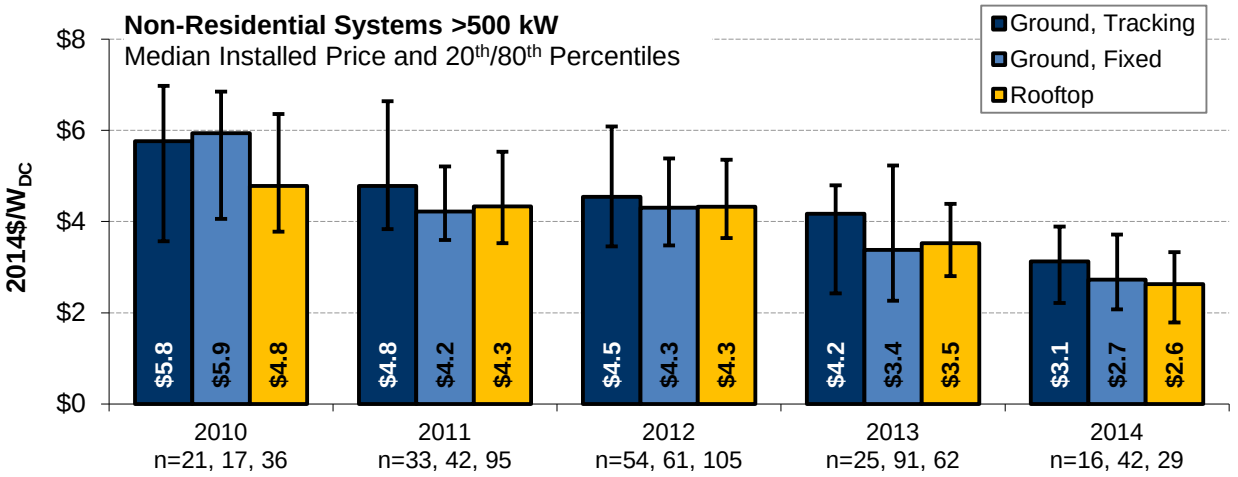
- Penetration of microinverters has grown substantially for residential and smaller non-residential systems (top chart)
- Microinverters cost roughly $0.3/W more than standard inverters in 2014 (GTM Research and SEIA 2015)
- Differential in total system prices has generally been smaller, though size and directionality varies over time (bottom chart)
- Microinverters may offer some offsetting reductions in other BOS and soft costs





Installed Prices for Large Non-Residential Systems Vary with Use of Tracking Equipment

- A relatively high percentage of large (>500 kW) non-residential systems in the data sample are ground-mounted (70% in 2014), often with tracking (20% in 2014)
- As expected, systems with tracking have higher installed prices than those without



Notes: The figure is derived from the relatively small subsample of systems for which data were available indicating whether the system is roof- or ground-mounted, and whether or not it has tracking.

- Among 2014 systems, the installed price premium for those with tracking was $0.4/W (15%) compared to fixed-tilt, ground-mounted systems and $0.5/W (19%) compared to roof-mounted (though small sample sizes can lead to erratic results)
- Installed price premium is on par with performance improvement from tracking (e.g., 12-25% increase in generation, per Drury et al. 2013)

Outline

- Data Sources, Methods, and Sample Description
- Historical Trends in Median Installed Prices
- Variation in Installed Prices
- **Conclusions**

Conclusions

- PV installed prices declined substantially from 1998 through 2014 (and into 2015), but the pace and source of those reductions have varied over time
- Dramatic declines in module prices from 2008 to 2012 were the driving force behind reductions in installed system prices over that period, but module prices have since flattened (or risen slightly)
- The continued decline in installed prices is attributable to steady reductions in non-module costs and suggests that recent efforts by industry and policymakers to target soft costs have begun to bear fruit
- Lower installed prices in other major national PV markets and within some U.S. states, as well as the high degree of variability in U.S. system pricing, suggests that deeper reductions in soft costs are possible in the near term
- Achieving dramatic reductions in soft cost may accompany market scale, but also likely requires some combination of incentive policy designs that provide a stable and straightforward value proposition, targeted policies aimed at specific soft costs, and basic and applied research and development

For more information

Download the report along with the companion briefing and data file:

trackingthesun.lbl.gov

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