Tracking the Sun VIII

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

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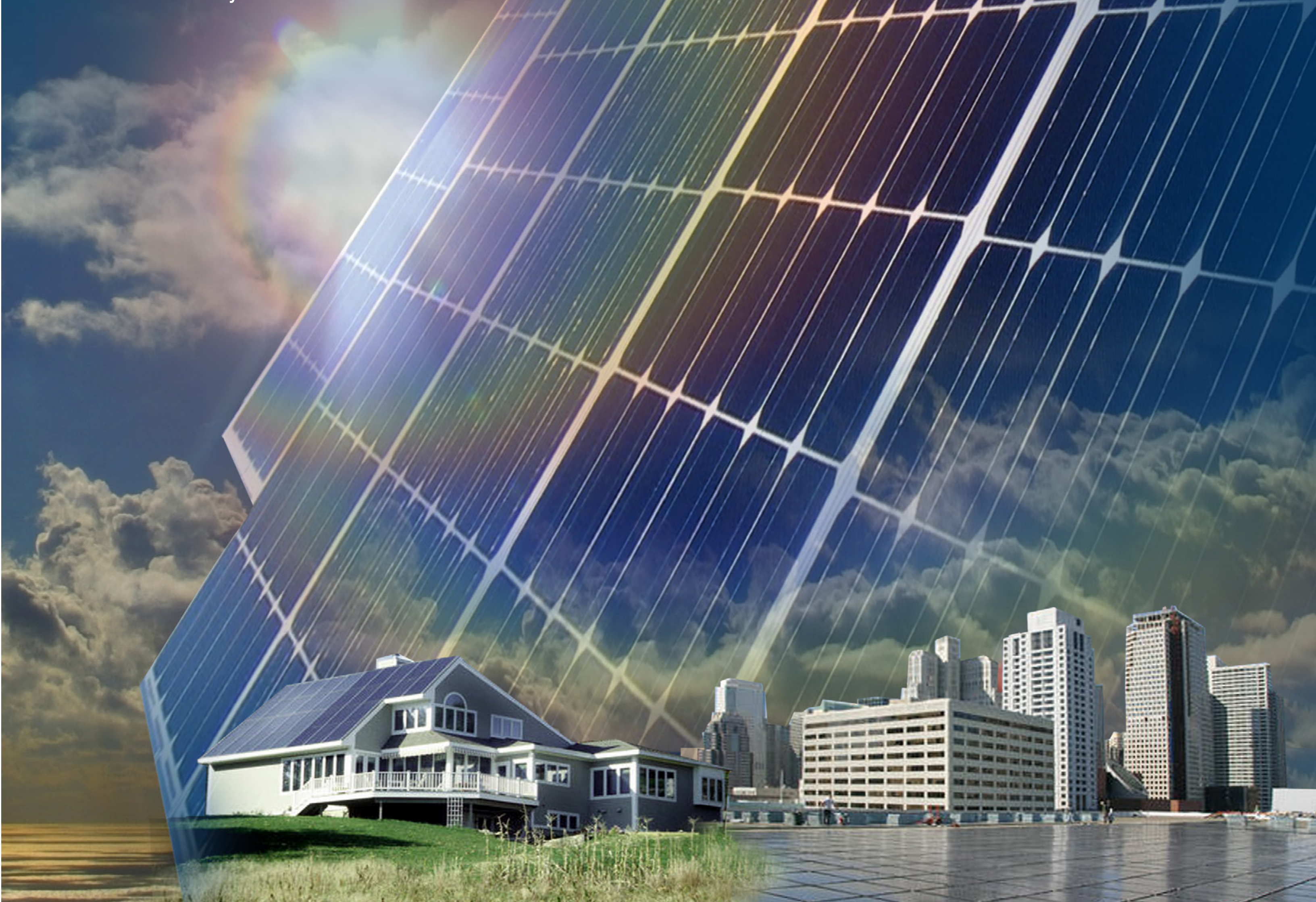

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Executive Summary

Now in its eighth edition, Lawrence Berkeley National Laboratory (LBNL)'s *Tracking the Sun* report series is dedicated to summarizing trends in the installed price of grid-connected solar photovoltaic (PV) systems in the United States. The present report focuses on residential and non-residential systems installed through year-end 2014, with preliminary trends for the first half of 2015. As noted in the text box below, this year's report incorporates a number of important changes and enhancements. Among those changes, this year's report focuses solely on residential and non-residential PV systems; data on utility-scale PV are reported in LBNL's companion *Utility-Scale Solar* report series.

Installed pricing trends presented within this report derive primarily from project-level data reported to state agencies and utilities that administer PV incentive programs, solar renewable energy credit (SREC) registration systems, or interconnection processes. In total, data were collected for roughly 400,000 individual PV systems, representing 81% of all U.S. residential and non-residential PV capacity installed through 2014 and 62% of capacity installed in 2014, though a smaller subset of this data were used in analysis.[1]

Important to note is that the data analyzed within this report:

- Represent the up-front price paid by the PV system owner, prior to receipt of incentives
- Are self-reported data provided by PV installers to program administrators
- Differ from the underlying cost borne by the developer and installer
- Are historical and therefore may not be indicative of prices for systems installed more recently or prices currently being quoted for prospective projects
- Exclude third-party owned (TPO) systems for which reported installed prices represent appraised values, but include TPO systems for which reported prices represent the sale price between an installation contractor and customer finance provider (see Text Box 2 within the main body of the report for further details)

What's New in *Tracking the Sun*

Focus on Residential and Non-Residential PV. Prior editions of the report have included installed pricing trends for utility-scale PV. Starting with this year's edition, the report now focuses exclusively on the residential and non-residential markets. Installed pricing data and other market data for the utility-scale sector are published in LBNL's companion *Utility-Scale Solar* annual report series.

Expanded Data Sources. To supplement and benchmark the primary set of installed pricing trends, the report also selectively incorporates installed price and cost data from a variety of other sources.

New Trends. This year's report includes new analyses related to system size and module efficiency trends, differences in installer-level pricing, and more details on the characteristics of PV systems in the data sample.

Key findings from this year's report are as follows, with all numerical results denoted in real 2014 dollars and DC watts:

Installed Prices Continued their Rapid Descent through 2014 and into 2015. National median installed prices in 2014 declined year-over-year 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

[1] The sample coverage for 2014 installations is temporarily eroded as California transitions its solar data collection from the California Solar Initiative program to the utilities' net metering and interconnection processes.

kW. Preliminary data for the first half of 2015 indicate that installed price declines have persisted into 2015 and are on pace to match those witnessed in recent years.

Recent Installed Price Reductions Have Been Driven Primarily by Declines in Soft Costs. Installed price reductions over the 2008 to 2012 period were a steep drop in global prices for PV modules. Since then, however, module prices have generally flattened, while installed prices have continued to fall as a result of a steady decline in non-module costs. From 2013 to 2014 specifically, residential non-module costs fell by $0.4/W, representing virtually the entire year-over-year decline in total installed prices. Recent non-module cost declines can be partly attributed to reductions in inverter and racking equipment costs, but are primarily associated with reductions in PV soft costs, which include such items as marketing and customer acquisition, system design, installation labor, permitting and inspection costs, and installer margins. Soft cost reductions are partly due to steady increases in system size and module efficiency, though likely also reflect a broad and sustained emphasis within the industry and among policymakers on addressing soft costs.

Installed Price Declines Have Been Partially Offset by Falling Incentives. Cash incentives (i.e., rebates and performance-based incentives) provided through state and utility PV incentive programs have fallen substantially since their peak a decade ago. Depending on the particular program, reductions in cash incentives over the long-term equate to roughly 70% to 120% of the corresponding drop in installed prices. This trend is partly a response to installed price declines and the emergence of other forms of incentives, but it has also been a deliberate strategy by program administrators to provide a long-term signal to the industry to reduce costs, and is likely among the many drivers for recent declines in solar soft costs.

National Median Installed Prices Are Relatively High Compared to Other Recent Benchmarks, Particularly for Residential and Smaller Non-Residential Systems. Across all systems in the data sample installed in 2014, the median installed price was $4.3/W for residential systems, $3.9/W for non-residential systems ≤500 kW in size, and $2.8/W for non-residential systems >500 kW. By comparison, a number of other recent benchmarks for PV system prices or costs range from $2.8/W to $4.5/W for residential systems, and from $1.7/W to $4.1/W for non-residential systems. Differences between national median prices and these other benchmarks reflect the diversity of underlying data sources, methodologies, and definitions. For example, national median prices are historical in nature, represent prices not costs, are heavily impacted by several large and relatively high-priced state markets, and in some instances may be subject to inconsistent reporting practices across installers. These national median prices presented in this report thus should not necessarily be taken as indicative of "typical" pricing in all contexts, and should not be considered equivalent to the underlying costs faced by installers.

Installed Prices in the United States Are Higher than in Most Other Major National PV Markets. Compared to median U.S. prices, installed prices reported for residential systems and non-residential systems ≤500 kW in size are substantially lower in a number of other key solar markets – most notably Germany, China, and Australia. These pricing disparities are primarily attributable to differences in soft costs.

Installed Prices Vary Widely Across Individual Projects. Although installed price distributions have generally narrowed over time, considerable pricing variability continues to persist. For example, among residential systems installed in 2014, roughly 20% of systems were priced below $3.5/W (the 20th percentile value), while 20% were priced above $5.3/W (80th percentile). Non-residential systems ≤500 kW exhibit a similar spread, while the distribution for non-residential systems >500 kW is somewhat narrower. The potential underlying causes for this variability are numerous, including differences in project characteristics, installer characteristics, and local market or regulatory conditions.

Economies of Scale Occur Among Both Residential and Non-Residential Systems. For residential systems installed in 2014, median prices for systems in the 8-10 kW range are roughly 15% lower than for smaller 2-4 kW systems. Among non-residential systems installed in 2014, median installed prices for the largest class of systems >1,000 kW in size were 36% lower than for the smallest set of non-residential systems ≤10 kW. 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, with Relatively High Prices in Some Large State Markets. For residential systems installed in 2014, median installed prices range from a low of $3.4/W in Delaware and Texas to a high of $4.8/W in New York. Some of the largest state markets – California, Massachusetts, and New York – are relatively high-priced, which tends to pull overall U.S. median prices upward; pricing in most states is below the aggregate national median price. Cross-state installed pricing differences can reflect a wide assortment of factors, including installer competition and experience, retail rates and incentive levels, project characteristics particular to each region, labor costs, sales tax, and permitting and administrative processes.

Installed Prices Reported for Third-Party Owned Systems Are Generally Similar to Those for Customer-Owned Systems. This report does not evaluate lease terms or power purchase agreement (PPA) rates for TPO systems; however, it does include data on the dollar-per-watt installed price of TPO systems that are sold by installation contractors to non-integrated customer finance providers. Although prices for these TPO systems are not perfectly comparable to purchase prices paid for customer-owned systems, median prices for the two classes of systems are, in fact, quite similar, at least when comparing nationally. Within individual states, however, median prices for TPO and customer-owned systems can differ, in some cases substantially.

Prices Vary Considerably Across Residential Installers Operating within the Same State. In examining four large residential markets (Arizona, California, Massachusetts, and New Jersey), installer-level median prices within each state differ by anywhere from $1.1/W to $1.4/W between the upper and lower 20^{th} percentiles, suggesting a substantial level of heterogeneity in pricing behavior or underlying costs. Low-priced installers in these states – e.g., 20% of installers in Arizona have median prices below $3.0/W – can serve as a benchmark for what may be achievable in terms of near-term installed price reductions within the broader market. Interestingly, however, no obvious or consistent relationship is observed between installer volume and prices – i.e., high-volume installers are not associated with lower-priced systems.

Residential New Construction Offers Significant Installed Price Advantages Compared to Retrofit Applications. Within California, systems installed in residential new construction have been consistently lower-priced than those installed on existing homes, with a median differential of $0.7/W in 2014, *despite* the significantly smaller size and higher incidence of premium efficiency modules among new construction systems. If comparing among systems of similar size and module technology, the installed price of new construction systems was $1.4/W lower than for retrofits.

Installed Prices Are Higher for Systems at Tax-Exempt Customer Sites than at For-Profit Commercial Sites. Tax-exempt site hosts include schools, government facilities, religious organizations, and non-profits, and these customers collectively represent a substantial share of the non-residential data sample. Systems at tax-exempt customer sites are consistently higher priced than similarly sized systems at for-profit commercial customer sites. In 2014, the median differential was roughly $0.3/W for systems ≤500 kW and $0.6/W for >500 kW systems. Higher prices at tax-exempt customer sites reflect potentially lower negotiating power 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 the 2014 systems in the data sample have module efficiencies greater than 18%, and installed prices for systems in this class have consistently been higher-priced than those with lower- or mid-range module efficiencies (<18%). In 2014, the median differential was roughly $0.8/W within both the residential and ≤500 kW non-residential segments. These trends suggest that the price premium for high-efficiency modules in many cases has outweighed any offsetting reduction balance-of-system (BOS) costs associated with a smaller array footprint.

Microinverters Have a Seemingly Small Effect on Installed Prices. Microinverters have made significant gains in market share in recent years, representing more than 35% of residential systems and roughly 20% of smaller (sub-500 kW) non-residential systems in the data sample installed in 2014. Microinverter costs are higher than standard string inverters, though the data suggest that the net impact on total system prices is smaller, potentially as a result of offsetting reductions in non-inverter BOS and soft costs.

Installed Prices for Large Non-Residential Systems Vary with the Use of Tracking Equipment. Many of the large non-residential systems in the data sample have tracking equipment, including roughly 20% of systems installed in 2014. The median installed price of those systems was $0.4/W (15%) higher than fixed-tilt, ground-mounted systems and $0.5/W (19%) higher than roof-mounted projects. Although these pricing differentials are based on a relatively small underlying data sample, they are generally of a similar magnitude to the increased electricity generation associated with single-axis tracking equipment.

1. Introduction

The market for solar photovoltaics (PV) in the United States has been, and continues to be, driven by incentives and other forms of policy support for solar and renewable energy. Given the relatively high historical cost of PV, a key goal of these policies has been to encourage cost reductions over time. The U.S. Department of Energy (DOE)'s SunShot Initiative seeks to reduce the cost of PV-generated electricity by 75% between 2010 and 2020, and various state and local programs have also aimed to drive down solar costs through deployment scale and targeted interventions. As public and private investments in these efforts have grown, so too has the need for comprehensive and reliable data on the cost and price of PV systems – in order to track progress towards cost reduction targets, assess the efficacy of existing programs, identify opportunities for further cost reduction, and evaluate transparency and competition within current solar markets.

To address these varied needs, Lawrence Berkeley National Laboratory (LBNL) initiated the annual *Tracking the Sun* report series to summarize historical trends in the installed price of grid-connected PV systems in the United States. The present report, the eighth in the series, describes installed price trends for projects installed from 1998 through 2014, with preliminary trends for the first half of 2015. Beginning with this year's edition, the report covers only the residential and non-residential sectors; data on utility-scale PV are reported separately in LBNL's companion *Utility-Scale Solar* report series.

The installed price trends in the present report are based primarily on project-level data collected from more than 400,000 residential and non-residential PV systems, representing roughly 81% of all residential and non-residential PV capacity installed in the United States through 2014 and comprising one of the most comprehensive and detailed sources of installed PV price data. These data are subject to a variety of quality controls, and several categories of PV systems are excluded from the final analysis. Based on the final cleaned dataset, the report describes historical installed price trends over time, and by location, market segment, and technology and application type. The report briefly compares recent PV installed prices in the United States to those in other major international markets, and describes trends in customer incentives for PV installations. The report also includes, for the first time, a summary and comparison to other data sources and benchmarks for PV system pricing and costs.

Related National Lab Research Products

Tracking the Sun is produced in conjunction with several related and ongoing research activities:

- *Utility-Scale Solar* is a separate annual report series produced by LBNL that focuses on utility-scale solar and includes trends and analysis related to project cost, performance, and pricing.
- *The Open PV Project* is an online data-visualization tool developed by the National Renewable Energy Laboratory (NREL) that incorporates data from *Tracking the Sun* and *Utility-Scale Solar*.
- *Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections* is an annual briefing produced jointly by NREL and LBNL that provides a broad overview of PV pricing trends, based on ongoing research activities at both labs.
- *In-Depth Statistical Analyses* of PV pricing data by researchers at LBNL and several academic institutions seek to further illuminate PV pricing dynamics and the underlying drivers, using more-advanced statistical techniques.

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

It is essential to note at the outset what the primary data presented within this report represent. These data derive primarily from system prices reported to state agencies and utilities that administer PV incentive programs, solar renewable energy credit (SREC) registration systems, or interconnection processes. These reported prices represent the up-front price paid for PV systems by the system owner, prior to receipt of incentives, and for a variety of reasons may differ from the underlying costs borne by the developer or installer. Furthermore, these data are, by their nature, historical, and therefore may not be indicative of prices for systems installed more recently or prices currently being quoted for prospective projects. Finally, the trends presented in this report exclude data for the subset of third-party owned (TPO) systems installed by integrated companies that perform both the installation and customer financing, as the prices reported for these systems represent appraised values, rather than transaction prices.

The remainder of the report is organized as follows. Section 2 summarizes the data sources, key methodological details, and characteristics of the data sample. Section 3 presents an overview of long-term, installed-price trends, focusing on median values drawn from the large underlying data sample. The section illustrates and discusses a number of the broad drivers for those historical installed-price trends, including reductions in module prices and reductions in non-module costs associated with increasing system sizes, increasing module efficiencies, and declining state and utility incentives. The section also compares median installed prices for systems installed in 2014 to a variety of other recent U.S. benchmarks, and to prices in other international markets. Finally, Section 4 describes the variability in installed prices within the dataset, and explores a series of specific sources of installed pricing differences across projects, including: system size, state, installer, customer-owned vs. TPO, residential new construction vs. retrofit, for-profit commercial vs. tax-exempt site host, module efficiency level, microinverter vs. standard inverter, and rooftop vs. ground-mounted with or without tracking. The appendices provide additional details on the analysis methodology and data sample. The values plotted in each figure are available in tabular form in an accompanying data file, which can be downloaded from the report publication page accessible via trackingthesun.lbl.gov.

2. Data Sources, Methods, and Sample Description

The trends presented in this report derive from data on individual residential and non-residential PV systems. This section describes the underlying data sources and the procedures used to standardize and clean the data, with further information provided in the Appendix. The section then describes the sample size over time and by market segment, comparing the data sample to the overall U.S. PV market and highlighting any significant gaps. Finally, the section summarizes several key characteristics of the data sample, including: trends in system size over time and by market segment, the geographical distribution of the sample across states, and the distribution between host customer-owned and TPO systems over time and across states.

Data Sources

The data are sourced primarily from state agencies and utilities that administer PV incentive programs, solar renewable energy credit (SREC) registration systems, or interconnection processes. Ultimately, project-level installed price data were provided by roughly 50 state and utility entities (see Table B-1 in the Appendix for a list of these organizations and associated sample sizes). A limited amount of additional project-level data for states or market segments not covered by the aforementioned set of sources were collected from the U.S. Treasury Department's Section 1603 Grant Program and other miscellaneous sources (e.g., FERC Form 1, SEC filings, company presentations, trade press articles).

The data sources for this report series have evolved over time, particularly as incentive programs in a number of states have expired. In these instances, data collection has generally transitioned to other administrative processes, such as system interconnection or SREC registration. In California, this transition is currently underway, as the state's primary incentive program reaches its end, and data collection is transferred to utilities' net metering and interconnection process. As described further below, the data sample for California is somewhat depleted during this transitional period, though it nevertheless continues to include a significant share of the California market. In Arizona, the state's largest utilities have also discontinued their PV incentive programs, but have continued to collect project-level data through their interconnection processes (though the completeness of installed pricing data has diminished somewhat). In most other significant state markets, PV incentive and SREC programs are still offered and provide a continuing source of project-level data.

Text Box 1. Customer Segment Definitions

Prior editions of the report have segmented the data primarily in terms of system size. This year's report, instead, segments the data according to whether the site host is residential or non-residential, with further distinctions by system size.

Residential*:* Includes single-family residences and, depending on the conventions of the data provider, may also include multi-family housing.

Non-Residential: Includes non-residential roof-mounted systems regardless of size, and non-residential ground-mounted systems up to 5 MW_{AC}.

Both categories consist mostly, but not exclusively, of systems installed behind the customer meter. Ground-mounted systems larger than 5 MW_{AC} are considered **utility-scale**, regardless of whether they are installed on the utility- or customer-side of the meter. Those systems are not covered within this report, but are instead addressed in LBNL's companion *Utility-Scale Solar* annual report.

Note that these customer segment definitions may differ from those used by other organizations, and therefore some care must be taken in comparisons.

Data Standardization and Cleaning

Various steps were taken to clean and standardize the raw data. First, all systems with missing data for system size or installation date, as well as any utility-scale PV systems, were removed from the raw sample. The resulting dataset is referred to hereafter as the "preliminary" data sample. These data were then cleaned by correcting text fields with obvious errors and by standardizing the spelling of installers and module and inverter manufacturers and models. To the extent possible, each PV system was then classified as building-integrated PV or rack-mounted; the module technology type and efficiency was determined; and the system was classified as using either a micro-inverter or central or string inverter. Most programs provided data on system ownership type (customer-owned vs. TPO); in cases where these data were not provided, system ownership was inferred, where possible, based on the installer name and state. Finally, all price and incentive data were converted to real 2014 dollars (2014$), and if necessary, system size data were converted to direct current (DC) nameplate capacity. Further details on these steps, as well as other elements of the data cleaning process, are described in Appendix A.

Aside from the removal of incomplete observations from the data sample, various other categories of systems were excluded from the analysis. The most significant group of excluded systems are those installed by integrated TPO providers that provide both the installation service and the customer financing, as the installed price data for these systems generally represent some form of appraised value (see Text Box 2 below). Also excluded from the analysis are systems with battery-back up, self-installed systems, systems with missing installed price data, and systems with installed prices less than $1/W or greater than $20/W (assumed to be data entry errors). The resulting dataset after these various additional exclusions is referred to hereafter as the "final" data sample, and is the basis for all trends presented in the report, unless otherwise indicated.

Text Box 2. Treatment of Third-Party Owned Systems in the Data Sample and Analysis

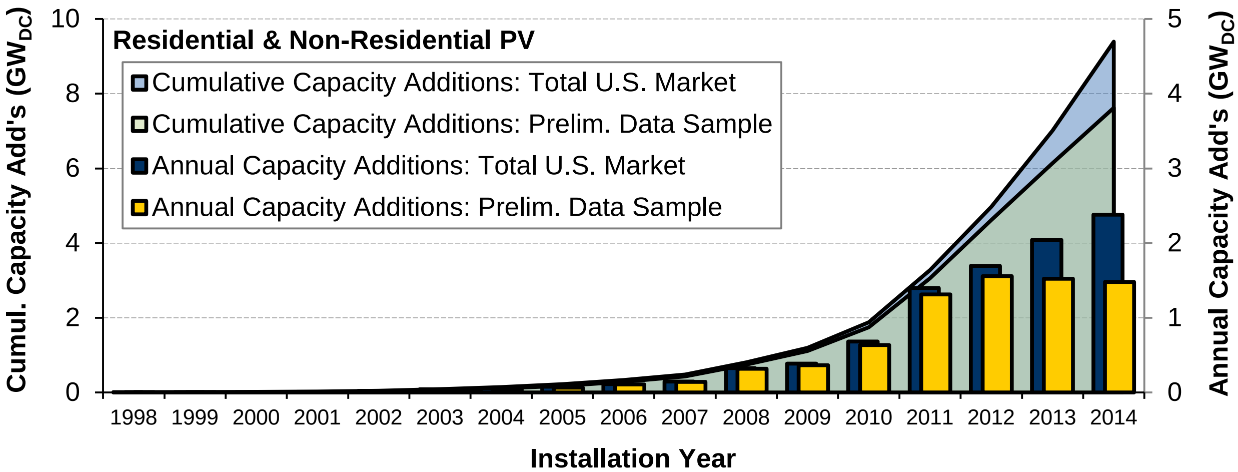
Third-party ownership of customer-sited PV systems through power purchase agreements and leases has become the dominant ownership model in many markets, and this trend has created certain complications for the tracking of installed prices. The nature of these complications, however, depends on whether the company providing the customer financing also performs the installation (i.e., an "integrated" TPO provider) or instead procures the system through an independent installation contractor.

For systems financed by integrated TPO providers, installed price data reported to PV incentive program administrators generally represent appraised values, as there is no sale of the PV system from which a price is established. To the extent that systems installed by integrated TPO providers could be identified, they were removed from the final data sample. Further details on the number of excluded appraised-value systems are provided below, and details on the procedure used to identify those systems are described in Appendix A, along with data on installed prices reported for those systems. Although excluded from the installed price trends presented in this report, we do summarize installed cost data from the financial reports of several integrated TPO providers in Figure 13, as a point of comparison.

In contrast, systems financed by non-integrated TPO providers were retained in the data sample. The installed price data reported for these systems represent an actual transaction price: namely, the price paid to the installation contractor by the customer finance provider. That said, differences may nevertheless exist between these prices and those reported for customer-owned systems. Later sections compare installed prices reported for non-integrated TPO systems and customer-owned systems, in order to discern whether those differences are potentially significant.

Sample Size

The preliminary data sample consists of more than 400,000 individual residential and non-residential systems totaling 7,600 MW, including roughly 1,500 MW installed in 2014. This represents 81% of all residential and non-residential PV capacity installed in the United States through 2014 and 62% of residential and non-residential capacity additions in 2014. As shown in Figure 1, coverage declined in the latter two years of the analysis period. This is primarily due to the transitional data collection issues in California, noted previously. As a result of this temporary loss of data availability, the sample includes just over one-third of 2014 capacity additions in California. The only other gap in sample coverage is Hawaii, largely absent from the dataset owing to the fact that the state's primary incentive program (a state income tax credit) does not collect installed pricing data from participating systems. Coverage for most other major state markets is relatively complete.[2]



Notes: 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).

Figure 1. Comparison of Preliminary Data Sample to U.S. Residential and Non-Residential PV Market

The final data sample, following removal of integrated TPO and all other excluded systems, consists of roughly 320,000 residential and non-residential PV systems totaling 6,000 MW (see Table 1). The difference between the preliminary and final data samples is primarily due to the removal of integrated TPO systems (roughly 75,000 systems), though a relatively sizable number of self-installed systems (approximately 8,000) and systems with missing installed price data (approximately 7,500) were also excluded from the final data sample. The section below, *Distribution between Customer-Owned and TPO Systems*, provides further details on the quantity of integrated TPO systems removed from the data sample over time and by state.

[2] The gaps in sample coverage for California and Hawaii may skew the national median values downward, given that both are generally high-cost states. Within California, one might also wonder whether the omission of data from systems outside of the incentive programs could bias the median prices for California – for example, if incentives induce higher prices through value-based pricing, or if administrative costs associated with participating in the program drive up prices. The direct CSI incentives provided in 2014, however, were likely far too small to have any appreciable effect on system prices, and thus we have no specific reason to suspect that pricing for California systems in the sample significantly differs from other California systems outside the sample frame.

Table 1. Final Data Sample by Installation Year and Market Segment

Installation Year	No. of Systems				Capacity (MW_{DC})			
	Residential	Non-Res. ≤500 kW_{DC}	Non-Res. >500 kW_{DC}	*Total*	Residential	Non-Res. ≤500 kW_{DC}	Non-Res. >500 kW_{DC}	*Total*
1998	31	2	0	***33***	0.1	0.1	0.0	***0.2***
1999	180	8	0	***188***	0.6	0.3	0.0	***1***
2000	214	6	0	***220***	0.8	0.2	0.0	***1***
2001	1,312	19	0	***1,331***	4	1	0.0	***6***
2002	2,516	79	3	***2,598***	10	7	2	***19***
2003	3,407	174	6	***3,587***	15	11	5	***32***
2004	5,457	314	7	***5,778***	25	15	5	***45***
2005	5,392	474	11	***5,877***	27	30	8	***65***
2006	8,607	618	22	***9,247***	43	33	18	***94***
2007	12,370	797	34	***13,201***	63	44	27	***134***
2008	12,708	1,503	91	***14,302***	65	100	78	***243***
2009	23,450	1,853	92	***25,395***	129	94	94	***317***
2010	34,683	3,411	150	***38,244***	208	183	156	***548***
2011	38,714	4,811	400	***43,925***	239	329	551	***1,119***
2012	46,964	5,872	396	***53,232***	301	388	610	***1,299***
2013	51,507	4,067	350	***55,924***	346	259	558	***1,163***
2014	45,368	2,634	213	***48,215***	314	189	450	***954***
Total	***292,880***	***26,642***	***1,775***	***321,297***	***1,792***	***1,684***	***2,564***	***6,040***

Sample Characteristics

Characteristics of the data sample provide important context for understanding installed price trends presented in this report, and in most cases correspond reasonably well to the broader market from which the sample is drawn. Below, we highlight trends associated with three key characteristics of the data sample: the evolution of system sizes over time, the geographical distribution among states, and the distribution between customer-owned and TPO systems. Unless otherwise indicated, the trends refer to the final data sample.

System Size Trends

As shown in Figure 2, residential systems in the data sample have grown steadily in size over the analysis time frame, rising from a median size of 2.4 kW in 1998 to 6.2 kW in 2014. System sizes for the large (>500 kW) non-residential class have also risen considerably, with the median system size surpassing 1,100 kW in 2014. System sizes in this customer segment have become progressively larger with the growing prevalence of multi-MW rooftop systems and “baby ground-mount” systems in the 1-5 MW range. The class of smaller non-residential systems ≤500 kW have not followed a regular temporal trend. If anything, they’ve declined somewhat in size over time, though have generally vacillated between roughly 20 to 30 kW over the past decade. Thus, although the upper bound for this class of systems is 500 kW, the vast majority of systems in this group is considerably smaller. This set of systems is thus sometimes referred to in this report as “small” or “smaller” non-residential systems.

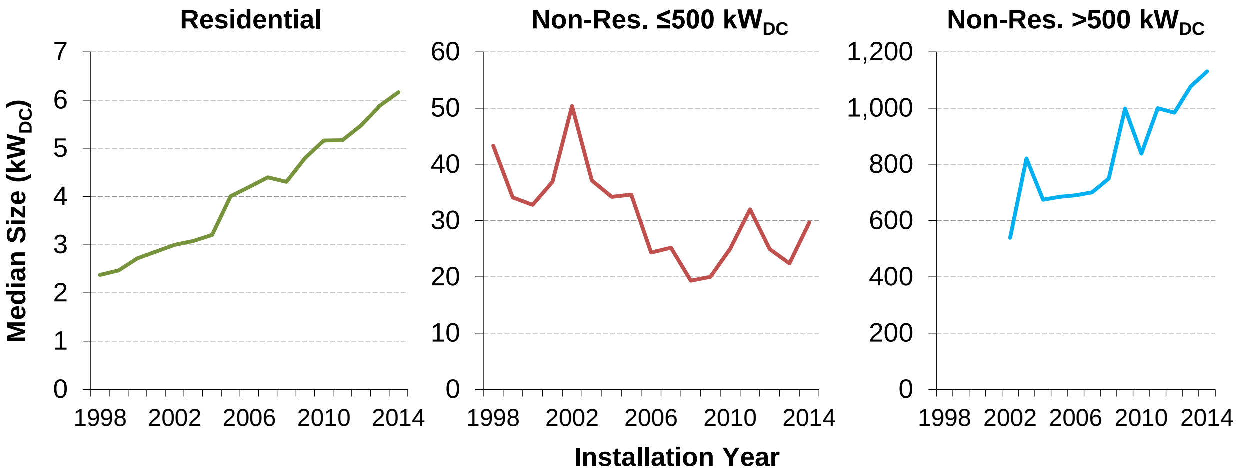


Figure 2. Median System Size over Time

Geographic Distribution

The data sample includes systems installed across 42 states. As with the broader U.S. PV market, however, the sample is concentrated in a relatively small number of state markets, though it has diversified over time. In terms of installed capacity (see Figure 3), California has historically dominated the sample, though its share has declined considerably in recent years as North Carolina and Massachusetts have emerged as significant state markets, and as data availability for California has contracted. Sample capacity additions in 2014 are distributed across California (27%), North Carolina (18%), Massachusetts (16%), New Jersey (13%), New York (8%), Arizona (7%), and all other states (12%).[3]

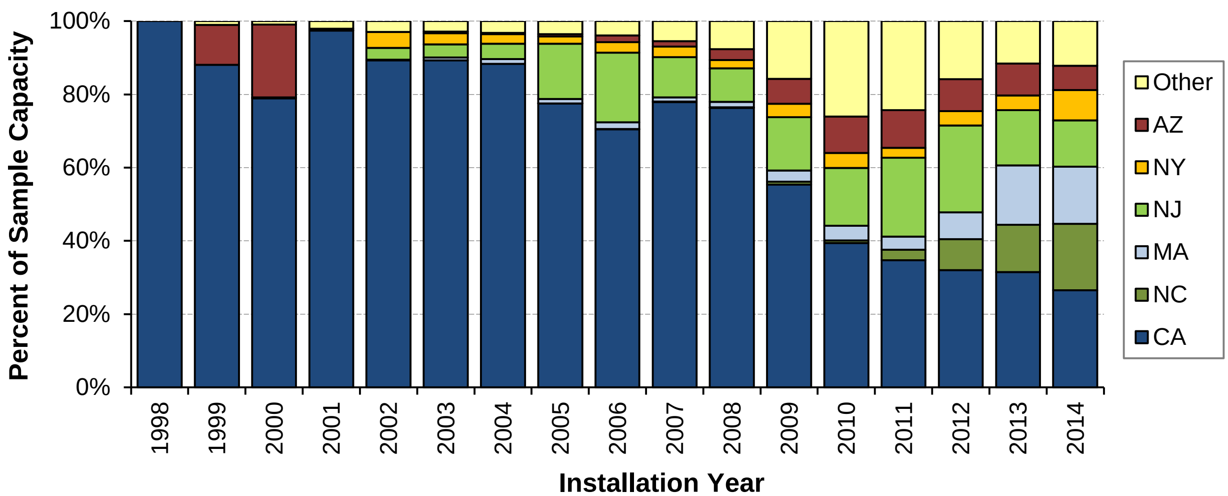


Figure 3. Sample Distribution among States (Installed Capacity)

[3] By comparison, total U.S. residential and commercial PV capacity additions in 2014, as reported by GTM Research and SEIA (2015), were distributed across states in the following shares: California (41%), North Carolina (<1%), Massachusetts (13%), New Jersey (7%), New York (6%), Arizona (6%), and all other states (27%). These state-shares differ from the sample distribution, due partly to incomplete sample coverage and partly to differences in how the non-residential and utility-scale sectors are defined. The definitional differences are most acute for North Carolina, where most of the capacity classified as non-residential in this report is installed on the utility-side of the meter, and therefore is classified by GTM Research and SEIA (2015) as utility-scale.

The geographic mix of the data sample varies across customer segments, as shown in Figure 4, again, mirroring trends within the broader market. For example, California has remained most dominant within the residential sector, though it constitutes a large share of the non-residential sample as well. North Carolina's prominence in the data sample, on the other hand, is limited largely to the class of non-residential systems >500 kW. To a lesser extent, several other states also tend to be concentrated within particular segments (e.g., Arizona in the residential segment and New York in the residential and ≤500 kW non-residential segments). Also worth noting is that the sample of >500 kW non-residential systems has the least amount of geographic diversity among the three segments, with almost 90% of 2014 systems concentrated in four states (California, New Jersey, North Carolina, and Massachusetts), albeit with a fairly even split among those states.

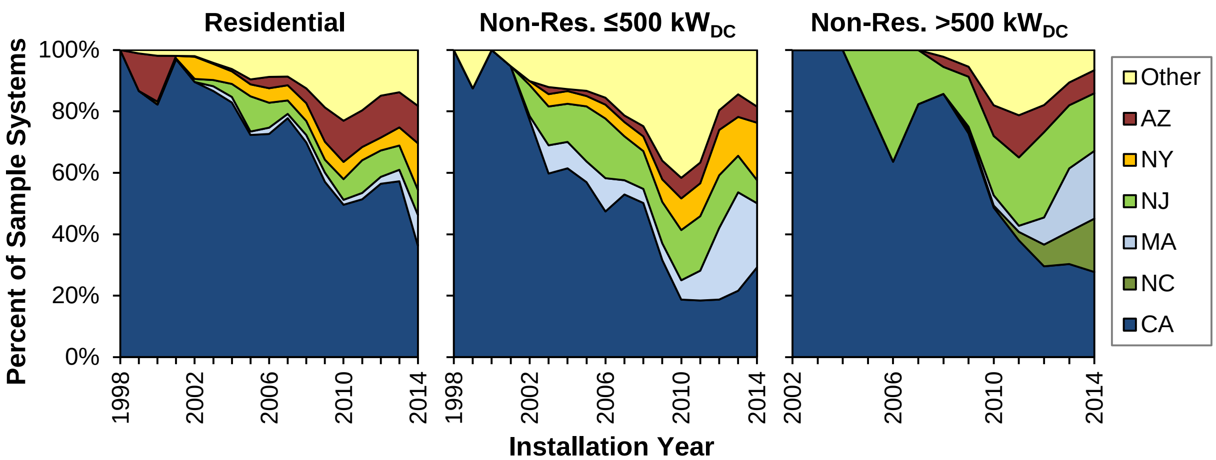


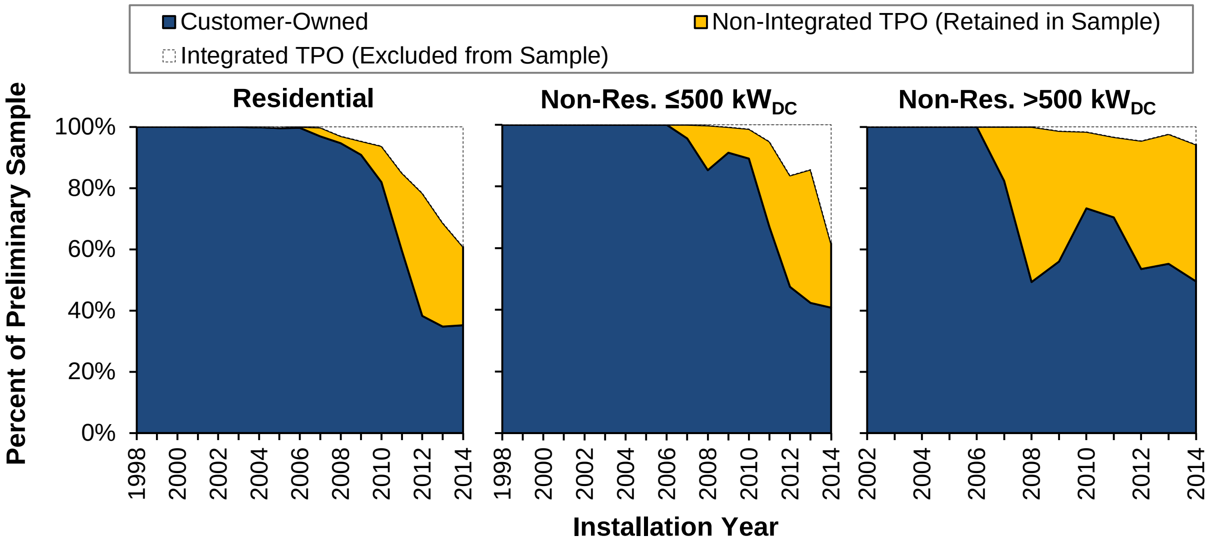
Figure 4. Sample Distribution among States (Number of Systems)

Distribution between Customer-Owned and TPO Systems

The composition of the data sample reflects the rapid growth of third-party ownership. This is shown in Figure 5, which includes the integrated TPO systems otherwise excluded from our data sample, along with the retained TPO and customer-owned systems. Within the residential sample, the percentage of systems that are TPO increased dramatically from 2007 up until 2012, reaching roughly 65% of the sample, and remained at that level through 2014.[4] The percentage of systems associated with integrated TPO providers, however, has continued to grow even after 2012, as those companies have taken over larger shares of the residential market. This growth in the market share of integrated TPO systems has thus eroded the sample frame, given that those systems are excluded from the core analysis.

Similar trends also apply to the class of sub-500 kW non-residential systems, with roughly 55% to 60% of the raw data sample consisting of TPO systems over the past several years, but a growing share of integrated TPO systems. The trends for large non-residential systems >500 kW, however, differ in several important respects. First, significant TPO shares extend much further back in time than for the other two customer segments, but have plateaued at a somewhat lower level. Second, integrated TPO systems constitute a negligible fraction of the raw sample; thus, relatively few such systems were screened out of the data sample for the large non-residential segment.

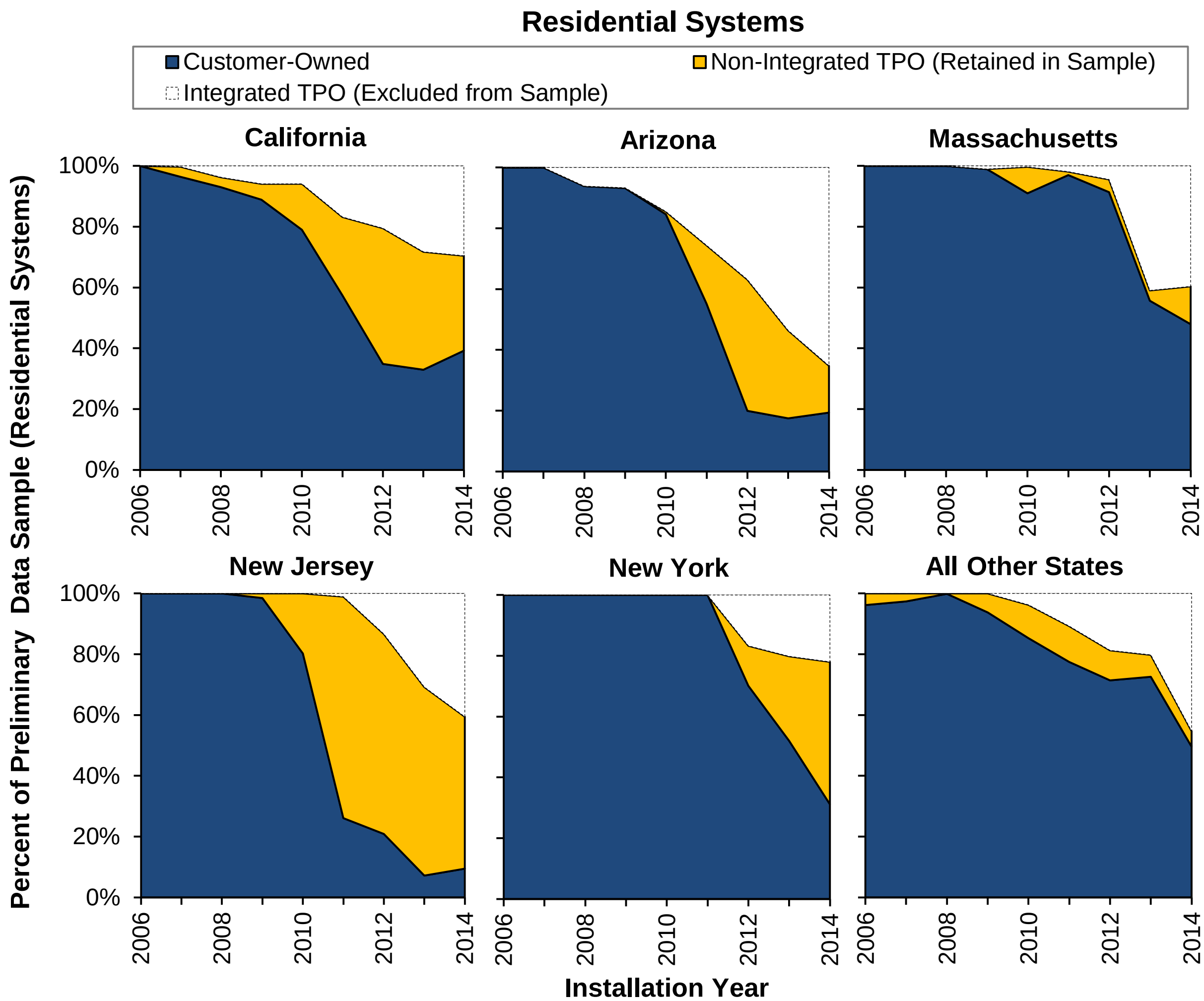
[4] The TPO percentage in the raw data sample is consistent with the broader U.S. market, where TPO share of the residential market, nationally, was 62% in 2012, 67% in 2013, and 72% in 2014 (GTM Research 2015c).



Notes: The figure is based on only those systems for which ownership model is known or can be readily inferred.

Figure 5. Distribution in Preliminary Data Sample between Customer-Owned and TPO Systems

The distribution of system ownership models can vary significantly by state, as shown in Figure 6, which focuses on the residential sample from 2006 onward. The figure helps to illustrate, first, which states may be most impacted by the removal of integrated TPO systems from the final sample. Of the five states highlighted – the five largest state residential markets in the data sample – Arizona is clearly the most impacted in this respect, though all are affected to some degree. The figure also illustrates the relative balance between TPO and customer-owned systems within the final data sample, following the removal of integrated TPO systems. For California, Arizona, and New York, the final samples of 2014 residential installations are, roughly speaking, evenly split between TPO and customer-owned. In contrast, the final sample for Massachusetts is almost entirely customer-owned, while for New Jersey, it is almost entirely TPO. Outside of these five states, TPO concentrations are generally lower, but consist primarily of integrated TPO systems, resulting in a final data sample consisting primarily of customer-owned systems.



Notes: The figure is based on only those systems for which ownership model is known or can be readily inferred. For several states, data on ownership model is quite incomplete for some earlier years, including: Massachusetts (2009-2010), New Jersey (2009-2011), and New York (pre-2011).

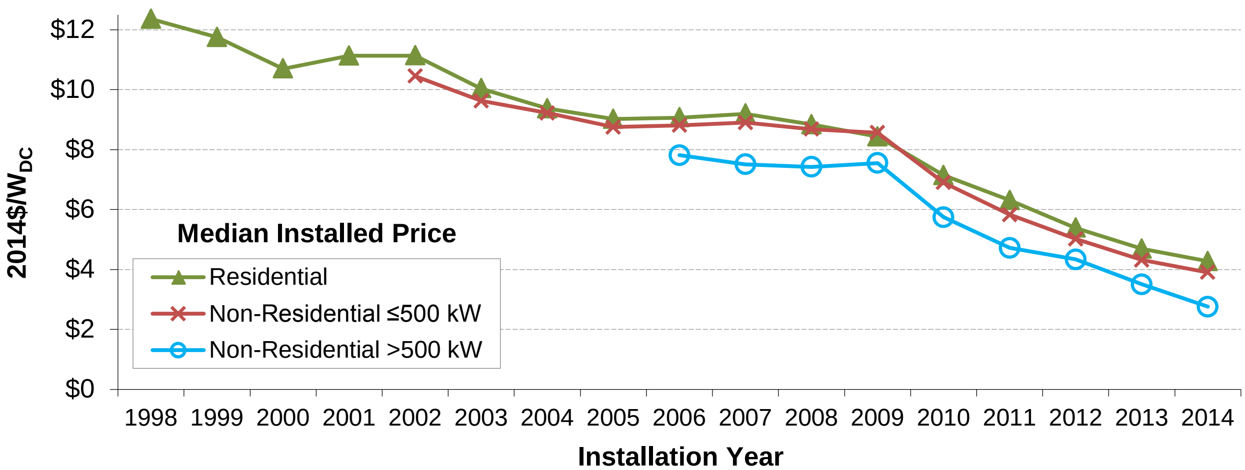
Figure 6. Distribution in Preliminary Data Sample between Customer-Owned and TPO Residential Systems

3. Historical Trends in Median Installed Prices

This section presents an overview of long-term historical trends in the installed price of residential and non-residential PV, focusing throughout on *median values* derived from the large underlying data sample. It begins by describing the installed price trajectory over the full historical period of the data sample (1998-2014), along with preliminary data for the first half of 2015. The section then discusses a number of the broad drivers for those historical trends, including reductions in module prices and reductions in non-module costs associated with increasing system sizes, increasing module efficiencies, and declining state and utility incentives. It then compares median installed prices for systems installed in 2014 to a variety of other recent benchmarks for the installed price or cost of PV, and finally compares installed prices between the United States and other international markets.

Long-Term Installed Price Trends

Figure 7 presents trends in median installed prices from 1998 through 2014, according to the date of system installation. Over the duration of the available time series data, median installed prices declined by 6% to 12% per year, on average, depending on the customer segment. Those declines, however, have not occurred at a steady pace. In particular, installed prices fell until 2005, but then stagnated through 2009, while surging global demand strained PV supply chains. Starting in 2009, installed prices resumed their descent and have fallen steeply and steadily since, with average annual declines of 13% to 18% per year across the three customer segments. As discussed in a later section, these recent price declines are the result of reductions in global PV module prices, as well as declines in other hardware costs and "soft" costs. Within the last year of the analysis period, from 2013 to 2014, median installed prices fell 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.

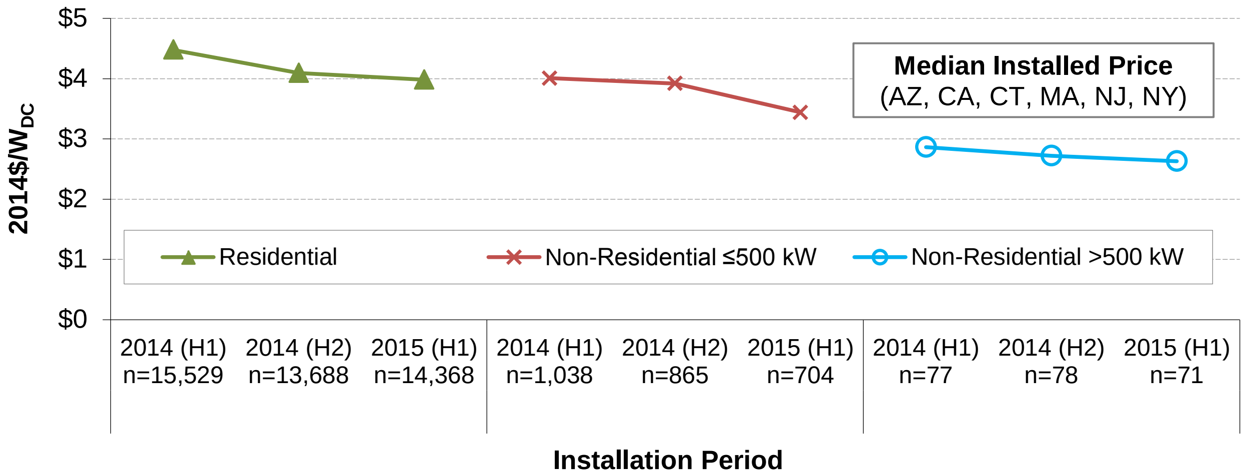


Notes: See Table 1 for sample sizes by installation year. Median installed prices are shown only if 20 or more observations are available for a given year and customer segment.

Figure 7. Median Installed Price Trends over Time

Preliminary data for the first half of 2015 (see Figure 8) indicate that installed prices have continued to decline beyond 2014. The figure is based on data from a subset of PV incentive programs and states covered elsewhere in this report (including most of the larger state markets).

Compared to 2014, median installed prices in the first half of 2015 fell by an additional $0.3/W (8%) for residential systems, $0.5/W (13%) for non-residential systems ≤500 kW, and $0.2/W (6%) for non-residential systems >500 kW. Although the data should be considered provisional – both because they are drawn from a limited pool of programs and because they may be impacted by seasonal trends – they suggest that installed price declines in 2015 are on pace to match those witnessed in recent years. As discussed further in the next section, however, the prospect for continued price declines in the latter half of 2015 (and beyond) will depend in large measure on continued declines in solar soft costs.



Notes: The figure is based on data from only a subset of programs from the larger dataset, and therefore cannot be directly compared to Figure 7.

Figure 8. Installed Prices for Systems Installed in 2014 and the First Half of 2015

Module and Non-Module Cost Reductions

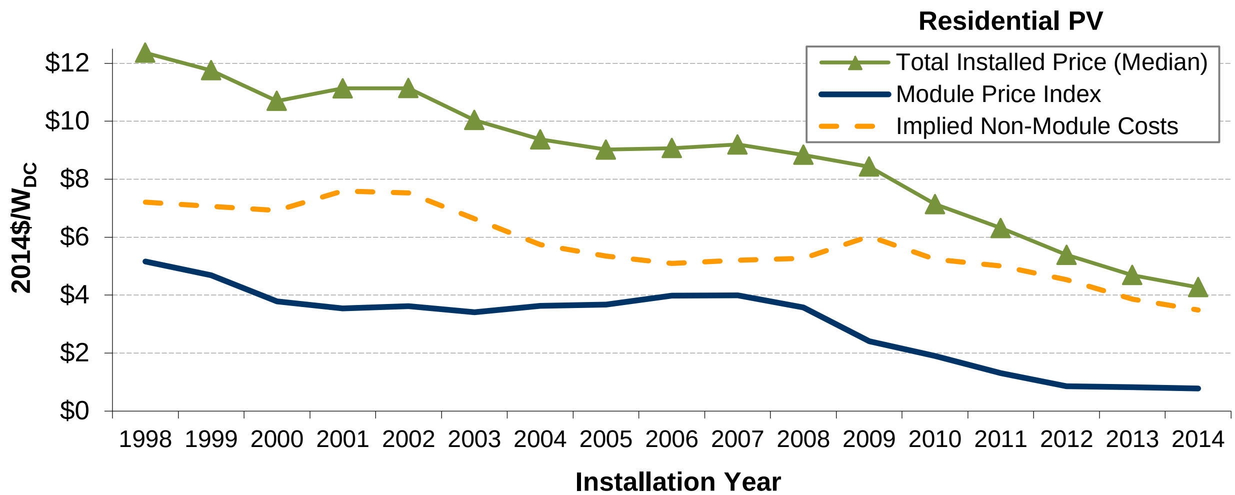
Over the long-term, installed price reductions reflect a combination of declines in PV module costs as well as declines in various non-module costs, such as inverters, racking equipment, and the wide assortment of soft costs – which include such things as marketing and customer acquisition, system design, installation labor, permitting and inspection costs, and installer margins.[5] This is apparent in Figure 9, which focuses on residential systems, and shows the historical trajectory of module prices along with the aggregate set of non-module costs (calculated as the residual between the total installed price and the module price index in each year, and therefore including whatever margin installers receive). Over the entirety of the historical period shown, from 1998 to 2014, module prices fell by $4.4/W (85%) and implied non-module costs fell by $3.7/W (52%).

Recent years have seen a shift in the relative importance of module and non-module cost reductions. Following a lengthy period of little price movement, module prices began a steep descent in 2008, falling by $2.7/W in real 2014 dollars from 2008 to 2012. Over this period, module price reductions were the dominant driver for the overall decline in installed prices, constituting roughly 80% of the total drop in installed price of residential systems.[6] Since 2012, however,

[5] The line between module costs and non-module costs can become somewhat blurred, such as for modules with integrated racking and AC modules with micro-inverters.

[6] Installed prices have not moved in perfect lock-step with changes in global module prices, and in some years appear to lag behind movements in module prices. This may reflect differences in time between when installation contracts are signed and when systems are installed, excess module inventory held by installers, higher-than-normal distributor mark-

module prices have flattened considerably, but installed prices have continued to fall with the steady decline in non-module costs. Over the last year of the analysis period, from 2013 to 2014, residential non-module costs fell by $0.4/W, or 10% year-over-year, more or less continuing the pace of non-module cost declines since roughly 2009.[7]



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.

Figure 9. Installed Price, Module Price Index, and Implied Non-Module Costs over Time for Residential PV Systems

Just as non-module costs are diverse, so too are the reasons for their recent declines. In part, these declines are the result of price reductions for key (non-module) hardware components, the largest being inverters and racking equipment. Based on data from GTM Research and SEIA (2015), the annual average cost of inverters and racking for residential PV fell, from 2013 to 2014, by roughly $0.04/W for systems with string inverters, or by $0.08/W for systems with microinverters. These hardware price declines constitute roughly 10-20% of the overall reduction in implied non-module costs from 2013 to 2014.

Non-module cost reductions have also been partly driven by changes in two specific technical attributes of residential systems: namely, their increasing system size and increasing module efficiency. As noted earlier in reference to Figure 2, median residential system sizes have grown substantially over time, enabling reductions in non-module costs-per-Watt by spreading fixed project costs across a larger base of installed watts. Within the last year of the analysis period, from 2013 to 2014, the median size of residential systems grew by 0.3 kW. Based on cost modeling by Goodrich et al. (2012), this increase in system size corresponds to a roughly $0.04/W decrease in non-module costs, or 10% of the total drop in implied non-module costs from 2013 to 2014.[8]

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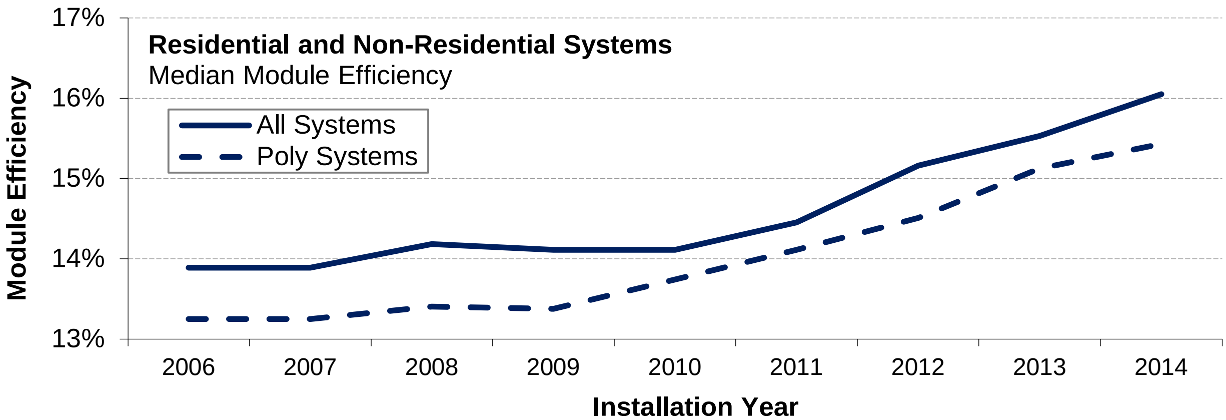
ups, variation in installer purchasing power or module technologies, and the ability of some installers to potentially retain some portion of module cost reductions as increased margin.

[7] Figure 9 suggests that Implied Non-Module Costs spiked in 2009. In fact, this apparent rise is likely just an artifact of the manner in which non-module costs are calculated and the previously noted lag between module and system prices.

[8] Goodrich et al. (2012) model installed prices over a wide range of system sizes. Based on that relationship and on their underlying module cost assumptions, we estimate the incremental change in non-module costs associated with an increase in residential system size from the median size in 2013 (5.9 kW) to the median size in 2014 (6.2 kW).

Increased module efficiencies have helped to drive non-module cost reductions, by reducing certain project costs that scale with the dimensional area of the array (e.g., the cost of mounting equipment and associated installation labor). As shown in Figure 10, median module efficiencies within the data sample rose steadily from 2010 through 2014. Within the last year of the analysis period, from 2013 to 2014, median module efficiencies increased from 15.5% to 16.0%. Relying again on the modeled PV cost relationships developed by Goodrich et al. (2012), this increase in module efficiency equates to a roughly $0.06/W reduction in non-module costs, representing 15% of the total drop in implied non-module costs over the corresponding period.



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.

Figure 10. Module Efficiency Trends over Time within the Project Data Sample

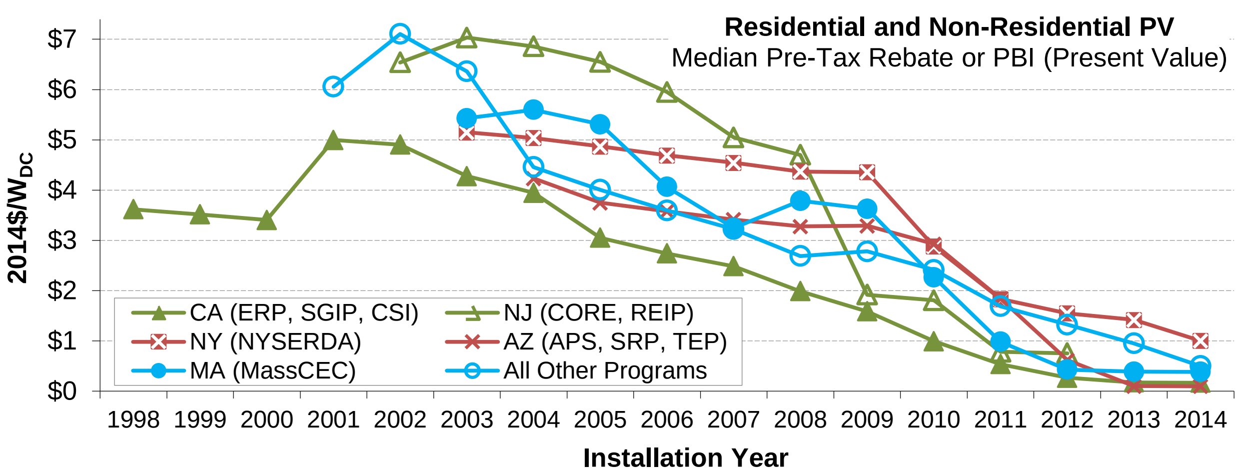
Increased system sizes and module efficiency serve to reduce both hardware and soft costs. Given the overall drop in non-module costs, however, it is clear that the decline in soft costs is much greater than what could be attributed to those technical factors alone. In particular, recent years have seen a significant shift of emphasis within the industry and among policymakers toward developing a wide assortment of strategies for targeting soft costs. Although it is beyond the scope of this report to evaluate the efficacy of those varied efforts, one might reasonably presume that this broad and sustained focus has played an important role in driving recent soft cost reductions. Also, as discussed in the next section, many states have continued to ramp down financial incentives for PV, applying sustained pressure on installers and others in the supply chain to streamline their business processes and reducing opportunities for value-based pricing.

Finally, it should be noted that recent reductions in non-module costs have occurred despite several countervailing cost drivers. First, residential loan products have become more prevalent in recent years, and origination fees associated with these loans are likely embedded in installed prices paid by system owners. Although data on the cost of these products is generally not publicly available, anecdotal sources report origination fees in the range of 5-20% of the loan amount. Based on the median installed price of residential PV in 2014, this could equate to an additional $0.2/W to $0.8/W for customer-owned systems financed through such loan products. A second source of potential upward pressure on installed prices is the increasing penetration of microinverters. Over the course of 2014, prices for microinverters averaged roughly $0.3/W higher than standard residential inverters (GTM Research and SEIA 2015), though that cost premium may be offset to some degree by indirect project cost impacts, as explored later.

State and Utility Cash Incentives

Financial incentives provided through utility, state, and federal programs have been a driving force for the PV market in the United States. For residential and non-residential PV, those incentives have – depending on the particular place and time – included some combination of cash incentives provided through state and/or utility PV programs (rebates and performance-based incentives), the federal investment tax credit (ITC), state ITCs, revenues from the sale of solar renewable energy certificates (SRECs), accelerated depreciation, and retail rate net metering.

Focusing *solely* on direct cash incentives provided in the form of rebates or performance-based incentives (PBIs), Figure 11 shows how these incentives have declined steadily and significantly over the past decade across all of the major incentive programs. At their peak, these programs were providing incentives of $5-7/W (in real 2014 dollars). By 2014, direct cash incentives were largely phased-out in many key markets – including California, Arizona, and New Jersey – and had diminished to well below $1/W elsewhere. This continued ratcheting-down of incentives is partly a response to the steady decline in the installed price of PV and the emergence of other forms of financial support (for example, SRECs, as discussed in Text Box 3). In many states, it is also a deliberate strategy intended to provide a long-term signal to the industry to reduce costs and improve installation efficiencies. Thus, in some sense, this steady decline in incentives is both a cause and an effect of the corresponding installed price reductions.



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.

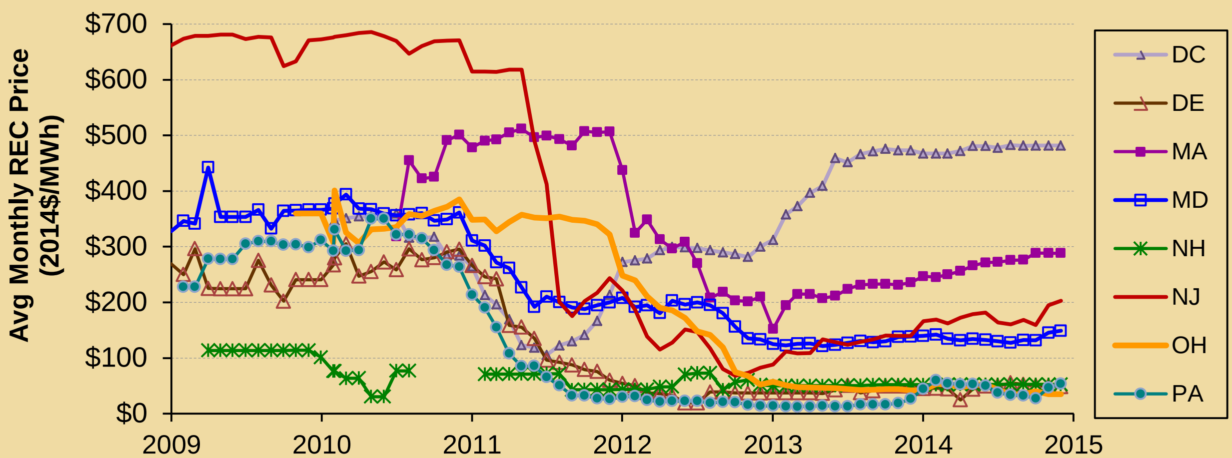
Figure 11. State/Utility Rebates and PBIs over Time

From the perspective of the customer-economics of PV, however, one thing is clear: the steady reduction in cash incentives has offset reductions in installed prices to a significant degree. Among the five markets profiled in Figure 11, the pre-tax value of cash incentives has declined by $4-7/W from each market's respective peak. This is equivalent to anywhere from roughly 70% to 120% of the drop in installed PV prices over the corresponding period of time. Of course, other forms of financial support have simultaneously become more lucrative over this period of time – for example, the increase in the federal ITC for residential solar starting in 2009 and the emergence of SREC markets – and new financing structures have allowed greater monetization of existing tax benefits. Thus, the customer economics of solar has undoubtedly improved, on balance, over the long-term, but the decline in state and utility cash incentives has nevertheless been a significant counterbalance to falling installed prices.

Text Box 3. SREC Price Trends

Eighteen states plus the District of Columbia have enacted renewables portfolio standards with either a solar or distributed generation set-aside (also known as a "carve-out"), and many of those states have established solar renewable energy certificate (SREC) markets to facilitate compliance. PV system owners in these states (and in some cases neighboring states) may sell SRECs generated by their systems, either in addition to or in lieu of direct cash incentives received from state/utility PV incentive programs. Many solar set-aside states have transitioned away from standard-offer based incentives, particularly for larger and non-residential systems, and towards SREC-based incentive mechanisms with SREC prices that vary over time.

Prior to 2011, SREC prices in most major RPS solar set-aside markets ranged from $200 to $400/MWh, topping $600/MWh in New Jersey (Figure 12). Starting around 2011, SREC supply began to outpace demand in these markets, leading to a steep drop in SREC pricing. As with the broader decline in solar incentives, this contraction in SREC pricing served as a source of further downward pressure on installed prices. Since 2013, that pressure has begun to ease in several states, as SREC prices slowly recover, though few are predicting a return to the pre-2011 pricing regime.



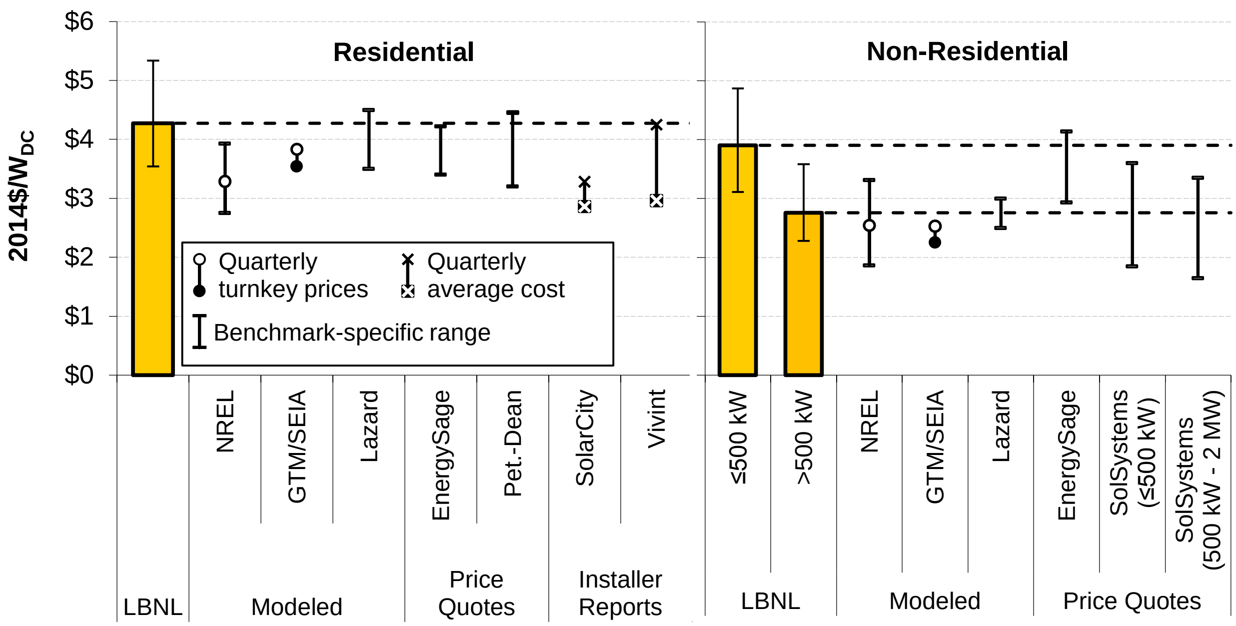
Notes: Data sourced from Marex-Spectron, SRECTrade, and Flett Exchange (data averaged across available sources). Plotted values represent SREC prices for the current or nearest future compliance year traded in each month. Data for Ohio are for in-state SRECs.

Figure 12. Monthly Average SREC Prices for Current or Nearest Future Compliance Year

Comparison of National Installed Price Data to Other Recent U.S. Benchmarks

Across the full set of systems in the dataset installed in 2014, the median installed price was $4.3/W for residential systems, $3.9/W for non-residential systems ≤500 kW in size, and $2.8/W for non-residential systems >500 kW (as shown previously in Figure 7). Importantly, these median values represent central tendencies, and considerable spread exists among the data, as will be illustrated and explained throughout much of the remainder of the report. Related, median installed prices drawn from the dataset at large are dominated by several high-cost states that constitute a large fraction of the total U.S. market (and hence the data sample). Later sections will show that prices in many other states are well below the national medians. Finally, as with any estimate or benchmark for PV system pricing, the data used in this report have their inherent limitations. Chief among these are that the data are historical and therefore do not capture more-recent trends; that the data are self-reported by installers and therefore susceptible to inconsistent reporting practices; and that the final sample excludes integrated TPO systems (which represent some of the largest U.S. installers) and has limited coverage in several key markets.

To provide a more-robust snapshot than can be offered by any single source, Figure 13 summarizes a broad, though by no means comprehensive, set of recent PV price and cost benchmarks, and compares those benchmarks to installed price statistics derived from the LBNL data sample. These other benchmarks are varied in nature and include modeled PV system prices, price quotes for prospective PV systems, and average costs reported directly by several major residential installers. A range is presented in each case, though depending on the particular benchmark, the data points bounding the range may refer either to average quarterly prices/costs or to some benchmark-specific values, as described in the detailed notes below the figure. Importantly, these various PV pricing benchmarks, including the LBNL data, each have their merits and limitations, and must be applied appropriately.



Notes: ***LBNL*** *data are the median and 20th and 80th percentile values among projects installed in 2014.* ***NREL*** *data are the median and 20th and 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 20th and 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).*

Figure 13. Comparison to Other Installed Price or Cost Benchmarks

Clearly, great variability exists both across and within the benchmark ranges summarized in Figure 13, reflecting a diversity of data, methods, and definitions. Among the non-LBNL sources, benchmarks for residential PV range from \$2.8/W to \$4.5/W. The median price of 2014 residential systems in the LBNL dataset falls within, though is near the upper end of, that broad range, and is notably higher than several other frequently cited sources. For non-residential systems, the non-LBNL benchmarks span a particularly wide range from \$1.7/W to \$4.1/W. The LBNL data for large non-residential systems >500 kW fall squarely within that broader benchmark range, while the median price for sub-500 kW non-residential systems is near the upper end (or well above) most of the other non-residential benchmarks.

Deviations among these benchmarks arise for a number of general reasons, and in many cases help to explain why median values drawn from the LBNL data sample for residential and smaller non-residential systems are higher than some of the other benchmarks:

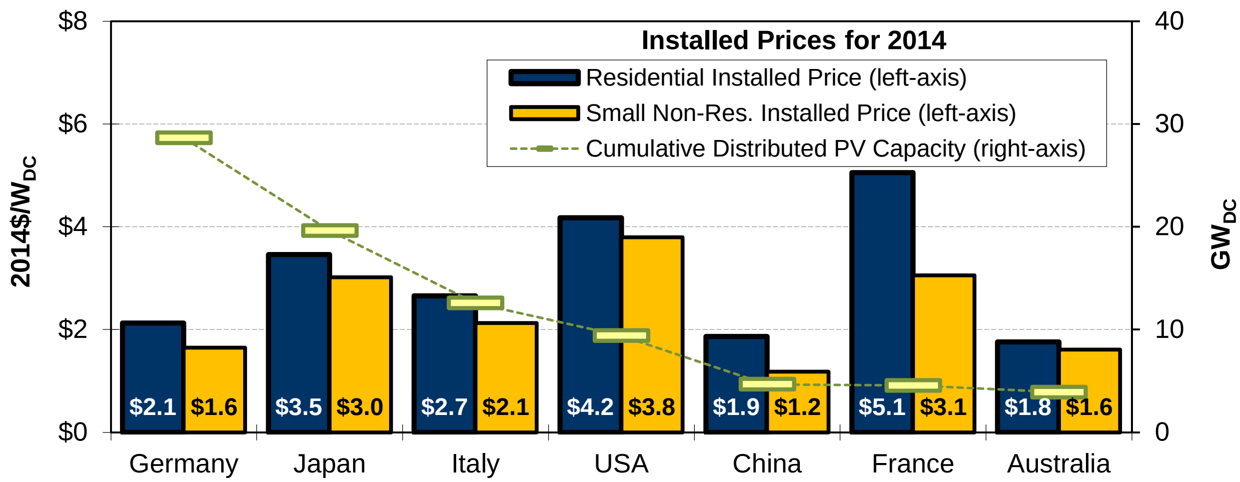
- *Timing*: The LBNL data in Figure 13 are based on systems installed over the course of 2014. A number of the other benchmarks cited in the figure are instead based on systems installed in Q4 2014, while others are based on price quotes, which may precede installation by several months to a year or more (for larger non-residential projects). These differences in timing can be significant given the rapid pace of cost and price declines within the industry.
- *Price versus cost:* The LBNL data represent reported prices paid to installers or project developers. Several of the other published benchmarks – in particular, the data points drawn from SolarCity's and Vivint's publicly-available financial reports – represent costs borne by these companies, which may differ, for a variety of reasons, from the prices ultimately paid by PV system owners.
- *Value-based pricing*: Benchmarks may reflect developer/installer margins based on some minimally sustainable level, as may occur in highly competitive markets. In contrast, the market price data assembled for this report are based on whatever profit margin developers are able to capture or willing to accept, which may exceed a theoretically competitive level in markets with high incentives and/or barriers to entry.
- *Location:* As noted earlier, statistics derived from the LBNL dataset are dominated by several high-cost states that constitute a large fraction of the sample (and of the broader U.S. market). Other benchmarks may instead be representative of lower-cost or lower-priced locations.
- *System size and components*: A number of the benchmarks in Figure 13 are based on turnkey project designs and prototypical system sizes. The LBNL data instead reflect the specific sizes and components of projects in the sample. For example, roughly 30% of 2014 systems in the sample have high efficiency modules, microinverters, or tracking equipment, and most of the non-residential systems in the ≤500 kW class are, in fact, smaller than 30 kW.
- *Scope of costs included*: The set of cost components embedded in the installed price data collected for this report undoubtedly varies across projects, and in some cases may include items such as re-roofing costs or loan origination fees that typically would not be included in other benchmarks for PV pricing or costs (though, from the customer's perspective, are part of the price of "going solar").
- *Installer characteristics*: Finally, the LBNL data reflect the characteristics and reporting conventions of the particular installers in the sample, many of which are relatively small or regional. Moreover, by virtue of excluding appraised value systems, the LBNL dataset excludes

several of the largest U.S. residential installers. The other benchmarks in Figure 13 may, in many cases, be reflective of relatively large and experienced installers.

The above discussion highlights and seeks to explain differences between LBNL's installed price data and other recent PV price or cost benchmarks. Much of the remaining analysis in this report, however, will show how these differences may be less significant than they first appear. Later analyses will show, for example, that pricing in many states and by many installers is well below the median values (or even below the 20th percentile values) shown in Figure 13 and aligns well with even the lowest of the other benchmarks shown. The national median installed prices in Figure 13 therefore should not necessarily be taken as indicative of "typical" pricing in all contexts.

Comparison of U.S. Median Installed Prices to Other International Markets

Notwithstanding the significant installed price reductions that have already occurred in the United States, international experience suggests that greater near-term reductions are possible. Figure 14 compares median installed prices for residential and sub-500 kW non-residential systems installed in the United States in 2014 to system prices for a number of other major national markets. To be sure, these data are not perfectly comparable to one another. Perhaps most importantly, U.S. prices are based on median values, while prices for other countries refer to "turnkey" systems, as reported by each country in its annual National Survey Report to the International Energy Agency's Photovoltaic Power Systems Programme.[9] Nevertheless, even considering the broader set of U.S. benchmarks presented in the previous section, the data suggest that U.S. installed prices are high compared to many other major markets, particularly with respect to Germany, China, and Australia.



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).

Figure 14. Comparison of Installed Prices in 2014 across National Markets (Pre-Sales Tax/VAT)

Other than the potential impacts of import duties, modules and other hardware items are similarly priced across countries. It therefore stands to reason that differences across countries in total system prices can be attributed primarily to differences in soft costs. Indeed, installer surveys

[9] In addition, although limited information is available about underlying data sources, it is reasonable to presume that some significant differences in data quality may exist across the system prices in each country report.

in Germany, Australia, and Japan have confirmed that soft costs in those countries, across all major soft cost elements, are substantially lower than in the United States (Seel et al. 2014, Ardani et al. 2012, Friedman et al. 2014, RMI and GTRI 2014). Several time-and-motion studies have further homed in on installation costs, identifying specific aspects of installation practices in Germany and Australia that enable lower labor costs in those countries than in the United States (RMI and GTRI 2013, 2014).

At a high-level, differences in soft costs between countries may be attributable partly to differences in market size, on the theory that larger markets facilitate cost reductions through learning-by-doing and economies of scale that enable reductions across the broad swath of soft cost elements. Indeed, as shown in Figure 14, cumulative distributed PV capacity in several of the lower-priced national PV markets (Germany, Japan, and Italy) is greater than in the United States. That said, China and Australia – also relatively low-priced compared to the United States – have much smaller distributed PV markets in absolute terms (though China has a larger base of installed capacity if utility-scale is included, and Australia has a larger distributed PV market on a per-capita basis). It is therefore clear that other factors, beyond absolute market size, contribute to installed price differences across countries. These may include things such as differences in: incentive levels and incentive design, solar industry business models, demographics and customer awareness, building architecture, systems sizing and design, interconnection standards, labor wages, and permitting and interconnection processes.

4. Variation in Installed Prices

While the preceding section focused on trends in median installed prices drawn from the dataset as a whole, this section instead highlights the substantial *variability* in installed prices and explores drivers for pricing differences across projects. The section begins by describing the distribution in installed prices across the dataset as a whole, and how that distribution has evolved over time. It then examines a series of specific sources of installed pricing differences across projects, including differences in: system size, state, installer, customer-owned vs. TPO, residential new construction vs. retrofit, tax-exempt vs. for-profit commercial site hosts, module efficiency, use of microinverters vs. standard inverters, and rooftop vs. ground-mounted systems with and without tracking.

These comparisons focus primarily on systems installed in 2014, but include time series data in many cases as well, in order to illustrate whether the observed relationships are consistent over time. Due to limited availability of certain data elements (e.g., missing data on module models), these comparisons are, in many cases, drawn from a subset of the data sample. It should also be noted that the analysis presented here is purely descriptive in nature, and does not control for the many potential correlations among installed price drivers and other confounding dynamics. Thus the results should be construed as illustrative, but other methods – such as more-advanced statistical analyses or bottom-up cost modeling – would be required to develop precise estimates of particular installed price drivers.

Overall Installed Price Variability

Considerable spread exists within the data, as clearly illustrated in Figure 15, which presents installed price distributions for systems installed in 2014 within each customer segment. Among residential systems, roughly 20% of systems installed were priced below \$3.5/W (the 20th percentile value), and 20% were above \$5.3/W (80th percentile), with the remaining 60% of systems distributed across the wide range in between. Non-residential systems in the sub-500 kW class exhibit a similar spread, with 20th and 80th percentile values of \$3.1/W and \$4.9/W, respectively. The installed price distribution for larger >500 kW non-residential systems is somewhat narrower than for the other two segments, though by no means uniform, with a 20th-to-80th percentile band of \$2.3/W to \$3.6/W.

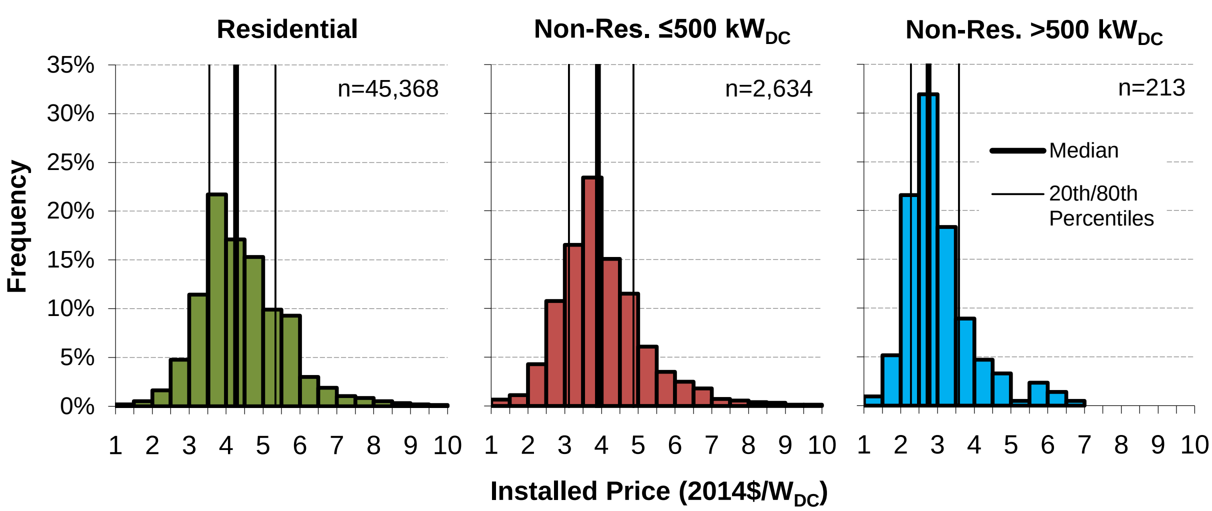
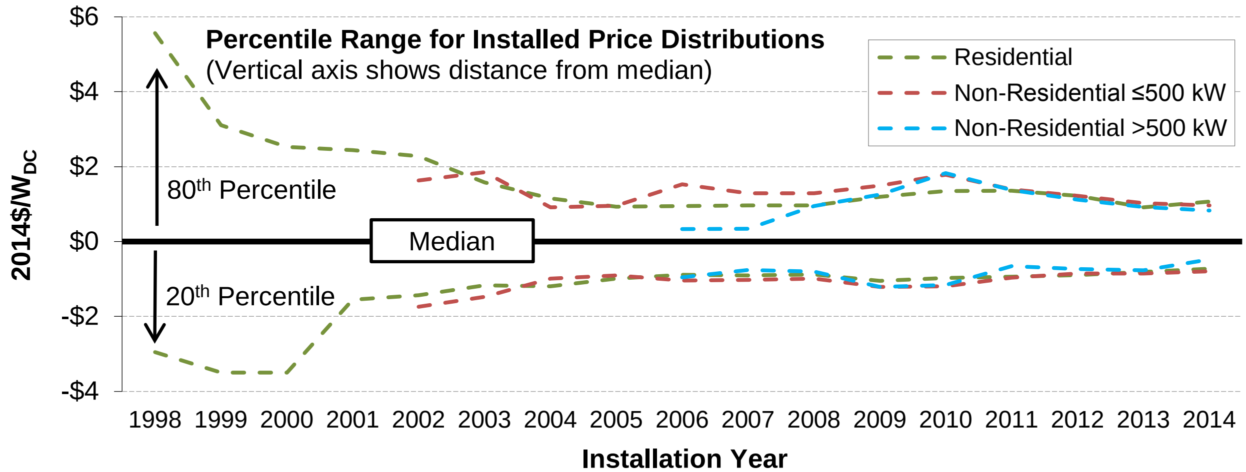


Figure 15. Installed Price Distributions for Systems Installed in 2014

Notwithstanding the significant pricing variability that exists among systems installed in 2014, installed price distributions have generally narrowed over time. This can be seen in Figure 16, which shows the range between the 20th and 80th percentiles over time, relative to the median installed price in each year. This narrowing trend was especially pronounced during the early years (1998 to 2004) of the U.S. residential market. Since then, the percentile spreads have remained relatively stable, though prices have been slowly – but steadily – converging across all three customer segments since roughly 2010. This narrowing trend is consistent with a maturing market characterized by increased competition among installers and vendors and by better-informed consumers.



Notes: See Table 1 for sample sizes by installation year. Percentile ranges are shown only if 20 or more observations are available for a given year and customer segment.

Figure 16. Installed Price Percentile Ranges over Time

The potential underlying causes for the remaining variability are numerous. These may include project characteristics (e.g., related to system size, technology type, or configuration) as well as attributes of individual installers. Installed price variation likely also reflects differences in regional or local market and regulatory conditions. For example, markets with less competition among installers, higher incentives, and/or higher electricity rates for net metering may have higher prices if installers are able to value-price their systems or if overheated demand strains the capacity of the local supply chain. Variability in prices also likely derives from differences in administrative and regulatory compliance costs (e.g., permitting and interconnection) as well as differences in labor wages and taxes. Many of these potential pricing drivers are explored throughout the remainder of this report. In addition, LBNL and its collaborators are also engaged in a series of separate analyses, using more sophisticated statistical methods, to further understand and isolate the sources of PV pricing variability (see Text Box 4). Regardless of its causes, however, the fact that such variability exists underscores the need for caution and specificity when referring to the installed price of PV, as clearly there is no single "price" that uniformly and without qualification characterizes the U.S. market, or even particular market segments, as a whole.

Text Box 4. Findings from Recent In-Depth Analyses of PV Pricing Dynamics

In collaboration with researchers from Yale University, University of Wisconsin, and University of Texas at Austin, LBNL has engaged in a series of in-depth analyses to better understand PV pricing dynamics. These studies leverage the dataset assembled for *Tracking the Sun* in conjunction with other data, and apply a variety of more-advanced statistical and econometric techniques. To date, several studies in this series have been completed, and several others are planned or underway.

Gillingham et al. (2014) examined a broad range of potential drivers for PV pricing variability among residential systems installed during 2010 to 2012. Of the various factors considered, the single-largest contributor was system size, with a difference of roughly $1.5/W between the smallest and largest residential systems (within an overall range of 1-10 kW). The study found that installed prices were $0.5/W lower in markets with the greatest density of installers, potentially due to greater competition, and that prices were $0.2/W lower for systems installed by the most-experienced companies. The study also found evidence that rich incentives can lead to higher prices, with a difference of more than $0.4/W between markets with the highest and lowest incentive levels (considering not only direct incentives, but utility bill savings and SRECs). As noted in the paper, that latter finding may reflect value-based pricing, though it may also simply be the result of high demand for solar enabling higher-cost installers and higher-cost systems.

Other studies in the series have focused on narrower issues related to the installed price of residential PV. Two of these studies have examined the impact of local permitting processes on residential PV pricing. Dong and Wiser (2013) found that cities in California with the most-favorable permitting practices had installed prices $0.3/W to $0.8/W lower than in cities with the most-onerous practices. Examining a broader geographical footprint, Burkhardt et al. (2014) found that variations in local permitting procedures lead to differences in average residential PV prices of approximately $0.2/W across jurisdictions; when considering variations not only in permitting practices, but also in other local regulatory procedures, price differences grew to $0.6/W to $0.9/W between the most-onerous and most-favorable jurisdictions.

Another study, Dong et al. (2014), examined incentive pass-through – i.e., the degree to which installers pass through the value of incentives to consumers – in California's statewide rebate programs. This analysis included two wholly distinct modeling approaches, and in both cases found average pass-through rates ranging from 95% to 99%. These finding thus indicate that installers in California have not artificially inflated their prices as a result of available rebates, though the findings do not rule out the possibility of value-based pricing more generally, for example associated with utility bill savings or tax incentives.

Installed Price Differences by System Size

Larger PV installations benefit from economies of scale by spreading fixed project and overhead costs over a larger number of installed watts and, depending on the installer, through price reductions on volume purchases of materials. These scale economies are evident in preceding figures that show higher installed prices for residential systems than for non-residential systems. They also arise, to varying degrees, among both residential and non-residential systems, contributing to the overall pricing variability within each customer segment.

Among residential systems installed in 2014 (Figure 17), economies of scale are most apparent within the range of 2 kW to 10 kW, where the vast majority of residential systems reside. Across this range, median prices are roughly 15% lower for systems 8-10 kW in size ($4.0/W), compared to 2-4 kW systems ($4.7/W). The relatively low median price for systems ≤2 kW is associated with the high proportion of those systems installed in new construction – which are relatively low-priced, as will be shown later. Beyond 10 kW, further price declines taper off for residential systems, suggesting strongly diminishing returns to scale. Table B-2 in the appendix presents time series data for residential system installed prices by system size, and shows generally consistent trends to those observed in Figure 17.

For non-residential systems (Figure 18), economies of scale are substantial across the broad range of system sizes. Among systems installed in 2014, median installed prices were 36% lower for the largest class of non-residential systems >1,000 kW in size ($2.7/W) than for the smallest non-residential systems ≤10 kW ($4.2/W).[10] Of course, even greater scale effects may arise when moving from large non-residential systems to utility-scale, though the latter are not covered in this report. See Table B-3 in the appendix for time series data on non-residential pricing by system size.

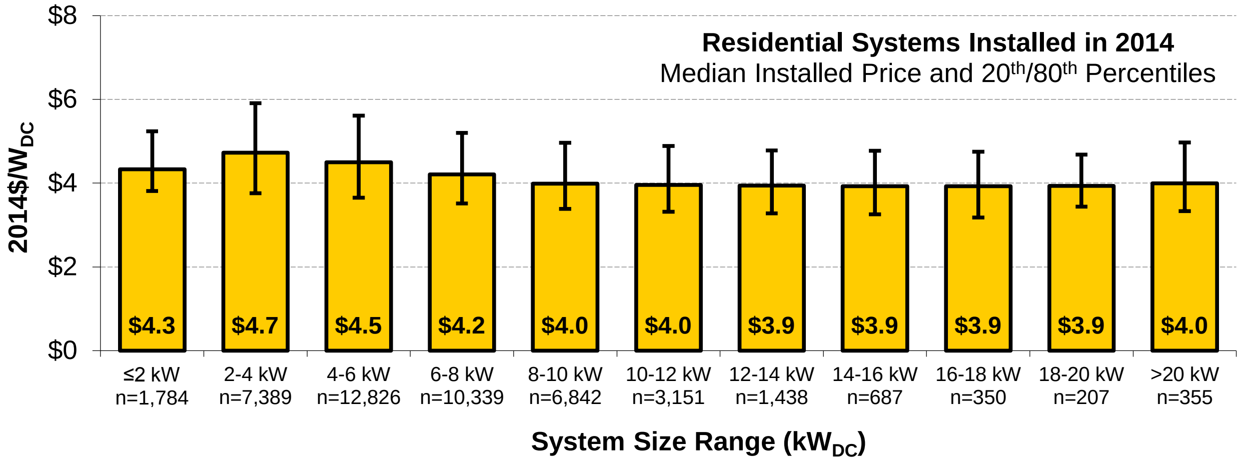


Figure 17. Installed Price of 2014 Residential Systems by Size

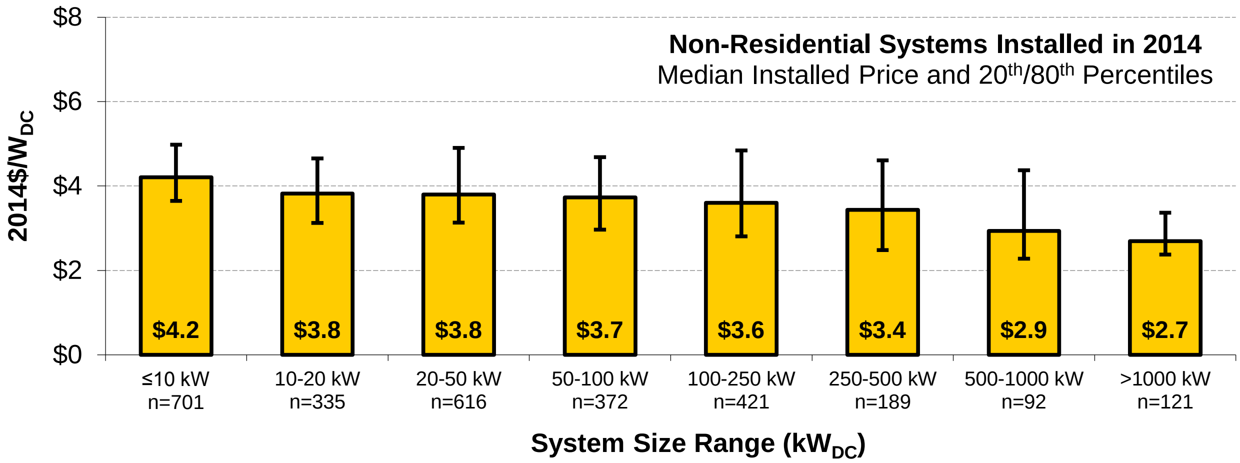


Figure 18. Installed Price of 2014 Non-Residential Systems by Size

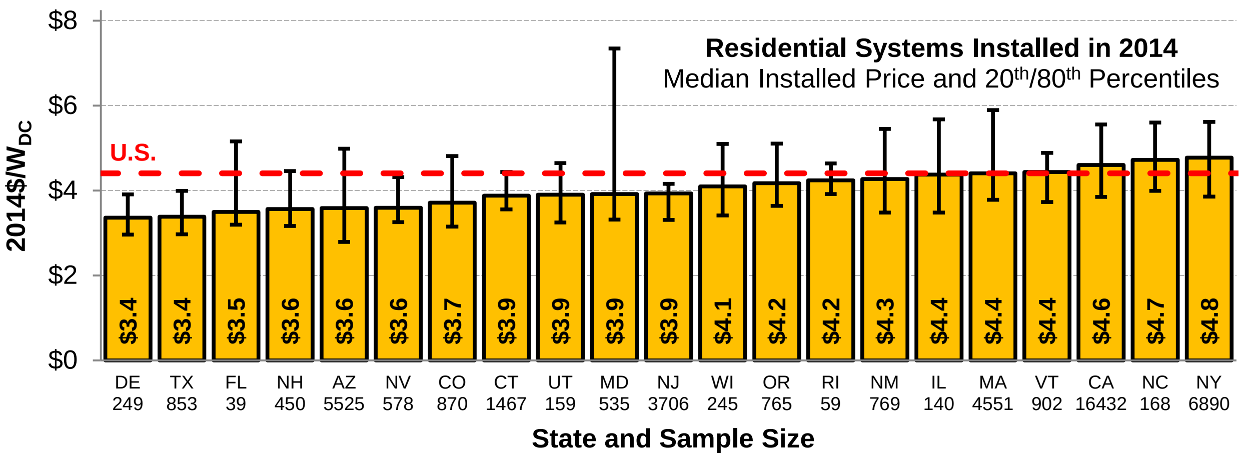
Installed Price Differences across States

The U.S. PV market is fragmented into regional, state, and local markets, each with potentially unique pricing dynamics. Figure 19 and Figure 20 focus, in particular, on state-level differences for systems installed in 2014 (see Table B-4 in the Appendix for time series data by state). Although the specific prices shown for some individual states should be interpreted with caution – either

[10] Economies of scale for non-residential systems appear to become much more pronounced at system sizes beyond 500 kW. Although that may partially be true, the effect is exaggerated in the graphic due to the irregular size groupings (with much wider size bins required for large non-residential systems in order to capture a sufficient sample size).

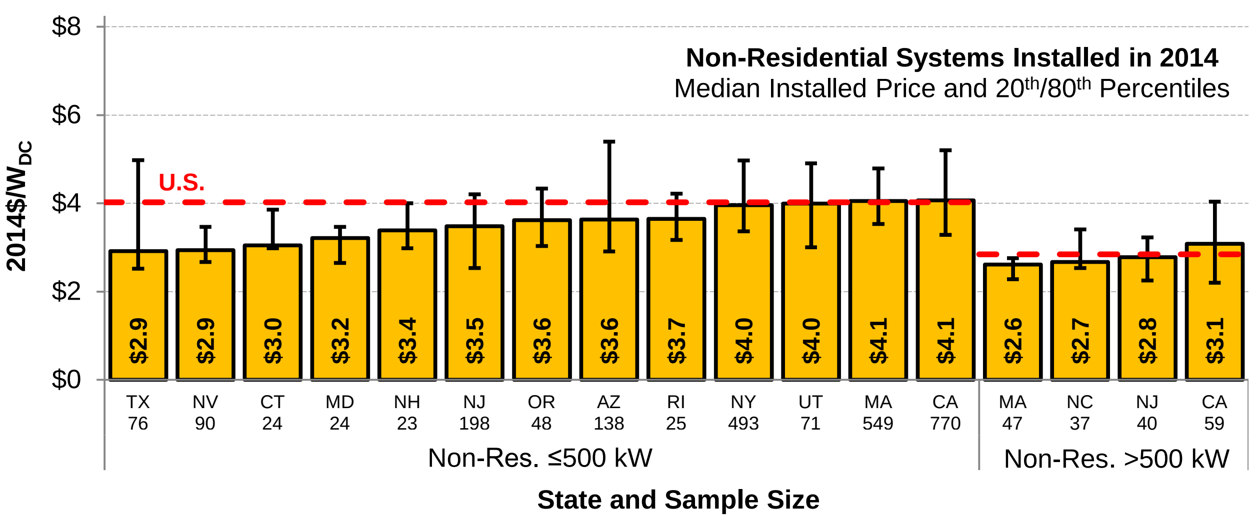
because of small sample sizes or because of potentially irregular reporting by particular installers – the figures nevertheless serve to illustrate the significant variability in pricing both across and within states.

Among residential systems installed in 2014, median installed prices range from a low of $3.4/W in Delaware and Texas to a high of $4.8/W in New York. Pricing for non-residential systems ≤500 kW similarly varies across a wide range, from $2.9/W in Texas and Nevada to $4.1/W in California and Massachusetts. For both of these customer segments, three of the largest state markets – California, Massachusetts, and New York – are relatively high-priced, which naturally tends to pull overall U.S. median prices upward (also shown in the figures). Pricing in most states, however, is below – in some states, far below – the aggregate national level. For larger non-residential systems>500 kW in size, the cross-state comparisons are somewhat less telling, given the limited set of states for which sufficient data are available. Nevertheless, even among this small set, median installed prices range from $2.6/W in Massachusetts to $3.1/W in California.



Notes: Median installed prices are shown only if 20 or more observations were available for a given state.

Figure 19. Installed Price of 2014 Residential PV Systems by State



Notes: Median installed prices are shown only if 20 or more observations were available for a given state.

Figure 20. Installed Price of 2014 Non-Residential PV Systems by State

The potential reasons for cross-state pricing differences are numerous, many of which have been explored through the research highlighted in Text Box 4. All else being equal, one would expect larger or more mature state markets to have lower prices, as a result of greater competition and experience among installers. Clearly, though, other countervailing factors can predominate, given the trends noted above. For example, higher incentives and/or higher electricity rates – often a key driver behind large state markets – may lead to higher pricing. This could reflect value-based pricing, though it may also simply be the result of the fact that rich incentives increase demand for solar, and higher demand for solar (as for any product) leads to higher prices in the short-run. Installed prices may also vary across states as a result of differences in labor costs, permitting and administrative processes, or sales tax. For example, differing sales tax rates and the fact that roughly half of the states shown in the figures exempt PV systems from state sales tax can lead to installed price differences of as much as \$0.2/W between states with relatively high sales tax and those that exempt PV systems from sales tax (or that do not have state sales taxes).[11]

State-level price variation can also arise from differences in the characteristics of systems installed in each state, such as typical system size and configuration, as well as differences in the composition of the PV customer base and installer base. For example, a high percentage of systems in California have premium-efficiency modules, which, as shown later, are priced substantially higher than systems with mid-range module efficiencies. Also in California, a large fraction of non-residential systems are at government, school, or non-profit facilities, which also tend to have high installed prices relative to systems at for-profit commercial facilities. This contrasts with North Carolina, for example, where non-residential systems consist primarily of relatively large commercial, ground-mounted systems.

Notwithstanding the significant cross-state differences, substantial pricing variation also clearly exists *within* each state, and for many states is at least as wide as the cross-state differences. This intra-state pricing variability reflects many of the same factors that contribute to pricing variability across states, as discussed above. Some of these pricing drivers, such as differences in permitting processes or installer experience, may manifest at more localized geographical scales than the individual state. To some extent, intra-state pricing variability may also reflect anomalous price reporting by individual installers in a state; for example, the exceptionally wide distribution for residential systems in Maryland is associated with a single installer with exceptionally high prices.

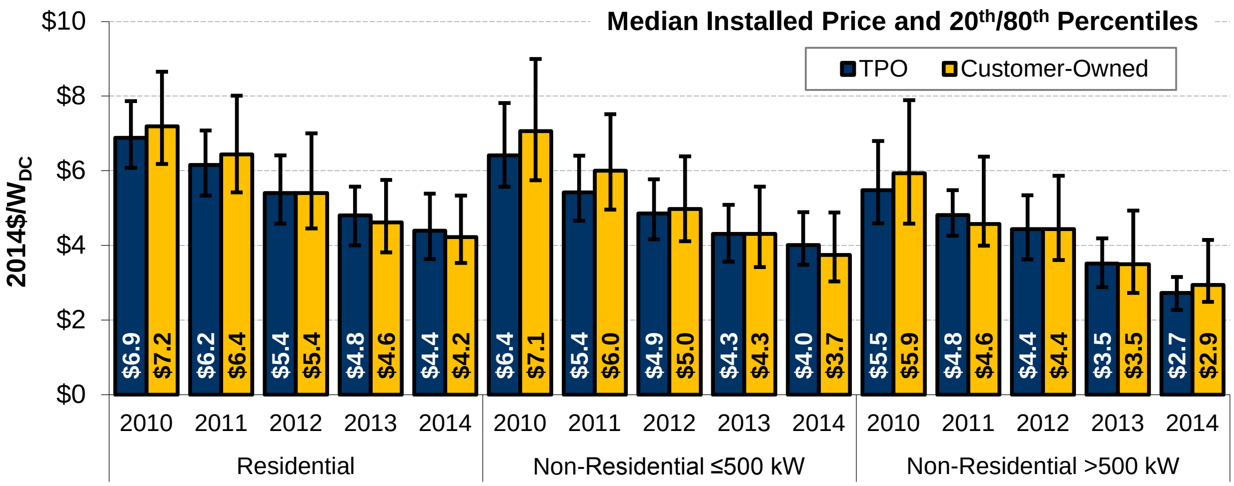
Installed Price Differences between Customer-Owned and TPO Systems

As described previously in Text Box 2, systems financed and installed by integrated TPO providers are excluded from the analysis, while those financed by non-integrated TPO providers are retained.[12] Installed prices reported for retained TPO systems represent the price paid to the installation contractor by the customer finance provider. In principle, these prices might be either lower or higher than for similar customer-owned systems. For example, installers selling systems to TPO providers may face incremental costs associated with arranging financing, which would tend to elevate reported system prices. On the other hand, for some TPO projects, the customer acquisition and project development functions may be performed by entities other than the installer, in which case the reported price might reflect pure “wrench-work”. One might also anticipate that

[11] Most, if not all, residential and non-residential PV systems are exempt from state sales tax in AZ, CO, CT, DE, FL, MA, MD, MN, NJ, NM, NY, RI, VT, WA, and WI (DSIRE 2015). Two other states, TN and UT, also have sales tax exemptions, though they apply to a much more limited set of PV systems.
[12] For reference, installed prices reported by integrated TPO providers, which are otherwise excluded from figures in this report, are summarized in Appendix A and compared to installed prices reported for non-integrated TPO systems.

TPO finance providers have significant negotiating power with installation contractors, or have a preference towards relatively standardized system designs, also tending to push pricing lower compared to customer-owned systems.

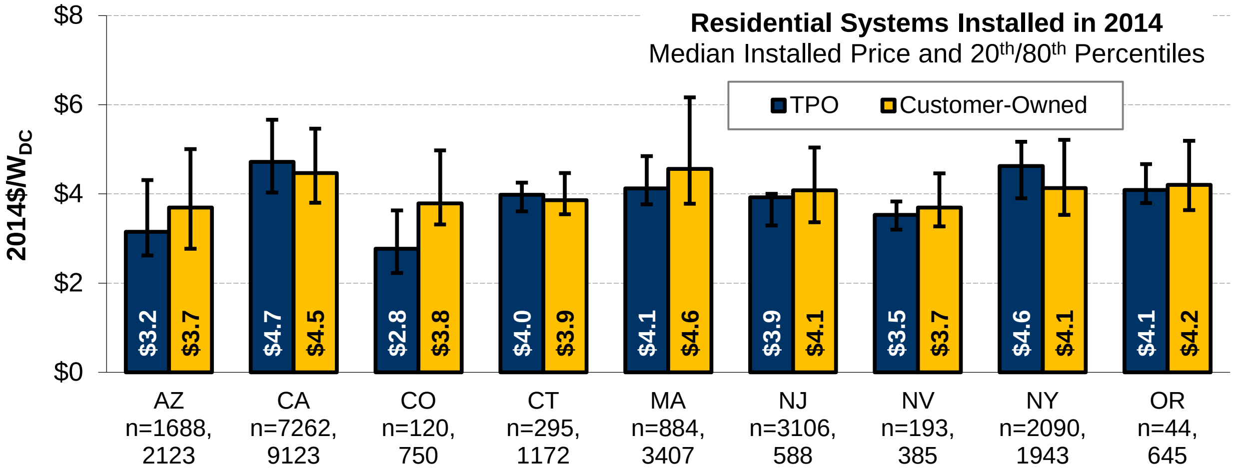
At an aggregate national level, differences in installed prices between non-integrated TPO and customer-owned systems have generally been small. As shown in Figure 21, TPO systems in 2014 were modestly higher-priced within the residential and sub-500 kW non-residential segments (by $0.2/W and $0.3/W respectively), but somewhat lower-priced for non-residential systems >500 kW (by $0.2/W). In years prior to 2014, pricing differences between TPO and customer-owned systems were also generally small, though the direction of that differential has inverted over time. In particular, Figure 21 shows that, among the residential and smaller non-residential segments, TPO systems in 2010 and 2011 had slightly lower median prices than customer-owned systems, but those median prices declined more slowly over time than for customer-owned systems. This might reflect any number of factors, for example, a relatively rapid expansion of TPO into higher-priced markets and/or increased demand and prices in markets driven by the entry of TPO. Regardless, the absolute differences between TPO and customer-owned systems have remained relatively small, suggesting that the growth of TPO business models seemingly has not had a sizable effect on aggregate national installed price trends.



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.

Figure 21. Installed Prices Reported for Customer-Owned vs. TPO Systems over Time

Within individual states, however, differences in installed prices between TPO and customer-owned systems have in some cases been sizeable. This can be seen in Figure 22 which focuses on residential systems installed in 2014. Out of the nine states shown, TPO systems were substantially lower-priced than customer-owned systems in Arizona, Colorado, and Massachusetts, but were higher-priced in New York, and roughly similar in all other states. These trends might reflect real differences in TPO business practices across states – e.g., a greater prevalence of installation-only transactions in certain markets. That said, the small sample sizes and potentially idiosyncratic pricing behavior of individual installers in particular states warrants some caution in attributing too much significance to these comparisons. Whatever their cause, though, the trends in Figure 22 do suggest that the growth of TPO has potentially impacted installed price trends in some states, and is another contributor to observed cross-state pricing differences.



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.

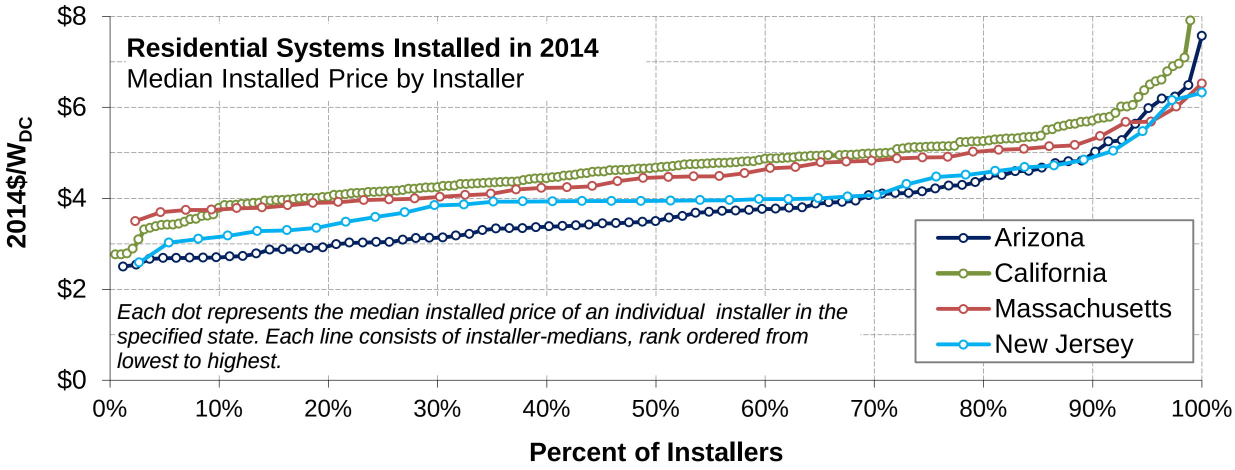
Figure 22. Installed Prices Reported for Customer-Owned vs. TPO Residential Systems by State

Installed Price Differences across Installers

The U.S. PV market is serviced by a large number of installers of varying size, experience, and business models. Although the residential market, in particular, has become increasingly dominated by several large national companies, a great many smaller regional players and "mom-and-pop" shops continue to operate throughout the country. The data sample assembled for this report includes more than 2,000 companies that installed PV systems in 2014, most of which were active only in the residential sector.[13] Because of the removal of integrated TPO systems, the sample is considerably less concentrated than the broader market. For example, among the 2014 residential systems in the sample, the highest installer-share is 6%, and the top 5 installers comprise 16% of systems – compared to 34% and 54%, respectively, for the U.S. residential market as a whole in 2014 (GTM Research 2015b).

In order to illustrate how installed pricing may vary across installers, Figure 23 shows median prices for individual installers in four of the largest state markets, focusing on residential systems installed in 2014. In each of these four states, installer-level median prices differ by anywhere from \$1.1/W to \$1.4/W between the upper and lower 20th percentiles of installers, demonstrating substantial heterogeneity in pricing across installers. Related, the figure serves to highlight "low-price leaders" that provide a benchmark for what may be achievable in terms of near-term installed price reductions within the broader market. In Arizona, for example, 20% of installers have median prices below \$3.0/W – compared to \$3.6/W for all 2014 residential systems in Arizona and \$4.3/W nationally. At the other end of the spectrum, of course, are the high-priced installers. In some cases, these may be companies that specialize in "premium" systems of some form, or that include in their reported prices additional items beyond what might be typically counted as part of the PV system.

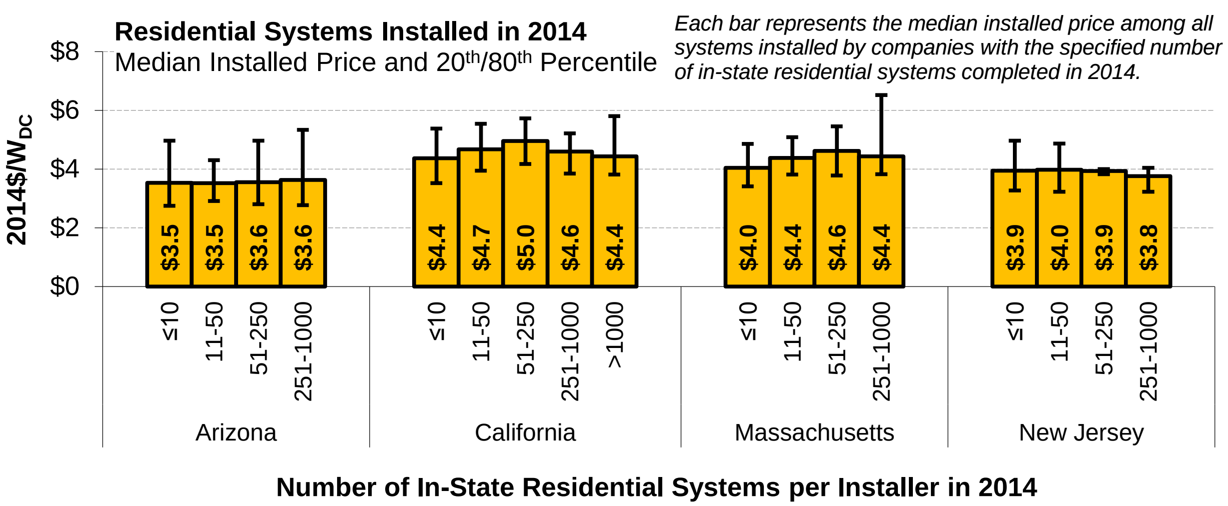
[13] The spelling of installer names often varies within the raw data received from program administrators. As part of the data cleaning, we attempt to standardize these spellings, though this process is undoubtedly imperfect and thus the actual number of unique installers within the data sample will be somewhat lower than the number cited here.



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

Figure 23. Median Installed Prices by Installer for Residential Systems in 2014

One might also anticipate that installer-level pricing varies according to the size of the company, and in particular, that larger installers may be able to offer lower pricing due to economies of scale within their business operations and greater levels of efficiency that arise through their accumulated experience. The data, however, do not necessarily bear this out. Figure 24 presents installed prices for residential systems installed in 2014, segmented according to the number of systems that the corresponding installer completed in 2014 within the specified state. In both Arizona and New Jersey, there is virtually no discernable difference in median prices across the installer volume ranges. In California and Massachusetts, the relationship that does emerge is rather irregular, with relatively low prices for small installers and the highest prices for mid-sized installers.



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.

Figure 24. Installed Prices According to Installer Volume by State

It is conceivable, of course, that scale advantages do exist but are simply washed out by the greater variability in the dataset, or that they materialize over geographical scales other than the state-level (either more locally or within broader regions). It is also possible that the scale advantages of high-volume installers are offset by other competing dynamics. For example, large installers may have relatively high customer acquisition costs and other business operation costs associated with aggressive growth. It is also conceivable that high-volume installers (or, for that matter, smaller installers with a dominant presence in particular locations) may enjoy a certain degree of market power, permitting higher pricing. These competing hypotheses have, to varying degrees, been substantiated in Gillingham et al. (2015) and are a subject of continuing investigation by Berkeley Lab and its collaborators in the study series referenced in Text Box 4.

Installed Price Differences between Residential New Construction and Retrofits

Residential solar markets in some states include a sizeable contingent of systems installed in new construction. Within the data sample assembled for this report, roughly 17% of all residential systems installed in California in 2014 were new construction – though, to be clear, the actual market share of new construction in California is much smaller, given the erosion of the residential retrofit sample for California and the exclusion of integrated TPO systems. The following analysis focuses specifically on California, as the vast majority of all residential new construction systems identifiable within the overall dataset are in that state, but may apply to other states as well.[14]

Residential systems installed in new construction differ from retrofit systems in several important ways relevant to any comparison of installed prices. First, new construction systems tend to be quite small. This is shown in the left-hand panel of Figure 25, which compares median system sizes for residential retrofit and new construction systems in California. Among systems installed in 2014, residential new construction systems had a median size of just 2.2 kW, compared to 6.1 kW for retrofits. Second, new construction systems have a much higher incidence of mono-crystalline modules and, in earlier years, building integrated PV (BIPV). This is shown in the right-hand panel of the figure, where almost 90% of new construction systems in 2014 had premium-efficiency or BIPV modules, compared to roughly 40% for retrofit systems in California. These two differences – smaller systems and higher incidence of premium or BIPV modules – would generally be expected to boost the installed price-per-watt of new construction systems relative to retrofits.

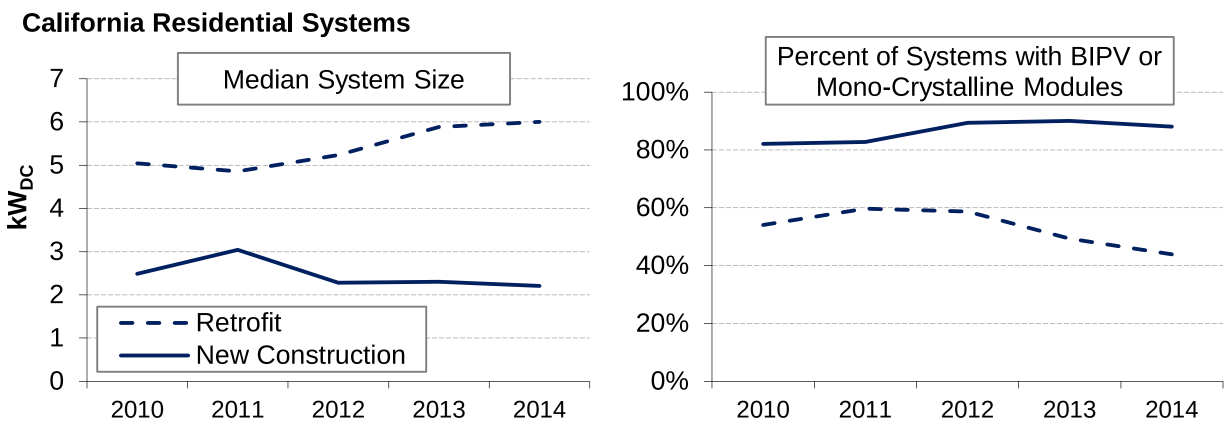


Figure 25. Key Characteristics of Residential Retrofit vs. New Construction in California

[14] Data from most other states did identify residential systems as either retrofit or new construction.

Aside from those technical differences are several other inherent features of new construction systems that may have implications for their installed price. First and foremost, perhaps, is that most new construction systems (in California, at least) are installed in new housing developments with multiple solar homes, and may therefore benefit from scale economies and bulk purchasing that reduce unit costs. New construction systems may also benefit from economies of scope, where certain labor or materials costs can be shared between PV installations and other elements of home construction. Conversely, some installers have reported more complex scheduling and logistics for new construction that might conceivably boost costs. Clearly, there are a variety of countervailing factors that could steer installed prices for new construction either higher or lower relative to systems on existing homes.

In order to reveal how these competing dynamics play out, Figure 26 compares the installed price of PV systems in residential retrofit and new construction in California. The left-hand half of the figure compares the two classes of systems, irrespective of key differences in their technical characteristics. As shown, new construction systems have consistently (with the exception of 2010) been lower-priced than retrofit systems, with a differential of roughly \$0.7/W in 2014, *despite* the smaller size and higher incidence of premium efficiency modules among new construction systems. To the extent that California's market includes a larger share of new construction systems than elsewhere, this also suggests that the state might appear even higher-priced relative to others, were it not for the large number of new construction systems.

In order to better control for the differing technical characteristics between new construction and retrofit systems, the right-hand side of Figure 26 focuses solely on 1-4 kW, rack-mounted (i.e., non-BIPV) systems with mono-crystalline modules. Not surprisingly, the cost advantages of new construction appear even greater in this comparison. Among systems installed in 2014, for example, the median price of systems installed in new construction was \$1.4/W below similarly sized and configured residential retrofit systems. These trends therefore suggest that the economies of scope and scale with large developments of new solar homes may indeed offer quite substantial savings on PV system pricing.

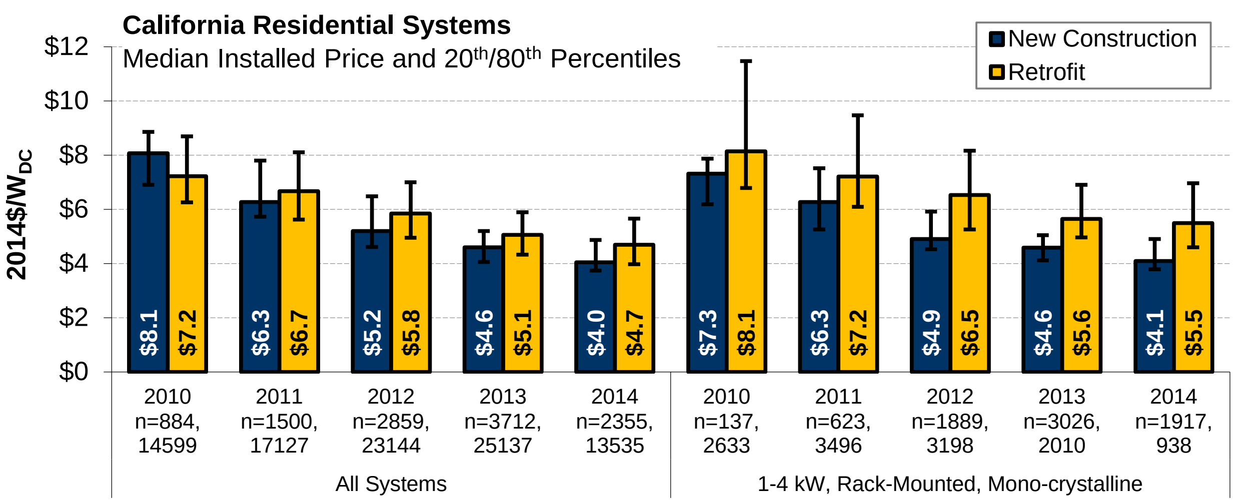


Figure 26. Installed Price of Residential Retrofit vs. New Construction in California

Notwithstanding the consistency of the trends exhibited in Figure 26, some degree of caution is warranted, given potential complications or ambiguities in how installed price data may be reported for new construction systems. For example, to the extent that certain costs are shared between the

PV installation and other aspects of home construction (e.g., roofing and electrical work), there may be some discretion on the part of those reporting data in terms of how those costs are allocated to the PV system. It is also common practice for identical installed prices to be reported for all PV systems within an individual development, consistent with the manner in which those systems are procured by the housing developer, which partly explains the greater uniformity of pricing observed among new construction systems.

Installed Price Differences between Tax-Exempt Customer Sites and For-Profit Commercial Sites

The non-residential solar sector is highly diverse in terms of the composition of the underlying customer base, including not only for-profit commercial entities, but also a sizeable contingent of systems installed at schools, government buildings, religious organizations, and non-profits. That latter set we collectively refer to as "tax-exempt" site hosts. In 2014, systems at tax-exempt customer sites comprised about 10% of the sub-500 kW non-residential systems and 30% of the >500 kW non-residential systems – based on the sub-set of the sample for which data on type of site host could be obtained.

Installed prices for systems at tax-exempt customer sites are consistently higher than at for-profit commercial facilities. This is evident in Figure 27, which compares installed prices for these two sub-sectors over time. In 2014, systems at tax-exempt customer sites were roughly \$0.3/W higher-priced within the sub-500 kW non-residential segment, and \$0.6/W higher among >500 kW non-residential systems. Similar or larger price differentials also exist in prior years. In addition to higher median values, installed prices also tend to be more varied at tax-exempt customer sites.

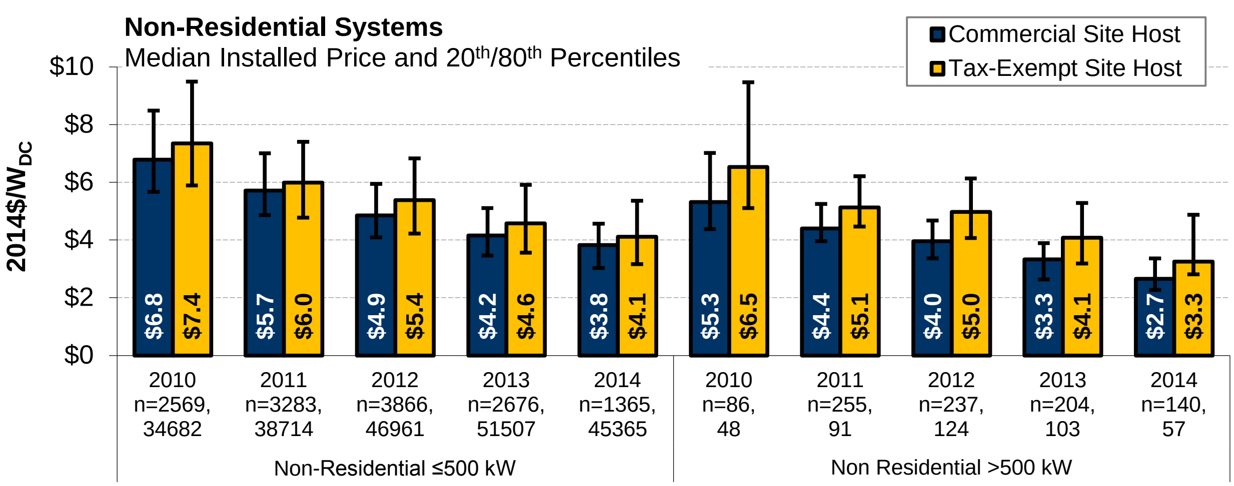
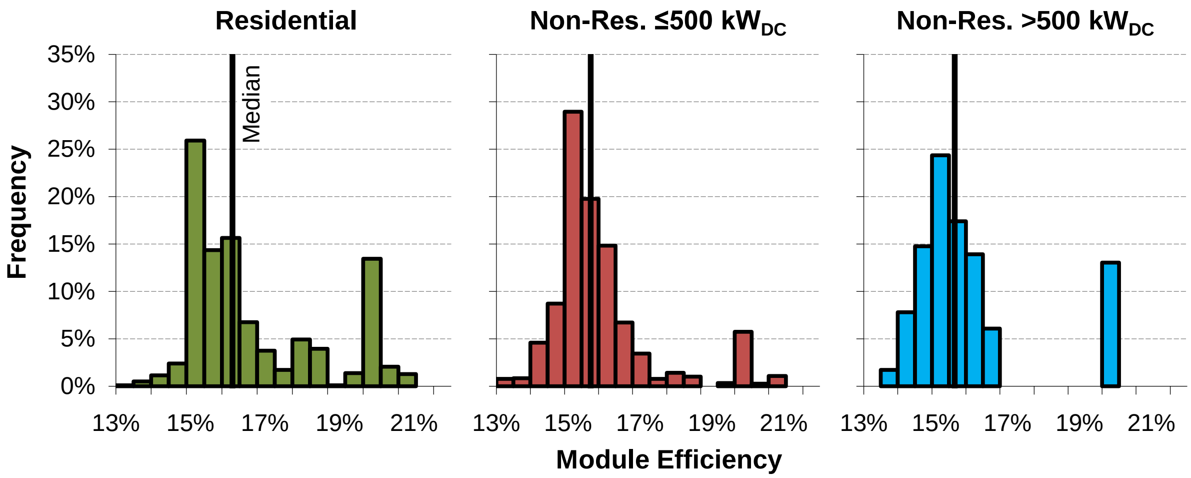


Figure 27. Installed Price Variation across Host Customer Sectors

These trends potentially reflect a number of underlying sources of higher costs or prices at tax-exempt customer sites, including prevailing wage/union labor requirements, preferences for domestically manufactured components, a high incidence of shade and parking structure PV arrays, additional permitting requirements, more complex government procurement processes, and different incentives. Tax-exempt customers may also have less negotiating power than their for-profit commercial counterparts. And finally, systems at tax-exempt customer sites are also disproportionately located in relatively high-priced states – specifically, two-thirds of 2014 systems are in California – which also contributes to their higher prices relative to commercial systems.[15]

Installed Price Differences by Module Efficiency

The conversion efficiency of commercially available PV modules varies considerably, from less than 13% for amorphous silicon and certain other types of thin-film modules to 20% or more for high-performance mono-crystalline silicon modules. Within the data sample for this report, the distribution of module efficiencies has a distinctly "bi-modal" shape (see Figure 28). Among residential systems installed in 2014, most have module efficiencies between 15.0% and 16.5%, characteristic of current poly-crystalline silicon module technology, though high-efficiency modules also comprise a sizable share (27% of the 2014 residential sample of systems had module efficiencies greater than 18%). The distributions for non-residential systems exhibit similar trends.



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.

Figure 28. Module Efficiency Distributions for Systems Installed in 2014

Module efficiency impacts the installed price of PV systems in countervailing ways. On the one hand, increased module efficiency reduces area-related balance-of-systems (BOS) costs. Cost modeling by Goodrich et al. (2012) estimate that, for example, an increase in module efficiency from 15% to 16% would reduce residential BOS costs by roughly \$0.1/W. On the other hand, high-efficiency modules are typically more expensive than standard efficiency modules. In 2014, for example, global average selling prices (ASPs) were roughly \$0.3/W higher for mono-crystalline than for poly-crystalline modules (Mints 2014), though pricing for both classes of module technology can vary considerably by manufacturer and module wattage.

To examine the net effect of these opposing cost drivers, Figure 29 compares installed prices according to module efficiency for systems installed in 2014. The figure focuses only on residential and sub-500 kW non-residential systems, and distinguishes between systems with module efficiencies less than 18% (primarily poly-crystalline modules) and those with module efficiencies

[15] Alternatively, one might reason that installed prices are higher in California because of the prevalence of tax-exempt systems. Both are true; however the fact that installed prices for residential and commercial systems in California are also relatively high-priced suggests that other causes are also at play, beyond the high incidence of PV systems at tax-exempt customer sites.

greater than 18% (primarily mono-crystalline modules). As shown, systems with high-efficiency modules have consistently been higher-priced than those with lower- or mid-range module efficiencies. In 2014, for example, the median differential was roughly $0.8/W within both the residential and non-residential segments, and was of generally similar magnitude in prior years.

Among other things, the trends exhibited in Figure 29 suggest that the price premium for high-efficiency modules generally has outweighed the corresponding reduction in BOS costs. To be clear, that implication applies to the specific mix of modules and systems represented within the data sample, and does not necessarily extend generically to a comparison between systems with poly- and mono-crystalline modules. Indeed, the installed price premium for systems with high-efficiency modules is substantially larger than the global ASP premium for mono-crystalline over poly-crystalline modules, implying that high-efficiency systems in the data sample may have even-higher priced modules, or may differ in others ways (e.g., greater prevalence of tracking systems or more complex, space-constrained installations) compared to the lower-efficiency PV systems in the data sample.

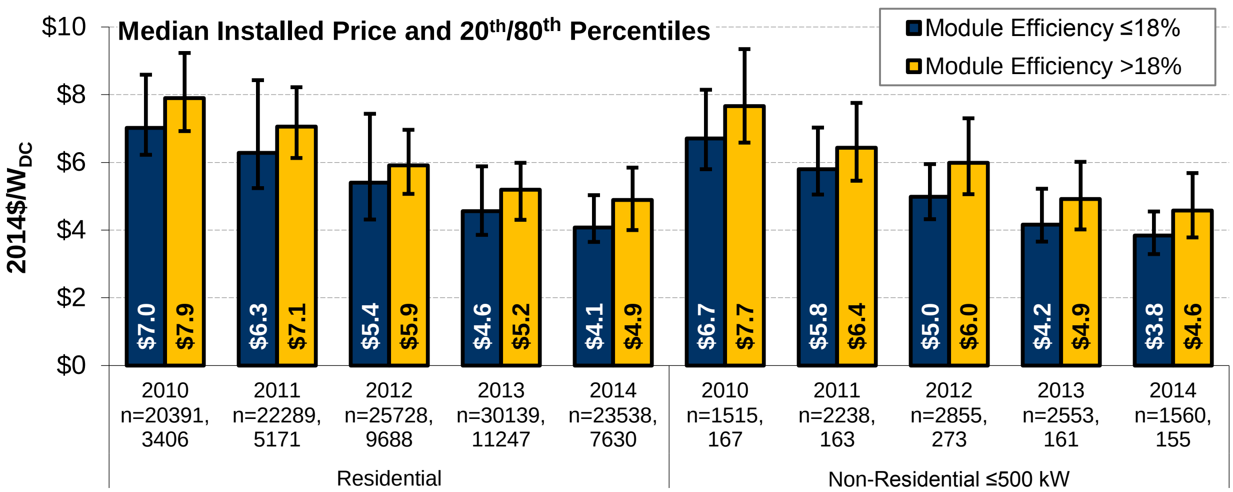


Figure 29. Installed Price Differences Based on Module Efficiency

Installed Price Differences for Systems with Microinverters vs. Standard Inverters

Microinverters have made significant gains in market share in recent years, as suggested by their steadily increasing share within the data sample (see Figure 30). That growth has been most pronounced within the residential sector, though has also been significant among sub-500 kW non-residential systems. Penetration among larger non-residential systems, by comparison, has remained rather limited. Note that the figure shows microinverter penetration levels within both the final data sample, as well as the preliminary sample that includes integrated TPO systems. The latter is perhaps more representative of the broader U.S. market, and suggests that microinverters may be slightly over-represented within our final data sample for residential systems.

The increased adoption of microinverters has been driven by their performance advantages relative to standard central or string inverters.[16] Microinverters typically sell at a premium relative

[16] Deline et al. (2012) estimate 4-12% greater annual energy production from systems with microinverters. Such performance gains are associated primarily with the ability to control the operation of each panel independently, thereby eliminating losses that would otherwise occur on panels in a string when the output of a subset of panels is compromised (e.g., due to shading or orientation) or when mismatch exists among modules in the string.

to standard inverters, with a difference in component pricing of roughly $0.28/W for residential inverters in 2014, and $0.36/W for commercial inverters (GTM Research and SEIA 2015). All else being equal, this would tend to increase installed prices for systems with microinverters, and dampen installed price reductions over time with the rising penetration of microinverters. However, aside from their direct impact on inverter costs, microinverters may have indirect impacts on other non-inverter balance of system (BOS) and soft costs, for example on installation labor, system design, and electrical costs, and thus the net impact of microinverters on overall system-level installed prices may either be larger or smaller than the difference in component pricing.

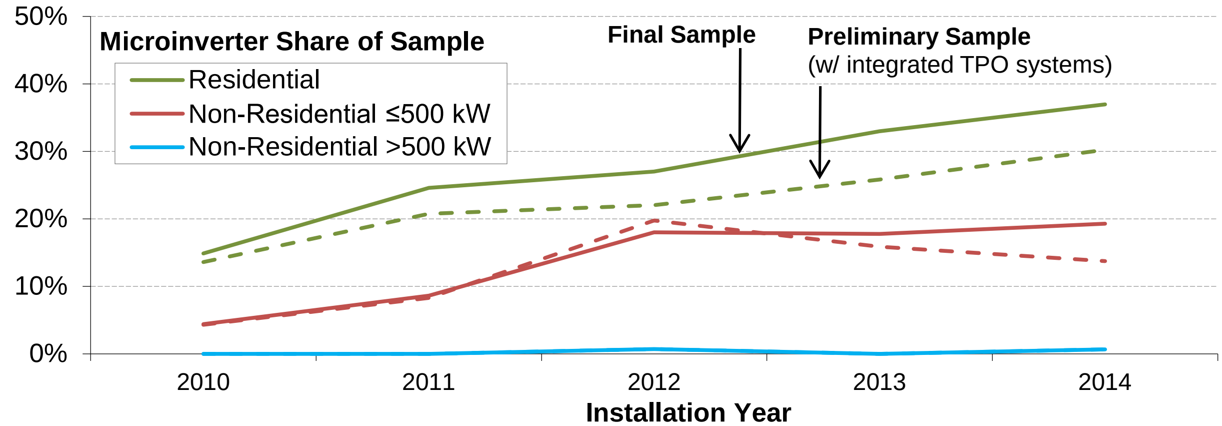


Figure 30. Microinverter Penetration within the Data Sample

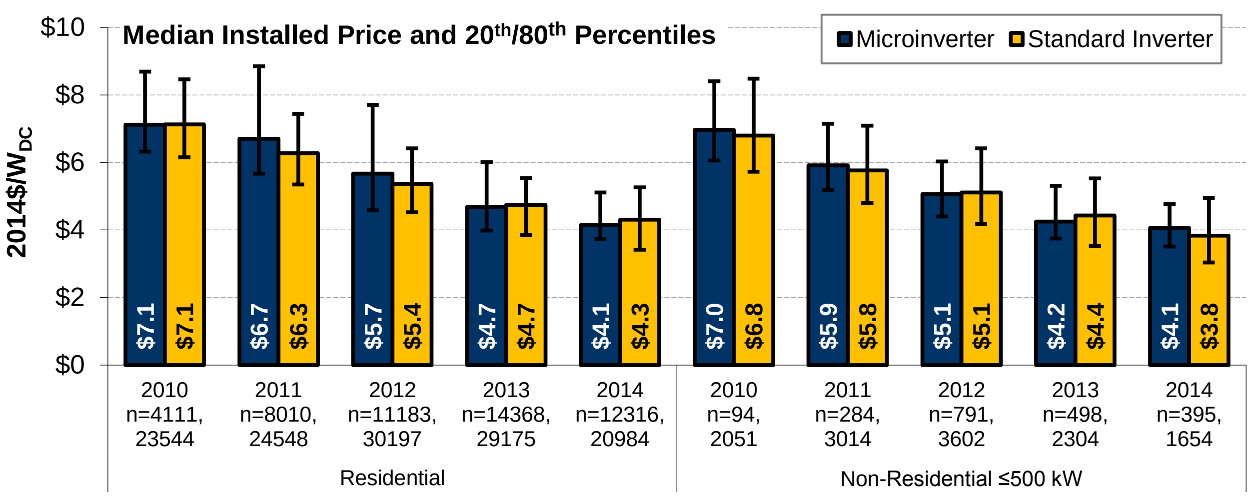


Figure 31. Installed Price Differences between Systems with Microinverters and Standard Inverters

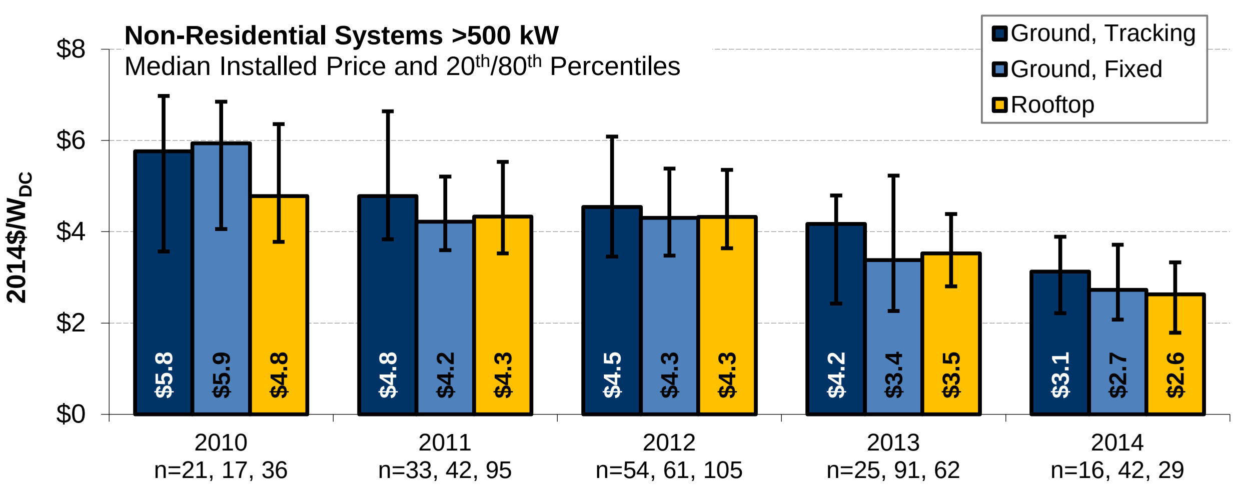
Ultimately, the levelized cost of electricity (LCOE) is the most meaningful metric for comparing the cost of systems with microinverters and those with standard inverters; however, the up-front installed price is one key driver for that broader cost comparison. In order to discern how microinverters impact up-front installed prices, Figure 31 compares reported installed prices for systems with microinverters and those with standard inverters. The figure focuses on residential and sub-500 kW non-residential systems, as those are the segments for which microinverter adoption has been most significant. As shown, installed price differences between systems with microinverters and standard inverters have generally been small, and have also varied in both magnitude and direction over time. Among residential systems, median installed prices for systems with microinverters were lower than for systems with standard inverters in 2014; however, the opposite was true for sub-500 kW non-residential systems, and for residential systems in some earlier years.

One must be cautious about ascribing too much precision to the comparisons shown here. That said, the fact that differences in median installed prices are generally less than the component price premium for microinverters does loosely suggest that they offer some offsetting reduction to non-inverter BOS and soft costs. Moreover, it is conceivable that installers tend to choose microinverters for more-complex installations (e.g., systems on multiple roof planes), especially for small systems where space constraints are binding. To the extent that this is the case, microinverters might provide greater savings on non-inverter BOS and soft costs than suggested by Figure 31.

Installed Price Differences for Systems with Tracking vs. Fixed-Tilt

Unlike residential and smaller sub-500 kW non-residential systems, which are almost entirely roof-mounted, a sizeable fraction of large >500 kW non-residential systems are ground-mounted arrays, often with tracking equipment. For example, among the large non-residential systems within the data sample installed in 2014, almost 70% were ground-mounted, and 20% had tracking (primarily single-axis). Thus, many of what are referred to within this report as large non-residential systems might elsewhere be classified as small utility-scale systems (see Text Box 1).

Not surprisingly, these differences in system configuration can impact installed prices, as shown in Figure 32, which focuses on non-residential systems >500 kW and is drawn from the (relatively small) sub-sample of systems for which data on mounting location and use of tracking equipment were available.[17] As one would expect, installed prices are consistently higher for systems with tracking than for others. In 2014, for example, the median installed price of systems with tracking was $0.4/W (15%) higher than for fixed-tilt, ground-mounted systems and $0.5/W (19%) higher than for roof-mounted projects.



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.

Figure 32. Installed Price of Large Non-Residential Systems by Mounting Configuration over Time

[17] Information on mounting location and use of tracking equipment was available for roughly 40% of large non-residential systems in the data sample installed in 2014.

To be sure, the size of these differentials varies irregularly from year-to-year, reflecting the small underlying data sample and abundance of other competing cost-drivers; thus, the figure does not necessarily provide an accurate measurement of the incremental cost of tracking equipment, per se. As one point of comparison, earlier cost modeling by Goodrich et al. (2012) estimated a $0.6/W premium for tracking equipment in utility-scale applications, though that estimate applied to systems quoted in 2010 and thus does not capture any intervening drop in tracking equipment costs.

It is also important to stress that the purpose of tracking equipment is to increase electricity production; Drury et al. (2013) estimate that systems with single-axis tracking generate 12% to 25% more electricity than fixed-tilt systems. The relevant metric of comparison between systems with and without tracking is therefore the levelized cost of electricity (LCOE). The fact that the performance gain associated with tracking equipment is similar in magnitude to the difference in median installed price in 2014 illustrates (loosely) how the additional up-front cost of tracking equipment can be offset by performance gains.

5. Conclusions

The number of PV systems installed in the United States has grown at a rapid pace in recent years, driven in large measure by government incentives. Given the relatively high historical cost of PV, a key goal of these policies has been to encourage cost reductions over time through increased deployment. Key research and development efforts to drive cost reductions have also been led by the U.S. DOE's SunShot Initiative, which aims to reduce the cost of PV-generated electricity by about 75% between 2010 and 2020.

Available evidence confirms that the installed price of PV systems (i.e., the up-front cost borne by the PV system owner, prior to any incentives) has declined substantially since 1998, though both the pace and source of those cost reductions have varied over time. Following a period of relatively steady and sizeable declines, installed price reductions began to stall around 2005, as the supply-chain and delivery infrastructure struggled to keep pace with rapidly expanding global demand. Beginning in 2008, however, global module prices began a steep downward trajectory, and those module price reductions were the driving force behind the decline in total system prices for PV from 2008 through 2012. Since 2012, however, module prices have remained relatively flat (or risen slightly), yet installed prices have continued to fall as a result of a steady decline in non-module costs. Given the limits to further reductions in module prices, continued reductions in non-module costs will be essential to driving further deep reductions in installed prices.

Unlike module prices, which are primarily established through global markets, non-module costs consist of a variety of soft costs that may be more readily affected by local policies – including deployment programs aimed at increasing demand (and thereby increasing competition and efficiency among installers) as well as more-targeted efforts, such as training and education programs. The heightened focus on cost reductions within the solar industry and among policymakers, and recognition of the importance of soft costs for achieving further price reductions, has spurred a flurry of initiatives and activity in recent years, aimed at driving reductions in solar soft costs. The fact that installed prices fell substantially in 2013 and 2014 and continued to fall through the first half of 2015 – despite level or slightly rising module prices – suggests that these efforts have begun to bear fruit.

Nevertheless, lower installed prices in other major international markets, as well as the wide diversity of observed prices within the United States, suggest that broader soft cost reductions are possible. Although such cost reductions may accompany increased market scale, it is also evident that market size alone is insufficient to fully capture potential near-term cost reductions – as suggested by the fact that many of the U.S. states with the lowest installed prices are relatively small PV markets. Achieving deep reductions in soft cost thus likely requires a broad mix of strategies, including: incentive policy designs that provide a stable and straightforward value proposition to foster efficiency and competition within the delivery infrastructure, targeted policies aimed at specific soft costs (for example, permitting and interconnection), and basic and applied research and development.

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Appendix A: Data Cleaning, Coding, and Standardization

To the extent possible, this report presents data as provided directly by PV incentive program administrators and other data sources; however, several steps were taken to clean and standardize the data.

Conversion to 2014 Real Dollars: Installed price and incentive data are expressed throughout this report in real 2014 dollars (2014$). Data provided by PV program administrators in nominal dollars were converted to 2014$ using the "Monthly Consumer Price Index for All Urban Consumers," published by the U.S. Bureau of Labor Statistics.[18]

Conversion of Capacity Data to Direct Current (DC) Watts at Standard Test Conditions (DC-STC): Throughout this report, all capacity and dollars-per-watt ($/W) data are expressed using DC-STC capacity ratings. Most PV incentive programs directly provided data in units of DC-STC; however, several provided capacity data only in terms of the California Energy Commission Alternating Current (CEC-AC) rating convention, which represents peak AC power output at PVUSA Test Conditions (PTC). DC-STC capacity ratings in these cases were calculated based on information provided about the module model (from which DC ratings could be obtained from manufacturer spec sheets) and module quantity. If this approach was not feasible for any reason, DC capacity was estimated based on an assumed conversion between $W_{DC\text{-}STC}$ and $W_{CEC\text{-}AC}$, derived from other similar systems.

Incorporation of Data on Module and Inverter Characteristics. The raw data provided by PV incentive program administrators generally included module and inverter manufacturer and model names. We cross-referenced that information against various databases of PV component specification data (primarily SolarHub[19]) to characterize the module technology efficiency, module technology (e.g., mono-crystalline vs. poly-crystalline, building-integrated PV vs. rack-mounted systems), and inverter technology (microinverter vs. standard central or string inverter).

Identification of Customer Segment: Almost all programs provided some explicit segmentation of host customers, at least into residential and non-residential customers. In the rare cases where even this minimal level of segmentation was not provided, systems less than or equal to 20 kW in size were assumed to be residential, and those larger than 20 kW were assumed to be non-residential. The choice of this threshold was based on an inspection of data where customer segmentation was available, and is roughly the value that minimizes the error in these assignments to customer segments.

Identification of Customer-Owned vs. TPO Systems: Most programs explicitly identify the ownership type of each system as either customer-owned or TPO. Where such data were not provided, however, inferences were made wherever possible. First, systems were assumed to be customer-owned if: (a) installed in a state where TPO was not allowed at the time of installation, (b) installed in a state where TPO is technically allowed but actual market activity is known to be quite low, or (c) the PV incentive program providing data is not available to TPO systems. Next, any remaining systems with unknown ownership type were assumed to be TPO if installed by companies known to be providers almost exclusively of TPO systems, including: SolarCity, Sungevity, Vivint, SunRun, and Roof Diagnostics & Solar.

Identification and Removal of Integrated TPO Systems: A total of 75,126 integrated TPO systems were removed from the data sample, on the grounds that the installed prices reported for these systems represent appraised values. In the vast majority of cases, integrated TPO systems were identified simply based on the reported installer name and system ownership type. Specifically, all TPO systems installed by these companies were flagged as integrated TPO and removed from the data set: SolarCity, Sungevity, or Vivint. (Host customer-owned systems installed by those entities, however, were retained within the sample).

[18] ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt
[19] http://www.solarhub.com/

If information on installer name was not available, appraised-value systems were identified using a "price clustering" approach. The logic for the price clustering approach is founded on the observation that systems installed by integrated TPO providers are typically clustered with an identical price reported for a large group of systems (which may reflect, for example, the average per-kW assessed fair market value of a bundle of systems sold to tax equity investors). The first step in the price clustering analysis was to identify the price clusters among the systems explicitly identified within the dataset as being TPO and installed by an integrated TPO provider. Then, among the set of systems for which data on installer name was unavailable, systems were identified as appraised value if they fell within any of those price clusters (provided that the system was not also identified as host customer-owned). The price clustering analysis resulted in 2,279 systems being identified as integrated TPO systems (out of the aforementioned total) and removed from the data sample.

For reference, Figure 33 compares the reported installed prices for these integrated TPO systems to prices for other, non-integrated TPO systems that are retained in the data sample. For simplicity, the figure focuses on residential systems installed over the past five years. As shown, through 2011, installed prices reported for integrated TPO systems were dramatically higher than for non-integrated TPO systems. For many integrated TPO systems, the appraised values used as the basis for reported installed prices were an assessed "fair market value", which is often based on a discounted cash flow from the project. Starting in 2012, however, at least one major integrated TPO provider changed its installed price reporting methodology for PV incentive programs, and is now reporting a standard appraised cost rather than an appraised fair market value. As a result, the disparity between installed prices reported for integrated and non-integrated TPO systems has since largely disappeared, as shown in Figure 33.

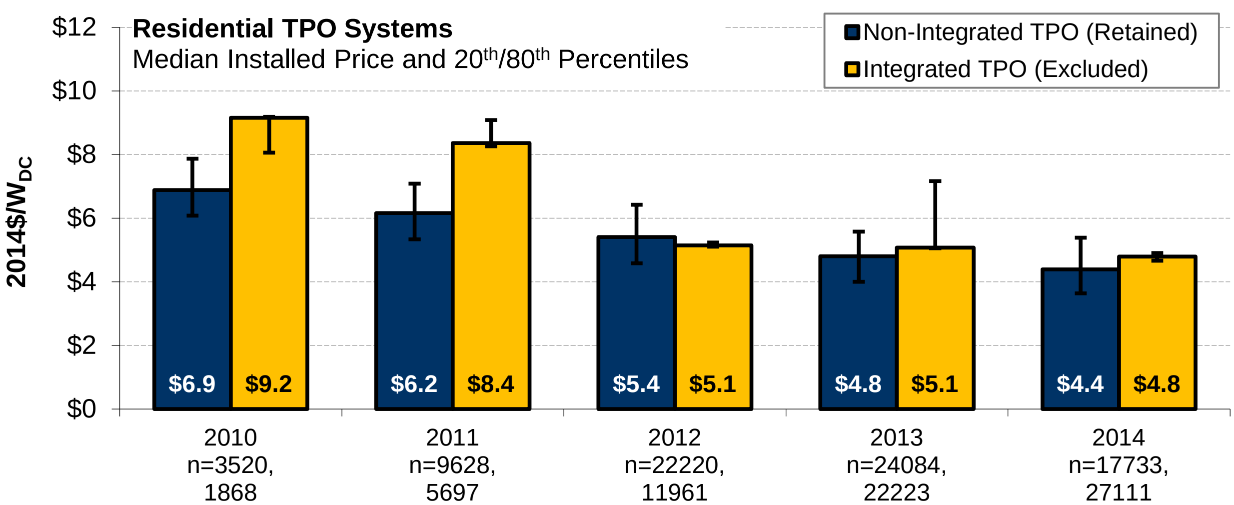

Figure 33. Installed Prices Reported for Non-Integrated and Integrated Residential TPO Systems

Identification of Self-Installed Systems: Self-installed systems were identified in several ways. In some cases, these systems could be identified where the installer name was listed as "owner" or "self". In addition, all systems installed by Grid Alternatives were treated as self-installed, as this is a non-profit entity that relies on volunteer labor for low-income solar installations.

Calculation of Net Present Value of Reported PBI Payments: Six PV incentive programs in the data sample provided performance-based incentives (PBIs), paid out over time based on actual energy generation and a pre-specified payment rate, to some or all systems. In order to facilitate comparison with up-front rebates provided to the other systems in data sample, the net present value (NPV) of the expected PBI payments were calculated based on an assumed 7% nominal discount rate.

Appendix B: Additional Detail on Final Data Sample

Table B-1. Sample Summary by Program Administrator

State	Program Administrator	Size Range (kW_{DC})	Year Range	2014 Sample		Total Sample	
				No. of Systems	Total MW_{DC}	No. of Systems	Total MW_{DC}
AR	Arkansas Energy Office	0.5 - 25	2010 - 2011	0	0.0	97	0.7
AZ	Ajo Improvement Company	2.1 - 2.1	2012 - 2012	0	0.0	3	0.0
	Arizona Public Service	0.4 - 3,903	2002 - 2014	2784	34.7	18,137	316.9
	Graham County Electric Coop.	0.06 - 25	2005 - 2010	0	0.0	96	0.5
	Mohave Electric Coop.	1.0 - 47	2004 - 2014	104	0.7	355	2.7
	Morenci Water & Electric	5.8 - 20	2010 - 2011	0	0.0	3	0.0
	Navopache Electric Coop.	1.0 - 55	2003 - 2012	0	0.0	129	0.9
	Salt River Project	0.5 - 1,703	2005 - 2014	1145	13.9	6,546	61.4
	Sulpher Springs Valley Electric Coop.	0.1 - 984	2009 - 2014	187	1.5	957	7.0
	Tucson Electric Power	0.01 - 1,100	1999 - 2014	1003	7.5	4,903	55.2
	Trico Electric Coop.	0.4 - 346	2006 - 2014	128	0.9	588	4.0
	UniSource Electric Services	0.5 - 98	1999 - 2014	327	2.7	1,213	11.1
CA	California Center for Sustainable Energy (Rebuild a Greener San Diego)	1.9 - 7.1	2004 - 2008	0	0.0	154	0.8
	California Energy Commission (Emerging Renewables Program)	0.07 - 670	1998 - 2008	0	0.0	27,420	144.9
	California Energy Commission (New Solar Homes Partnership)	0.08 - 286	1999 - 2014	2250	6.9	12,477	45.3
	California Public Utilities Commission (California Solar Initiative)	0.9 - 5,946	2007 - 2014	12714	217.6	115,969	1624.8
	California Public Utilities Commission (Self Generation Incentive Program)	34 - 1,266	2002 - 2009	0	0.0	855	159.9
	City of Palo Alto Utilities	0.7 - 882	1999 - 2014	53	1.0	570	5.3
	Imperial Irrigation District	1.0 - 1,104	2006 - 2014	48	0.4	459	9.8
	Los Angeles Dept. of Water & Power	0.3 - 3,966	1999 - 2014	1657	20.4	9,735	115.4
	PacifiCorp (California Solar Initiative)	1.3 - 257	2011 - 2014	12	0.2	134	1.9
	Sacramento Municipal Utility District	0.7 - 2,840	2005 - 2014	526	4.5	2,810	39.2
CO	Xcel Energy	1.0 - 1,998	2006 - 2014	873	7.1	881	7.2
CT	Clean Energy Finance Investment Authority	0.5 - 570	2004 - 2014	1491	14.0	4,942	56.1
DC	Dept. of Environmental Protection	0.9 - 101	2009 - 2013	0	0.0	763	3.8
DE	Dept. of Natural Resources & Env. Control (Delmarva PV rebate program)	0.3 - 1,434	2002 - 2014	253	2.2	1,312	14.5
	Dept. of Natural Resources & Env. Control (electric coop. PV rebate program)	1.1 - 88	2006 - 2013	0	0.0	285	1.9
	Dept. of Natural Resources & Env. Control (municipal PV rebate program)	1.8 - 151	2007 - 2014	5	0.0	137	1.0

State	Program Administrator	Size Range (kW_{DC})	Year Range	2014 Sample		Total Sample	
				No. of Systems	Total MW_{DC}	No. of Systems	Total MW_{DC}
FL	Florida Energy & Climate Commission[a]	2.0 - 1,016	2006 - 2012	0	0.0	1,122	9.3
	Gainesville Regional Utilities (Feed-In Tariff)[a]	2.3 - 1,040	2009 - 2014	13	0.4	258	18.5
	Gainesville Regional Utilities (Rebate Program)[a]	1.9 - 100	2006 - 2014	15	0.2	181	2.1
	Orlando Utilities Commission[a]	0.5 - 1,040	2008 - 2014	22	0.1	120	3.1
IL	Dept. Commerce and Economic Opportunity	0.8 - 700	1999 - 2014	154	2.5	939	10.5
MA	Massachusetts Clean Energy Center and Dept. of Energy Resources[b]	0.2 - 5,999	2002 - 2014	5147	149.1	14,883	514.4
MD	Maryland Energy Administration	0.7 - 200	2005 - 2014	559	5.0	4,912	40.5
ME	Efficiency Maine	0.9 - 171	2011 - 2013	0	0.0	550	3.5
MN	Minnesota State Energy Office	0.5 - 40	2003 - 2011	0	0.0	359	1.9
NC	NC Sustainable Energy Association	1.0 - 5,915	2005 - 2014	209	172.4	1,463	458.6
NH	New Hampshire Public Utilities Commission	0.3 - 81	2002 - 2014	473	3.4	1,495	8.7
NJ	Board of Public Utilities (Customer Onsite Renewable Energy Program)	1.0 - 2,372	2001 - 2012	0	0.0	4,049	85.4
	Board of Public Utilities (Renewable Energy Incentive Program)	1.2 - 51	2009 - 2013	0	0.0	3,629	36.1
	Board of Public Utilities (SREC Registration Program)	1.0 - 8,135	2007 - 2014	3944	120.6	18,645	899.3
NM	Energy, Minerals & Natural Resources Dept.	0.4 - 349	2007 - 2014	775	4.5	5,030	26.5
NV	NVEnergy	0.4 - 1,145	2004 - 2014	671	14.4	2,389	61.9
NY	NYSERDA	0.5 - 404	2003 - 2014	4051	47.5	11,966	142.9
	Public Service Electric & Gas Long Island	0.3 - 980	2000 - 2014	3332	30.6	10,536	94.5
OH	Dept. of Development	1.0 - 1,121	2005 - 2012	0	0.0	226	9.2
OR	Energy Trust of Oregon[c]	0.5 - 5,702	2002 - 2014	551	4.3	5,363	53.9
	Oregon Dept. of Energy[c]	0.1 - 22	1999 - 2014	182	0.8	1,321	4.0
	PacifiCorp (Solar Volumetric Incentive and Payments Program)	1.5 - 500	2010 - 2014	80	1.2	450	7.3
PA	Dept. Community and Economic Development	8.0 - 3,252	2010 - 2012	0	0.0	49	34.6
	Dept. Environmental Protection	1.0 - 922	2009 - 2014	25	0.3	7,000	97.8
	Sustainable Development Fund	1.1 - 12	2002 - 2008	0	0.0	200	0.7
RI	Commerce Rhode Island	1.0 - 253	2013 - 2014	84	2.3	125	2.7
TX	Austin Energy	0.2 - 300	1999 - 2014	837	10.9	3,883	29.8
	Clean Energy Associates (IOU programs)	0.4 - 300	2001 - 2014	92	1.5	1,329	15.4
UT	PacifiCorp (Solar Incentive Program)	0.7 - 364	2011 - 2014	230	3.7	398	5.1
VT	Renewable Energy Resource Center	0.2 - 358	2003 - 2014	909	5.9	3,487	23.9
WI	Focus on Energy	0.2 - 273	2002 - 2014	263	1.4	1,702	12.6
Miscellaneous other sources (multiple states)		30 - 10,150	2008 - 2014	37	34.3	1,308	632.7

State	Program Administrator	Size Range (kW_{DC})	Year Range	2014 Sample		Total Sample	
				No. of Systems	Total MW_{DC}	No. of Systems	Total MW_{DC}
	Total	***0.0 - 10,150***	***1998 - 2014***	***48,215***	***954***	***321,297***	***6,040***

[a] Florida systems that received incentives through both the Florida Energy & Climate Commission's solar rebate program and one of the Florida utility programs were retained in the data sample for the utility program and removed from the data sample for the state program.

[b] Massachusetts systems that received incentives through the Massachusetts Clean Energy Center are, in most cases, also registered within the Dept. of Energy Resources SREC registration program. A single consolidated data file was provided by the Dept. of Energy Resources that included all systems participating in one or both programs.

[c] Oregon systems that received incentives through both the Oregon Dept. of Energy's tax credit program and the Energy Trust of Oregon were retained in the data sample for the Energy Trust and removed from sample for the Dept. of Energy.

Table B-2. Median Installed Price of Residential Systems by Size over Time (2014$/W$_{dc}$)

System Size (kW_{DC})	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
≤2 kW	11.6	11.7	11.9	11.0	10.3	9.8	10.3	10.2	9.8	10.0	9.8	7.5	6.1	4.7	4.3
2-4 kW	11.6	11.2	11.5	10.1	9.4	9.0	9.2	9.4	9.0	8.8	7.6	6.8	5.7	4.9	4.7
4-6 kW	9.1	10.5	10.8	10.0	9.3	8.9	9.1	9.1	8.8	8.3	7.0	6.3	5.5	4.9	4.5
6-8 kW	6.6	11.4	10.7	9.8	9.1	8.7	8.7	8.9	8.6	8.1	6.9	6.1	5.2	4.6	4.2
8-10 kW	-	10.6	10.5	9.6	9.0	9.0	8.9	9.0	8.7	8.2	6.9	6.0	5.1	4.4	4.0
10-12 kW	-	10.8	10.8	9.8	8.9	8.9	8.7	8.9	8.5	8.2	6.8	5.9	5.1	4.3	4.0
12-14 kW	-	-	-	9.6	8.9	8.5	8.3	8.8	8.5	7.8	6.7	5.8	5.1	4.3	3.9
14-16 kW	-	-	-	-	8.5	8.4	8.5	8.8	8.4	7.8	6.7	5.9	5.0	4.2	3.9
16-18 kW	-	-	-	-	9.2	8.5	8.4	8.8	8.5	8.0	6.7	5.8	5.1	4.3	3.9
18-20 kW	-	-	-	-	-	8.3	8.3	8.4	8.6	8.0	6.9	5.9	5.3	4.3	3.9
>20 kW	-	-	-	-	-	-	-	9.2	8.6	7.9	6.9	5.8	5.3	4.6	4.0

Notes: Median installed price data omitted if fewer than 20 observations available. Although not presented here, large variation exists around these median values.

Table B-3. Median Installed Price of Non-Residential Systems by Size over Time (2014$/W$_{dc}$)

System Size (kW_{DC})	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
≤10 kW	-	-	-	10.5	9.8	9.5	9.8	9.5	9.1	9.2	7.6	6.3	5.1	4.4	4.2
10-20 kW	-	-	-	-	-	9.5	9.3	9.0	8.9	8.7	7.3	6.1	5.1	4.3	3.8
20-50 kW	-	-	10.7	9.6	9.1	8.5	8.6	8.8	8.5	8.3	6.8	5.9	5.1	4.4	3.8
50-100 kW	-	-	-	9.5	9.1	8.8	8.5	8.5	8.3	8.3	6.5	5.7	5.0	4.1	3.7
100-250 kW	-	-	-	8.5	8.5	8.4	8.5	8.2	8.2	8.1	6.1	5.2	4.7	4.1	3.6
250-500 kW	-	-	-	-	-	8.4	8.3	7.4	7.5	7.7	5.9	5.1	4.7	4.1	3.4
500-1000 kW	-	-	-	-	-	-	-	7.7	7.3	7.6	5.8	4.8	4.5	3.8	2.9
>1000 kW	-	-	-	-	-	-	-	-	7.5	7.6	5.5	4.6	4.1	3.4	2.7

Notes: Median installed price data omitted if fewer than 20 observations available. Although not presented here, large variation exists around these median values.

Table B-4. Median Installed Price (2014$/$W_{dc}$) by State and Customer Segment over Time

Note: Caution should be used before relying directly on these data, as underlying sample sizes may be small, wide variation may exist around the medians, and data quality may vary significantly from one state to another.

State	Customer Segment	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
AL	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AR	Residential	-	-	-	-	-	-	-	-	-	-	7.0	7.1	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AZ	Residential	6.5	-	-	-	8.3	8.2	8.5	8.0	7.7	7.6	6.4	5.5	4.9	4.0	3.6
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	8.6	8.2	6.8	5.7	5.1	5.1	3.6
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	6.7	5.7	5.4	-
CA	Residential	11.4	11.1	11.1	10.0	9.3	8.9	8.9	9.2	8.8	8.4	7.3	6.6	5.8	5.0	4.6
	Non-Res. ≤500 kW	-	-	10.5	9.1	9.0	8.5	8.5	8.6	8.4	8.5	7.0	6.1	5.2	4.4	4.1
	Non-Res. >500 kW	-	-	-	-	-	-	-	7.5	7.3	7.1	5.8	4.6	4.6	3.7	3.1
CO	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	6.5	6.1	5.1	4.7	4.2	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CT	Residential	-	-	-	-	-	9.7	9.9	10.0	9.3	8.8	7.9	6.6	5.0	4.1	3.9
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	9.0	8.6	8.6	6.2	-	-	3.1
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC	Residential	-	-	-	-	-	-	-	-	-	9.6	7.2	6.6	4.9	3.8	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DE	Residential	-	-	-	-	-	-	9.7	9.7	8.9	8.8	7.3	6.2	4.9	3.9	3.4
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	8.8	8.7	6.8	6.2	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FL	Residential	-	-	-	-	-	-	-	10.8	9.0	8.1	7.7	6.2	4.8	3.5	3.5
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	7.7	7.4	5.3	4.8	3.0	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GA	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	6.5	4.7	4.2	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

State	Customer Segment	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
HI	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	6.3	5.8	5.4	5.7	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IA	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IL	Residential	-	-	-	-	-	-	11.0	10.4	9.9	9.5	8.9	6.6	5.9	5.0	4.4
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IN	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KS	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KY	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LA	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MA	Residential	-	-	-	11.0	9.2	9.7	9.8	9.7	9.3	8.9	7.4	6.4	5.3	4.6	4.4
	Non-Res. ≤500 kW	-	-	-	-	9.9	10.2	11.4	10.2	9.3	8.8	6.5	5.8	4.7	4.3	4.1
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	3.8	3.3	2.6
MD	Residential	-	-	-	-	-	-	11.5	11.1	9.9	9.2	7.0	6.2	4.8	4.2	3.9
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	5.3	4.5	3.7	3.3
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ME	Residential	-	-	-	-	-	-	-	-	-	-	-	-	4.1	3.5	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MI	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

State	Customer Segment	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
MN	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	10.3	-	9.5	8.3	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MO	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NC	Residential	-	-	-	-	-	-	-	-	9.4	9.1	7.4	6.6	5.6	4.9	4.7
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	8.2	6.8	5.4	4.8	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	3.7	3.0	2.7
NH	Residential	-	-	-	-	-	-	-	-	9.8	8.5	6.5	5.8	4.7	3.9	3.6
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	5.4	5.0	3.5	3.4
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NJ	Residential	-	-	11.9	10.3	10.0	9.6	9.4	9.3	8.9	8.7	7.5	6.1	4.7	4.0	3.9
	Non-Res. ≤500 kW	-	-	-	10.5	9.9	9.5	9.0	9.1	8.7	8.6	6.5	5.4	4.9	4.1	3.5
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	5.1	4.6	4.5	3.6	2.8
NM	Residential	-	-	-	-	-	-	-	-	9.8	8.5	7.4	6.4	5.4	4.5	4.3
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NV	Residential	-	-	-	-	-	8.3	8.6	8.6	8.8	8.1	6.8	5.8	5.2	4.0	3.6
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	8.0	5.9	5.3	4.4	3.3	3.0
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NY	Residential	-	-	11.3	9.6	9.6	9.2	9.3	9.6	9.1	8.9	7.6	6.3	5.2	4.7	4.8
	Non-Res. ≤500 kW	-	-	-	-	-	-	8.1	10.1	9.7	9.2	7.8	6.8	5.4	4.9	4.0
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OH	Residential	-	-	-	-	-	-	-	10.4	9.4	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	8.7	7.2	6.7	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OR	Residential	-	-	11.7	8.7	8.2	8.6	9.4	9.7	9.4	8.5	6.9	6.2	5.4	4.8	4.2
	Non-Res. ≤500 kW	-	-	-	-	-	8.5	9.4	9.8	9.1	8.4	7.3	6.1	5.3	4.6	3.7
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

State	Customer Segment	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PA	Residential	-	-	-	10.8	11.7	10.1	-	-	-	8.3	7.2	6.1	4.9	4.1	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	8.1	6.5	5.2	4.5	3.7	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	4.5	-	-	-
RI	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	4.7	4.2
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SC	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	6.3	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TN	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	5.8	4.5	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TX	Residential	-	-	-	-	8.1	7.7	7.8	7.8	7.9	7.2	6.2	5.0	4.0	3.5	3.4
	Non-Res. ≤500 kW	-	-	-	-	-	-	11.9	8.3	8.2	8.4	6.4	6.8	5.4	4.0	2.9
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UT	Residential	-	-	-	-	-	-	-	-	-	-	-	6.2	5.2	3.9	3.9
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7	4.0
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VA	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VT	Residential	-	-	-	-	10.8	11.8	11.3	10.4	9.9	8.7	6.9	6.2	5.1	4.8	4.4
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	6.3	4.8	3.8	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WA	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WI	Residential	-	-	-	11.9	10.8	10.1	9.5	10.1	9.6	9.5	-	6.0	5.6	4.8	4.1
	Non-Res. ≤500 kW	-	-	-	-	-	-	-	9.9	10.2	9.6	8.3	7.2	6.3	-	-
	Non-Res. >500 kW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: Median installed prices are omitted if fewer than 20 data points available. Although not presented here, large variation exists around these median values.

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