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Tracking the Sun, 2021 Edition

Summary Brief

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Berkeley Lab's annual *Tracking the Sun* report describes pricing and design trends among grid-connected, distributed solar photovoltaic (PV) systems in the United States. This summary brief provides an overview of key trends from the latest edition of the report, based on project-level data for roughly 2.2 million systems installed through year-end 2020. For additional information, please refer to the full report and accompanying data resources, all available at http://trackingthesun.lbl.gov.

PV System Characteristics

Characteristics of projects in the data sample help to illustrate trends within the broader U.S. market and provide context for understanding installed price trends. Key technology and market trends based on the full data sample are as follows.

- PV systems continue to grow in size, with median sizes in 2020 reaching 6.5 kW for residential systems and 42 kW for non-residential systems (see Figure 1). Sizes also vary considerably within each sector, particularly for non-residential systems, 20% of which were larger than 200 kW in 2020. Within the residential sector, state-level median system sizes ranged from 6.4 kW to 10.6 kW in 2020, and in most states topped 7.5 kW.

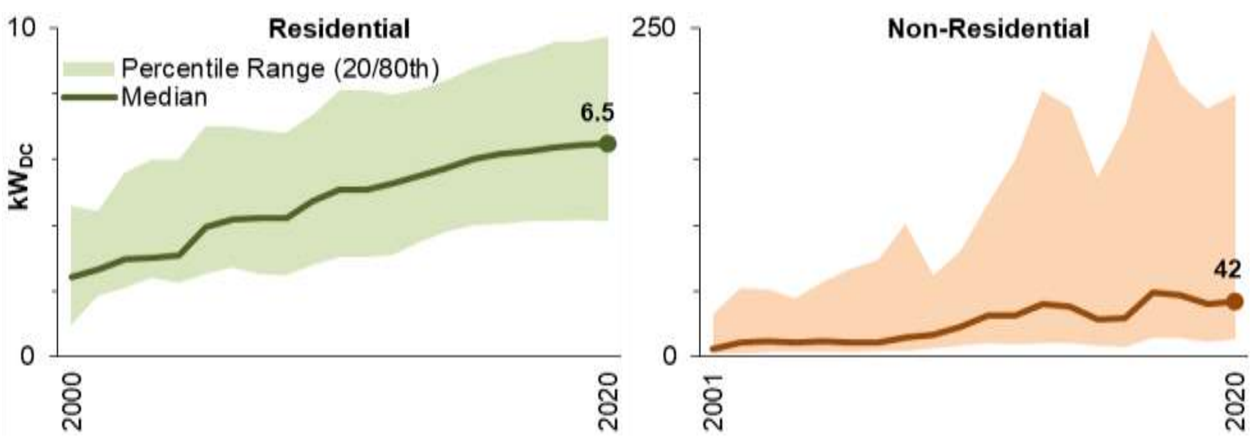

Figure 1. System Size Trends over Time

- Module efficiencies have risen steadily over time: for example, among residential systems, median module efficiencies rose from 13.4% in 2002 (the earliest year with sufficient data) to 19.8% in 2020, with similar rises for non-residential systems as well.
- Battery storage attachment rates (the percentage of PV installations each year that include storage) have been steadily rising in the residential sector, reaching 8.1% of the full data sample in 2020. Non-residential attachment rates are lower and, within the large non-residential segment, have fluctuated over the past several years.

- Module-level power electronics (either microinverters or DC optimizers) have continued to gain share across the sample, representing 94% of residential systems, 71% of small non-residential systems, and 26% of large non-residential systems installed in 2020.[1]
- Inverter-loading ratios (the ratio of module-to-inverter nameplate ratings) have generally grown over time, and are higher for large non-residential systems (a median of 1.23 in 2020) than for residential and small non-residential systems (both 1.16).
- Roughly half (48%) of all large non-residential systems installed in 2020 are ground-mounted, and 10% have tracking. In comparison, 18% of small non-residential and 2% of residential systems are ground-mounted, and negligible shares have tracking.
- Panel orientation has become more varied over time, with 54% of systems installed in 2020 facing southward (180±45 degrees), 24% to the west, and most of the remainder to the east.
- Third-party ownership (TPO) in the residential sample, which includes both leasing and power purchase agreements, has declined over time from a high of 59% of systems installed in 2012 to 35% in 2020. For the non-residential sample, TPO shares have remained comparatively steady and have historically been lower for small vs. large non-residential systems (18% vs. 34% in 2020). TPO shares are generally higher in states with richer incentives.
- For-profit commercial customers make up the largest share (>70%) of non-residential site hosts, with the remainder consisting of some combination of tax-exempt customers (schools, government, non-profits). As to be expected, TPO is considerably more prevalent among tax-exempt site hosts than for commercial hosts (58% vs. 12% in 2020).

Median Installed-Price Trends

The installed price data summarized in the report represent prices paid by system owners prior to receipt of any incentives. In contrast the system design trends summarized above, the analysis of installed pricing trends is based on a subset of the larger data sample, consisting of host-owned, stand-alone PV systems; that is, it excludes TPO systems as well as PV systems paired with batteries. Key trends in median installed prices include the following.

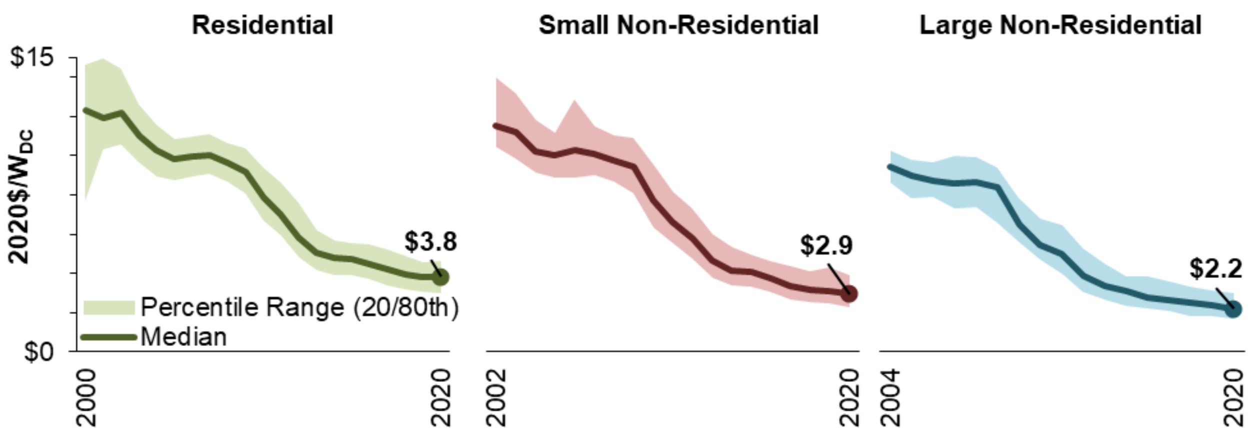

Figure 2. National Installed-Price Trends over Time

[1] Throughout the report, we refer to "Small" vs. "Large" Non-Residential systems. Small Non-Residential systems are defined to be <100 kW, while Large Non-Residential systems are ≥100 kW, up to 5,000 kW_{AC} if ground-mounted or with no upper size limit if roof-mounted.

- Over the long-term, U.S. median installed prices have fallen by roughly $0.4/W per year, on average, but that price decline has tapered off since 2014, with prices dropping since then at roughly $0.1-0.2/W per year (see Figure 2). Over the last year of the analysis period (2019-2020), median prices for residential systems remained effectively flat at $3.8/W, while median prices for small and large non-residential systems both fell by $0.2/W, continuing on their recent trajectory.
- While module prices continued to fall in 2020, those declines were offset for residential systems by a slight uptick in soft costs. This marks a departure from historical trends, where soft costs have generally fallen by $0.1-0.2/W per year, across all three customer segments.
- Year-over-year (YoY) pricing trends at the state-level can deviate from national trends, but tend to converge over longer time frames. In the residential sector, YoY changes in median prices ranged from a $0.5/W rise for WI to a $0.3/W drop for DE. Over the past 5 years, however, median residential prices fell by $0.1-0.2/W across almost all states in the sample. Similarly, YoY changes in the non-residential sector range from a $0.2/W increase to a $0.6/W decrease across individual states, while most states have seen an average 5-year price decline of $0.1-0.3/W per year.
- National median installed prices from the Tracking the Sun dataset are similar to average residential PV system costs reported by several large publicly traded companies, but are higher than several published benchmarks based on bottom-up modeled prices, reflecting the diversity of methods, data sources, and purposes of different cost and pricing benchmarks.
- Median national installed prices in the United States are more than double the prices in most other countries, as reported by the International Renewable Energy Agency; for example, benchmark 2020 residential prices in Germany and Australia were $1.6/W and $1.2/W, respectively, compared to the median price of $3.8/W in the U.S.

Variation in Installed Prices

While trends in median installed prices can be revealing, the installed pricing data also exhibit a substantial level of variability across projects. Key trends related to the variability in pricing across projects include the following.

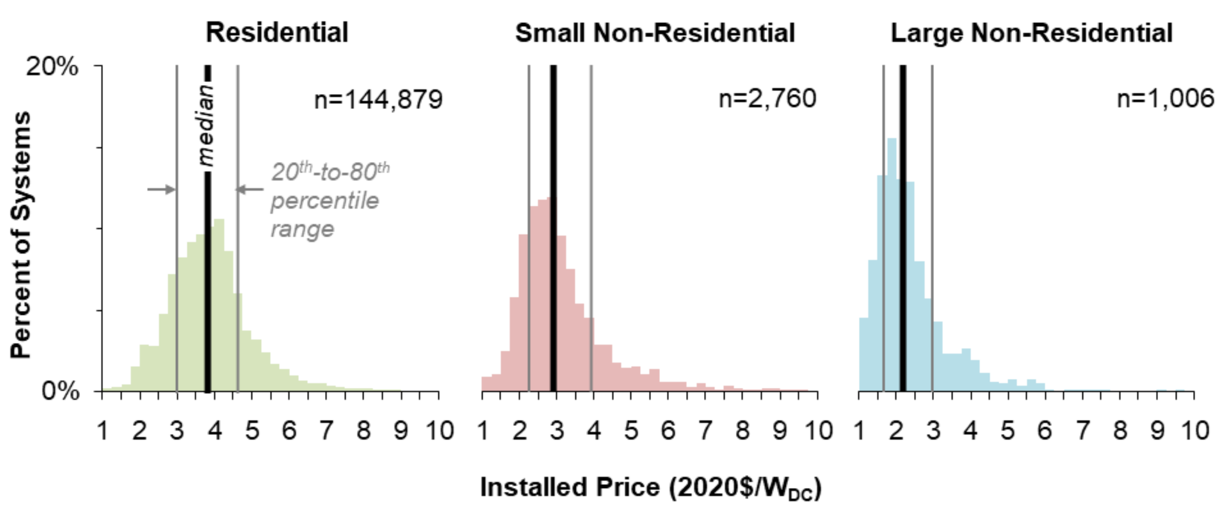

Figure 3. Installed-Price Distributions for Systems Installed in 2020

- As shown earlier in Figure 2, relatively constant levels of pricing variability has persisted over time in each customer segment. This pricing variability is shown in greater detail in Figure 3, for systems installed 2020. Between the 20th and 80th percentiles, prices ranged from $3.0-4.6/W for residential systems, from $2.3-3.9/W for small non-residential systems, and from $1.7-3.0/W for large non-residential systems.
- Installed prices within each customer segment vary substantially depending on system size, with a difference of $1.1/W in median prices between the smallest and largest residential systems, and $1.9/W between the smallest and largest non-residential systems.
- Installed prices vary widely across states, with state-level median prices ranging from $2.9-4.6/W for residential, $2.1-3.8/W for small non-residential, and $1.7-2.4/W for large non-residential systems. Notably, California—which makes up an outsized portion of the sample—continues to be a relatively high-priced state, driving overall U.S. median prices upward.
- Across the top-100 residential installers in 2020 (by volume), installer-level median prices generally ranged from $3-5/W, with most installers exhibiting a 20-80th percentile band of at least $1.1/W around their respective medians.
- Within the non-residential sector, installed prices are generally higher for systems installed at tax-exempt customer sites, compared to prices for commercial site hosts, with the most pronounced differences occurring large non-residential systems in California, where tax-exempt customers paid a median price of $3.4/W in 2020, compared to $2.2/W for commercial customers.

The full report also provides descriptive trends comparing median installed prices based on module efficiency and the use of MLPEs, though those pricing differences tend to be relatively small and are more clearly defined through the regression analysis below.

Econometric Analysis of Pricing Variability

We apply a multi-variate linear regression model to estimate the effects of individual factors on installed prices, focusing specifically on host-owned residential PV systems without storage and installed in 2020. This statistical model, described further in Barbose, Darghouth et al. (2019), includes variables related to system, market, and installer-level characteristics, as well as state- and quarterly fixed effects variables. Key results from this analysis, as depicted in Figure 4, include the following.

- Of the system-level pricing drivers, the largest effects are associated with system size ($0.38/W range between the 20-80th percentile sizes) and ground-mounting (+$0.40/W), though ground-mounting is relatively uncommon among residential systems.
- Effects are smaller for premium efficiency modules (+$0.14/W), microinverters (+$0.14/W), DC optimizers (+$0.24/W), and new construction (-$0.08/W).
- Effects associated with the various market- and installer-related drivers are all relatively small (<$0.2/W), but in general are directionally intuitive (e.g., lower prices in larger markets and for installers with more experience) and are consistent with prior research.

- Even after controlling for these various system-, market-, and installer-level variables, the regression analysis still found substantial residual pricing differences across states (a $1.4/W range), indicating that other, unobserved factors significantly impact installed prices at the state- or local-levels.

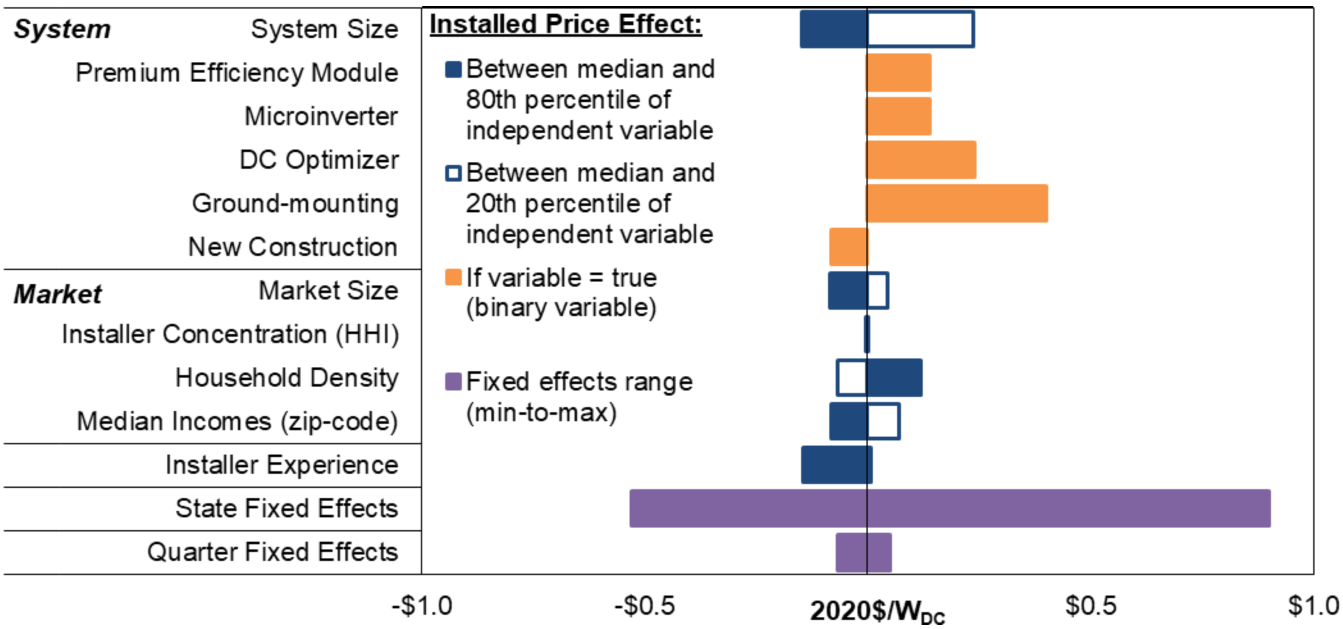

Figure 4. Sensitivity of Installed Prices to Modeled Pricing Drivers

Notes: For continuous variables, the figure shows the effect on system prices associated with moving from the median to the 20th percentile and from the median to the 80th percentile values of those variables. For binary variables, the figure shows the effect if that binary variable is true, and for fixed effects variables, the figure shows the range between the minimum and maximum effect of the variables in each set. All regression coefficients are significant at the 95% level (R^2 = 0.12).

Data Sources and Market Coverage

Trends in the report derive from project-level data provided by state agencies, utilities, and other organizations that administer PV incentive programs, renewable energy credit registration systems, interconnection processes, and net metering programs. Altogether, 63 entities spanning 30 states contributed data to this edition of the report.

The full data sample consists of roughly 2.2 million individual PV systems, representing 79% of all U.S. distributed PV systems installed through 2020, and 67% of systems installed in 2020 (see Figure 5). The analysis of installed prices is based on a subset of the full data sample, consisting of host-owned, stand-alone PV systems, totaling roughly 1.0 million systems installed through 2020. California and several other large state markets comprise a large share of the sample, as in the overall U.S. market, while smaller state markets tend to be under-represented in the sample.

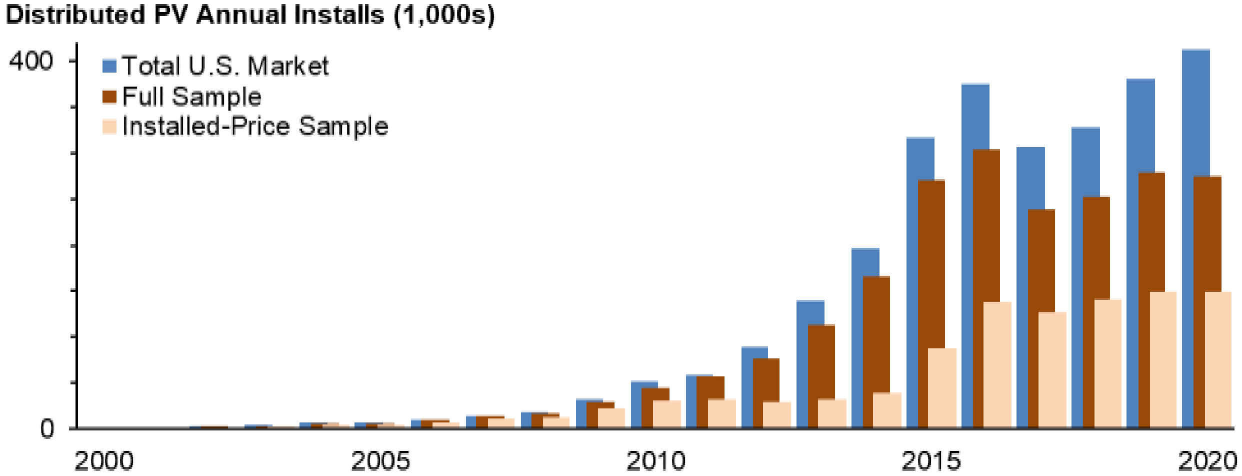

Figure 5. Sample Size Relative to Total U.S. Market

Notes: Total U.S. Market size is based on data from Interstate Renewable Energy Council for all years through 2010 and from Wood Mackenzie and the Solar Energy Industries Association for each year thereafter.

Acknowledgements

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