# What Factors Affect the Prices of Low-Priced U.S. Solar PV Systems?

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## Overview

A key goal for the solar industry, policymakers, and other decision makers—as exemplified by the U.S. Department of Energy's *SunShot Initiative*—is to foster continued, dramatic declines in solar costs, in order to facilitate a sizable future role for this technology in meeting energy supply needs. And yet, despite impressive recent cost reductions, there remains a considerable range of installed prices for small-scale solar photovoltaic (PV) systems in the United States. Past research by our team has explored some of the reasons for this pricing variability, broadly exploring factors affecting pricing differences (Gillingham et al. 2014) and identifying the impact of local regulatory and permitting processes (Burkhardt et al. 2015; Wiser and Dong 2013) and solar rebates (Dong et al. 2014).

Most recently, we have sought to pinpoint the characteristics of low-priced PV systems (Nemet et al. 2016a), defined here as the 10 percent of small-scale systems that are lowest priced. That study found that low-priced systems are associated with experienced installers; customer ownership; larger system size; retrofits rather than new home construction; and thin-film, low-efficiency, and Chinese modules. The analysis also found that low-priced systems are much more likely to occur in some states (e.g., AZ, CT, NJ, NM, ME, and NH) than in others (e.g., CA). Finally, low-priced systems are more likely to occur in the presence of higher incentives, at least in California.

The current study—conducted by researchers from University of Wisconsin, Yale University, University of Texas, LBNL and NREL—extends the work of Nemet et al. (2016a) by statistically evaluating what might drive low-priced systems to be *even lower priced*. Our research questions are: (1) What factors are associated with still-lower prices among low-priced PV systems, (2) Are those factors different from those for median-priced systems, and, ultimately, (3) What can be done to reproduce or facilitate those conditions more broadly, to drive down U.S. PV system prices?

## Data and Methods

The study relies on LBNL's sizable *Tracking the Sun* data set of system-level PV prices, supplemented with other data sets. We restrict our sample to systems: installed in 2013, sized from 1 kW to 15 kW, with prices between $1/W and $25/W, with known PV installers, and with known locations. Appraised-value third-party owned (TPO) systems are excluded from the analysis, but other TPO systems for which prices reflect transactions between installers and finance providers are retained. The final sample contains 42,611 PV systems across 15 states. Among these systems, the median price is $4.7/W, with the 10 percent of low-priced systems priced at $3.5/W and below.

This fact sheet summarizes the full report: Nemet et al. 2016b. *What Factors Affect the Prices of Low-Priced U.S. Solar PV Systems?* Berkeley, CA: Lawrence Berkeley National Laboratory. The full report is available here or via emp.lbl.gov/reports. This work was funded by the Solar Energy Technologies Office, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

In order to help gauge the possible drivers for achieving even lower PV system prices, as might be needed if solar is to play a major role in energy supply, we first examine certain descriptive characteristics of the trends and patterns in the entire data set, focused on low-priced systems. We then use "quantile" regression models to assess each variable's significance in driving lower prices both for median PV systems (priced ~$4.7/W) and low-priced PV systems (priced below $3.5/W).

## Results

Figure 1 summarizes some of the results of the study. For median-priced systems, consistent with Gillingham et al. (2014), drivers for lower costs include: larger system size, lower module and inverter prices, a lower "customer value of solar" but with greater revenue from SRECs, greater county-level installer experience, and locations with a smaller number of active installers and lower household density. Among the binary variables, factors that drive median-priced systems towards lower prices include: commercial installations (rather than residential), customer ownership (rather than third-party), thin-film modules, systems installed in new construction, and self-installations.

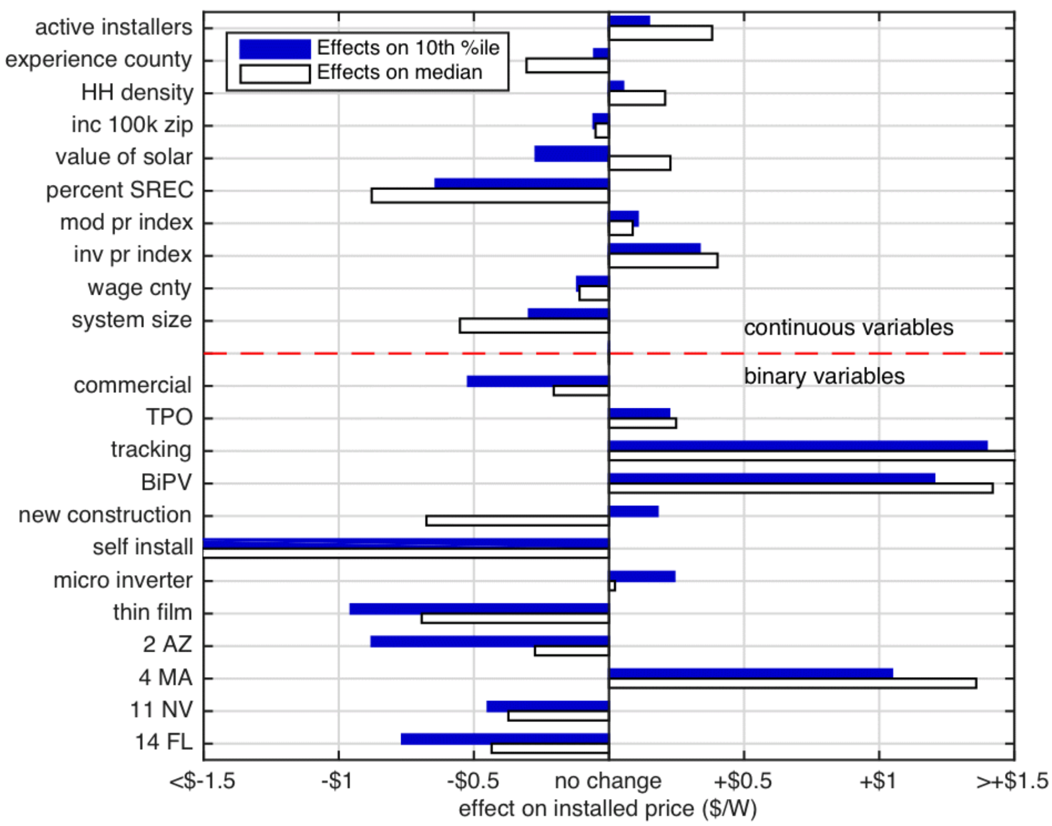


**Figure 1. Values indicate change in price from moving from 5th to 95th percentile for each variable. Blue bars represent effects on median-priced systems; white bars represent effects on low-priced systems.**

For low-priced PV systems, many of the same drivers still apply: most factors that drive down the price of median systems can also drive down further the price of already low-priced systems. Among the continuous variables, we see the largest effects in making low-priced systems even cheaper from system size, percentage SREC revenue, as well as module and inverter pricing. Greater county-level installer experience and areas with fewer active installers and lower household density are also found to make low-priced systems even cheaper, though the size of these effects is not particularly large. For the binary variables, the largest factors increasing prices for low-priced systems were tracking systems, building integrated PV, and being installed in Massachusetts. The largest price-reducing effects were from commercial systems, self-installations, and thin film, as well as being installed in Arizona, Nevada, and Florida.

Two key differences among the drivers for lower-prices among median-priced and low-priced systems stand out: new construction and customer value of solar.

**New construction:** In the case of PV systems installed in new construction (as opposed to being retrofitted on an existing house), we find that for median-priced systems, new construction can yield lower prices, but the opposite is observed for low-priced systems. Specifically, for median priced systems, prices for installations on new construction are $0.68 less than on existing homes. On the other hand, installations on new homes make low-priced systems $0.18/W more expensive than installations on existing homes.

Though the underlying reasons for this discrepancy are unclear, it is possible that—for median-priced systems—the economies of scale that come from volume installations in new subdivisions can drive prices lower, on average. The distribution of prices for new construction, however, is narrower than for PV retrofits, enabling a greater prevalence of low-priced systems among retrofits. Systems installed in new construction tend to be standardized, with housing developers less-likely to take risks in order to achieve very low prices. In part as a result, PV systems installed in new construction often use higher-quality and therefore potentially more-costly equipment, e.g., higher-efficiency solar modules. The benefits of volume installations may be offset by these other factors for low-priced systems. In retrofit applications, on the other hand, some particularly budget conscious consumers and installers may be more-willing to accept risks in order to lower installed costs. *As such, policymakers seeking to drive down PV system prices may wish to place some emphasis on the new home construction market, but should recognize that, while those systems are likely to be lower priced on average, they may not be the absolute lowest priced among all systems.*

**Customer Value of Solar:** Perhaps the most policy-relevant aspects of our findings relate to the customer value of solar (VoS), which reflects the present value of all incentives and electricity bill savings over the lifetime of a system. Specifically, our previous work suggests the presence of "value based pricing" at least for median-priced systems: those areas with a higher customer VoS also tend to have higher-priced PV systems, perhaps due to less-than-complete competition and the customer transaction costs of searching for lower prices. The same result is shown in Figure 1, for median-priced PV systems. The current research, however, also shows that—for low-priced PV systems—a higher customer VoS can actually yield even-lower prices. Specifically, for low-priced systems, moving from the 5th percentile of VoS ($3.39/W) to the 95th percentile ($8.32/W) reduces installed prices by $0.27/W. In contrast, VoS has the opposite effect at the median; a higher VoS increases the prices of systems by $0.23/W.

Again, the underlying reasons for these findings are require interpretation, and are somewhat speculative. It is possible that high customer VoS markets are fundamentally different than other markets. Specifically, our analysis suggest that VoS has a positive effect on prices up to a VoS of about

$6.8/W (i.e., "value based pricing"), and a negative effect on prices beyond $6.8/W. One reason for this—supported by the data—may be that high VoS systems (>$6.8/W) are located, in general, in more competitive solar markets, where "value based pricing" is offset by the presence of an active and competitive market of installers and greater levels of customer search. As such, it is plausible that value-based pricing drives a positive relationship between VoS and system pricing in less competitive low-VoS markets, while opposing forces such as economies of scale and market competition drive a negative relationship between VoS and system pricing in more competitive high-VoS markets.

*The policy implications of these findings are somewhat unclear. However, it is clearly appropriate for policymakers responsible for helping to define and set the customer VoS through incentives or rate design to pay close attention to the possibility of "value based pricing," which may especially affect average system prices. Tuning incentive levels to combat value based pricing and establishing programs to encourage installer competition and provide information to possible PV purchasers might be appropriate responses. At the same time, however, boosting the customer VoS might help drive very low-priced systems in some cases, especially in markets with active competition. To the extent that, over time, programs to increase customer VoS help spur active competition and facilitate customer search, value-based pricing may be offset by a growing presence of low-priced systems.*

## Conclusions

These results, in concert with our previous findings, can inform solar policy aimed at stimulating cost reductions, and our evaluation of low-priced PV systems might presage what average systems may look like in the future, as prices continue to drop. At the same time, the results raise questions about which drivers of even-lower-priced systems are controllable and which are likely to be exogenous or driven mainly by installer behavior or consumer preferences. If a goal of policy is to generate—and learn from—new system configurations, financing models, and adoption dynamics, then policy makers should examine these results and consider which low-priced system price drivers are appropriate for intervention via public incentives. Of particular note, our results suggest that solar subsidies might positively influence the incidence of even-lower-priced systems in some areas, but not in others. This analysis has focused on the 12 months of installations in 2013, however, a limited time period when prices were relatively stable. Ultimately, it will be important to identify the effects of policy (e.g. via the VoS variable) on the longer term evolution of PV prices over a number of years—with a special emphasis on the drivers of prices for systems at the low end of the price distribution. This will help enable improved assessments of the effects of policy on these longer-term goals and thus inform future polices on how most effectively to stimulate further cost reduction