Deconstructing Solar Photovoltaic Pricing:

The Role of Market Structure, Technology, and Policy

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Overview

Installations of solar photovoltaic (PV) systems have expanded rapidly over the past decade, with continued growth anticipated over the near- and longer-term. Along with this growth has been a substantial decline in PV system prices. Amid this decline, however, there remains considerable heterogeneity in PV system pricing. For example, among residential and small commercial systems installed in the United States in 2013, roughly 20 percent were sold for less than $3.90/Watt (W), while a similar percentage was priced above $5.60/W.

Researchers from Yale University, University of Wisconsin—Madison, University of Texas—Austin, and Lawrence Berkeley National Laboratory empirically examined observed heterogeneity in PV prices in the United States. The research explored different plausible sources of price variation, including characteristics of the PV systems and household demographics, as well as measures of installer competition, installer experience, demand for PV, and public policy. A rich dataset of nearly 100,000 PV systems over the 2010-2012 timeframe was analyzed, focusing on systems under 10 kW. Because of the study's scope, the results may not apply to third-party owned (TPO) PV systems.

The study finds, not surprisingly, that PV prices differ based on system characteristics. More interestingly, there is evidence that search costs, imperfect competition, installer experience, and public policy all affect solar PV pricing. A greater number of installers in the local market and higher levels of installer experience are both found to lower prices, while regions with relatively generous financial incentives for solar PV are associated with higher prices. By exploring how these factors influence PV prices in the United States, the research sheds light on sources of price variability that may be amenable to policy interventions aimed at facilitating cost reductions.

Methods and Data

The approach used in this study follows an extensive literature on price dispersion, and estimates the reduced-form relationship between PV prices and a wide variety of supply and demand factors that may impact those prices. The study relied on LBNL's sizable *Tracking the Sun* dataset of system-level PV prices. Additional data were compiled from SEIA/GTM, DSIRE, IREC, and the U.S. Census Bureau. Only system-level installation prices between $1.5/W and $20/W were retained, system size was limited to 1 kW to 10 kW, and only PV systems installed between 2010 and 2012 were included. Appraised-value TPO systems were excluded from the analysis, but other TPO systems for which prices reflect transactions between installers and finance providers were retained. The final sample contains 98,586 PV systems across 14 states.

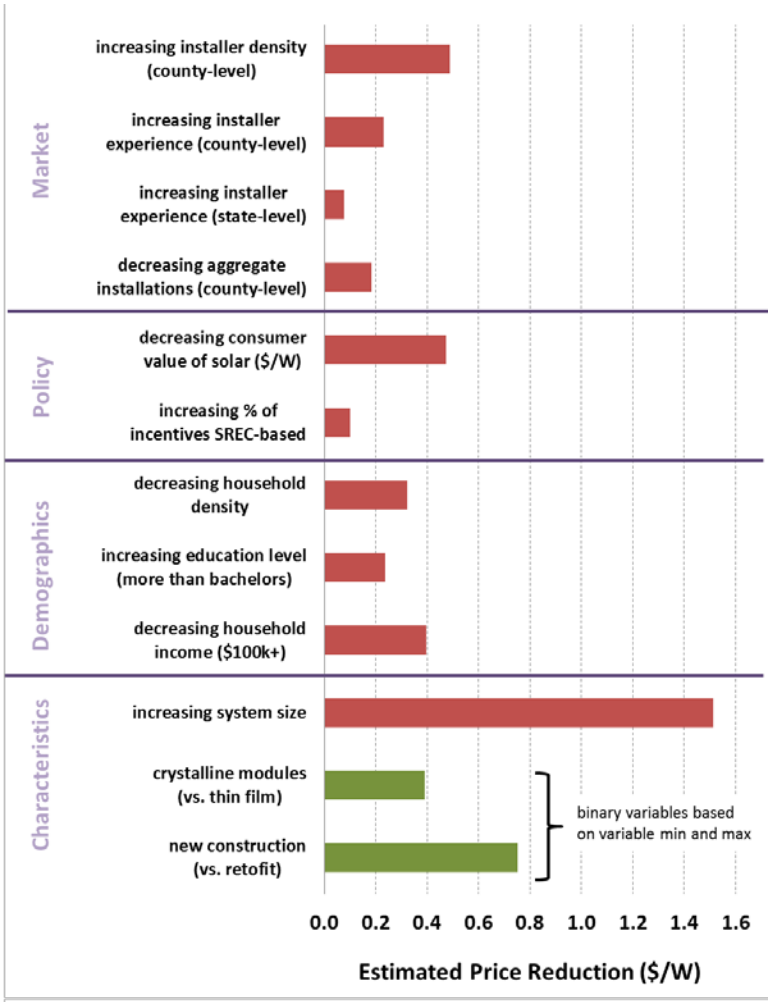
This fact sheet summarizes the full report: Gillingham et al. 2014. *Deconstructing Solar Photovoltaic Pricing: The Role of Market Structure, Technology, and Policy*. Berkeley, CA: Lawrence Berkeley National Laboratory. The full report, along with a summary slide deck, is available here or via emp.lbl.gov/reports. 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.

Results and Conclusions

The results demonstrate that a wide variety of factors can and do impact PV system pricing. Even after controlling for many plausible price drivers, however, much of the variation in prices remains unexplained. This suggests that highly installation-specific (unobservable) characteristics, such as the suitability of the roof or the willingness of the consumer to search for a lower price, may impact prices.

Key findings from the study include (see Figure 1):

- **PV system characteristics** have a strong influence on pricing: larger PV systems, even within the narrow range of 1 kW to 10 kW, are associated with lower prices per W; tracking, thin-film panels, building integrated panels, and batteries all increase prices; and systems installed as part of new home construction or that were self-installed have lower prices.
- **Installer competition and consumer search costs** affect pricing; for example, as the density of installers active in a local market increases, PV system pricing declines.
- **Installer experience and economies of scale** at the state and especially at the county level are found to reduce prices, consistent with a large literature on learning-by-doing in new technologies.
- **Policy variables** influence prices, as regions with a higher "consumer value of solar," which accounts for utility bill savings and incentives, tend to experience higher prices; these results may stem from a demand shift due to the higher incentives, or alternatively, may be a symptom of imperfect competition whereby installers are able to "value-price" systems based on consumer willingness to pay.



Notes:
The bars present the pre-incentive price reduction (per watt) from moving from the 5th to 95th percentile of each variable. For green bars, the range reflects the minimum to maximum as these are binary variables. Not all variables are presented in this figure; results for variables on HHI, sales tax, interconnection score, other educational and income categories, local labor cost, customer segment, third-party-owned, tracking, BIPV, battery, inverter and module indices are found in the full report.

Figure 1. Impact of Various Drivers in Reducing PV Prices

- **Demographic factors** influence prices: greater regional household density and household income increase prices, whereas greater levels of education in the region decrease prices.
- **Factors that increase demand** for or willingness to pay for PV, including many noted above and also including the aggregate number of PV systems in the local market, are found to increase system prices.

These results have several implications for policy:

- First, they provide a broad view of the factors influencing PV pricing. This overview is important given that price reduction is a stated policy objective.
- Second, several of the results are directly relevant for policymakers since they may involve market failures or other justifications for government intervention. Government efforts to foster a competitive market for PV, e.g., by encouraging entrants and reducing information search costs, have strong potential to bring down prices. Installer experience is also found to reduce prices. This result is important for forecasting future prices for PV systems, and indicates that efforts to increase deployment—whether publicly or privately funded—are likely to reduce costs.
- Finally, we find evidence of how policy actions, for example changes to the magnitude of financial incentives offered for PV, may directly influence prices. Attention may therefore be required when designing and evaluating deployment policies aimed at achieving cost reductions, given the potential for such policies to elevate prices in the short-term.