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# Evaluating the impact of third-party price reporting and other drivers on residential photovoltaic price estimates

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## HIGHLIGHTS

- This analysis evaluates residential PV price drivers using an econometric model.
- Reported prices for appraised systems are $1.13/W higher than non-appraised.
- Reported prices for appraised systems do not respond to expected price drivers.
- We find some evidence of market distortions in non-appraised systems.
- Installer heterogeneity is a substantial price driver for all systems.

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## ABSTRACT

*Aim:* Policy-makers typically track the rapidly evolving U.S. residential photovoltaic (PV) market by relying on price data reported by PV installers/integrators to incentive programs. Recent years have witnessed a shift toward third-party-owned (TPO) business models, in which the absence of a cash purchase price obscures data interpretation. Appraisals—often based on estimates of the average fair market value across a diverse fleet of systems—are one way TPO prices are reported.
*Scope:* This study investigates residential PV system price drivers to improve the accuracy, consistency, and relevance of PV price-tracking efforts. Our econometric approach evaluates system price drivers using California Solar Initiative data, controlling for system, installer, and geographic variables.
*Conclusions:* We find that reported prices for confirmed appraised systems are $1.13/W higher than non-appraised systems and do not respond to hypothesized price drivers. For non-appraised systems, we find preliminary evidence of market distortions based on the impact of the incentive level, module cost and household income on reported price. Further, unspecified installer heterogeneity—possibly due to differences in products, cost structure or reporting practices—is a substantial price driver. Using estimates, we develop a price model to approximate non-appraised system prices.


## 1. Introduction

The U.S. market for residential photovoltaic (PV) systems has grown rapidly over the past few years. Nationally, residential PV capacity has grown from roughly 100 MW in 2006 to over 1.2 GW in 2012 (Barbose et al., 2012; GTM Research and SEIA, 2012). With this growth, installed prices have declined precipitously, falling by almost 50% from 1998–2011 (Barbose et al., 2012). Given this rapid growth, there has been a concerted effort to track developments in this maturing market and to improve understanding of changes in PV installation cost and price trends over time.

A number of recent analyses estimate and track the price of installed PV systems through time (Barbose et al., 2011, 2012; Feldman et al., 2012; Goodrich et al., 2012; United States Department of Energy, 2012); however, differences in data sources and methodologies employed have produced often varying estimates of installed prices. Goodrich et al. (2012) developed a detailed project cost model for residential PV systems that estimates the installed price based on the sum of individual system costs including equipment costs (modules, inverters, and wiring), labor rates, permitting costs, profit margins, and other supply chain costs. Barbose et al. (2011, 2012) have based analyses on price figures reported to incentive programs by system installers/integrators. However, price tracking based on incentive program data is increasingly obscured by a definitive shift towards third-party owned (TPO) systems (Fig. 1).

A TPO PV system, rather than being owned by the resident or owner (the host) of the PV site, is owned by an outside party who either leases the system to the host or charges the host for the electricity produced by the system and consumed by the host. Because no outright cash purchase price exists for TPO systems, installers cannot report the sale or cash purchase price to incentive

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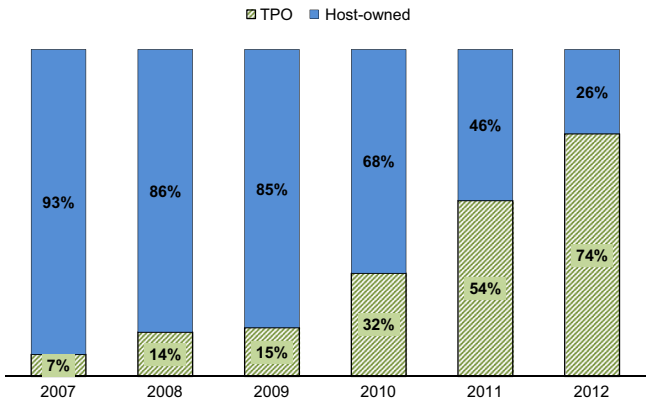


**Fig. 1.** Third-party owned systems as a percentage of the number of systems installed annually under the California Solar Initiative (2007–2012).

programs. Instead, installers either report a figure based on the system's fair market value (FMV) or, in some cases, the transaction between the financer and the installer/contractor or a bill of materials. The FMV of a solar property is based on the investor's appraised value of a fleet of systems, which often have widely varying characteristics. This value is derived by aggregating the discounted cash flows accruing to an example project (e.g., monthly system lease payments, state and federal incentives) and applying the resulting value to a fleet of systems. The stream of revenues associated with a system can be high; thus FMV prices historically have been higher than prices reported for host-owned systems (Bromley, 2012). On the other hand, the transaction between the financer and the installer, as well as the bill of materials figure, can underestimate the installed system price by excluding either financing costs and/or installer profit. Unfortunately, installers do not specify the particular metric they report to incentive programs; as a result, incentive program price data may represent different measures of value depending on installer practices, particularly for TPO systems. We therefore hypothesize that variation in reporting practices, particularly for TPO systems, may lead to a bias in reported prices.

We use an econometric approach to evaluate the drivers of installed PV prices, including potential limitations on the accuracy and consistency of price estimates introduced by third-party price-reporting practices. In addition, we explore the extent to which market conditions suggest non-marginal pricing of PV systems. We rely on data from the California Solar Initiative (CSI)—the most comprehensive data on U.S. installed solar available—and control for various system-specific and geographic variables that may influence installed prices.

## 2. Data and methodology

### 2.1. Data

This study uses data reported to the CSI to identify and explore the key drivers of variation in the installed price of residential PV systems in California and to examine how third-party ownership and price-reporting practices influence pricing trends. The CSI, administered by the California Public Utilities Commission (CPUC), is the largest U.S. solar incentive program; to date, the CSI has awarded grants for more than 100,000 systems. Although we focus solely on the California residential PV market, the CSI database represents an estimated 33% of the approximately 2 GW of residential and non-residential capacity installed nationwide (Barbose et al., 2012).

The CSI provides a cash rebate to an owner of a residential PV system based on the expected performance of the system. Initially, the CSI offered a cash incentive of \$2.50/$W_{AC}$[1]; however, to drive continued PV price reductions, the CSI incentive rate has declined incrementally as the program reaches cumulative installed capacity goals (separately specified in each of the three utility areas that CPUC regulates). As of October 2012, the incentive ranged from \$0.20–\$0.35/W for commercial and residential systems depending on the utility service area (CPUC 2011).

As part of the CSI incentive application process, the CPUC requires that the applicant submit PV system details. The CPUC provides a subset of these data to the public, including the system cost,[2] system capacity, host customer location (city, zip code, and county), number of modules, module manufacturer and type, installer company, and various dates related to the application process including the dates on which the incentive reservation was requested, approved, and paid.

On June 29, 2012, we downloaded system-level CSI data from more than 99,000 residential and commercial PV systems requesting incentives from 2007–2012. From these data, we excluded all commercial systems as well as any residential systems with a capacity greater than 10 kW. In addition, we excluded systems using cadmium-telluride modules as well as systems that had been canceled, withdrawn, removed, suspended, or transferred. In order to minimize the impact of outlier prices, we excluded systems outside the range of \$2.00–\$13.00/W. After cleaning the data, 67,006 observations remained in our final dataset.[3]

In addition to the CSI data, we drew from external data sources and aggregated the CSI data at the installer level to control for additional relevant factors beyond those fields supplied by the CSI. External data sources included the Bureau of Labor Statistics, the U.S. Census Bureau, and various sources for average module selling price. All control variables were linked to individual systems by system ID (where CSI provides system-specific data), system geographic location, or system installer.

### 2.2. Methodology

We used a multivariate linear regression approach to evaluate drivers of the variation in California's installed residential PV prices from January 1, 2007 through June 29, 2012. We report results from four model specifications to examine various drivers of reported prices.[4] In all cases, the dependent variable was the pre-rebate installed price in real 2010 dollars,[5] calculated as the quotient of a system's total installed price reported to the CSI (\$) and the system capacity or size (W). This multivariate regression approach assumes that reported prices take the following form[6]:

$$\text{Price}_i = \beta X + e \quad (1)$$

[1] Alternating current.

[2] While the CSI specifically requests that installers report the system cost, throughout the analysis we refer to these data as prices, understanding that they may represent price or cost depending on the reporting practices of the installer.

[3] Lower limit (\$2.00/W) consistent with (Barbose et al., 2012). Upper limit (\$13.00/W) selected as an subjective outlier cutoff point based upon viewing a scatterplot of prices.

[4] Additional specifications were run, but the results were omitted due to space constraints.

[5] Adjusted according to the California Consumer Price Index for Urban Consumers.

[6] While a true transaction price is simultaneously driven by supply and demand conditions, and therefore, requires a different parameter estimation procedure, this analysis recognizes that 'reported prices' do not consistently represent a transaction between the same types of buyers and sellers. As a result, parameter estimation does not lend itself to a theoretical structural form. Nevertheless, the explanatory variables described in proceeding sections are reasonably believed to be exogenous drivers of reported prices, and therefore reliable descriptors of the association between the independent and dependent variable(s).