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**ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY**

# Exploring California PV Home Premiums

**Ben Hoen, Geoffrey T. Klise, Joshua Graff-Zivin, Mark Thayer, Joachim Seel and Ryan Wiser**

**Environmental Energy Technologies Division**

**December 2013** **(version 2)**



This research builds on work published in 2011 entitled "An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California," LBNL-4476E, which can be downloaded here: [http://eetd.lbl.gov/ea/emp/reports/lbnl-4476e.pdf](http://eetd.lbl.gov/ea/emp/reports/lbnl-4476e.pdf).

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# EXPLORING CALIFORNIA PV HOME PREMIUMS

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# Executive Summary

Although photovoltaic (PV) penetration in the United States is increasing rapidly, properly valuing homes with PV systems remains a barrier to PV deployment. Previous studies show that PV homes command sales price premiums. Still, some appraisers and other home valuers assign no value to a home's PV system, and those who do often cannot find comparable home sales to help determine the PV premium. This has spurred the development of alternative methods of valuing PV homes, including the use of an income approach (based on the present value of PV energy produced over its useful lifetime) and the replacement cost approach (based on the present installed cost equivalent of the PV system). However, those approaches have just begun to have been validated against actual market premiums. Moreover, the drivers underlying PV home premiums are not well understood, which may deter some appraisers from assigning value to PV systems.

This study, which builds on a previous study conducted by the same authors (Hoen et al., 2011; 2013), helps fill both of those gaps by: 1) using regression analysis to examine actual PV home sales price premiums from a large dataset of California PV homes; 2) exploring the sensitivities of those estimated premiums to the size and age of the installed PV system at the time of home sale, and 3) comparing the actual premiums to predictions made with the income and cost approaches.

Our analysis offers clear support that a premium exists in the marketplace; thus, PV systems have value, and their contribution to home values must be assessed. We find that premiums in California are strongly correlated with PV system size and weakly correlated with PV system age, in other words larger systems garner larger premiums and older systems garner smaller premiums. We estimate that each 1-kW increase in size equates to a \$5,911 higher Premium ($p$-value 0.000) and each year systems age equates to a \$2,411 lower premium ($p$-value 0.087).

Additionally, the actual California premiums appear to erode over time (estimated to be approximately 9% per year), more quickly than either the income (approximately 0.5% per year) or cost approaches (5% per year) predict and thus the premiums for homes with older systems (e.g., between 6 and 10 years old) appear to be substantially smaller than predicted.

Further, premiums appear to be substantially larger than predicted using the income (42% of premiums when the average income estimate is used, $p$-value 0.000) and cost approaches (65% of premiums, $p$-value 0.000). There are a number of plausible explanations for this disparity including: premiums might be larger because buyers were willing to pay more for the PV system owing to its green cachet; there could be transaction costs that are avoided by purchasing a home with a PV system already installed that are not incorporated in the cost estimates; the average utility-specific California residential electricity retail rates, which are used for the income estimates, might be lower than they should be in CA where steeply tiered rates are commonplace; and, the market-based Premium estimates could contain effects from omitted variables and therefore potentially overestimate the actual premiums.

We conclude by proposing future research ideas to further improve understanding of the impact of PV systems on home values and therefore related barriers to deployment.

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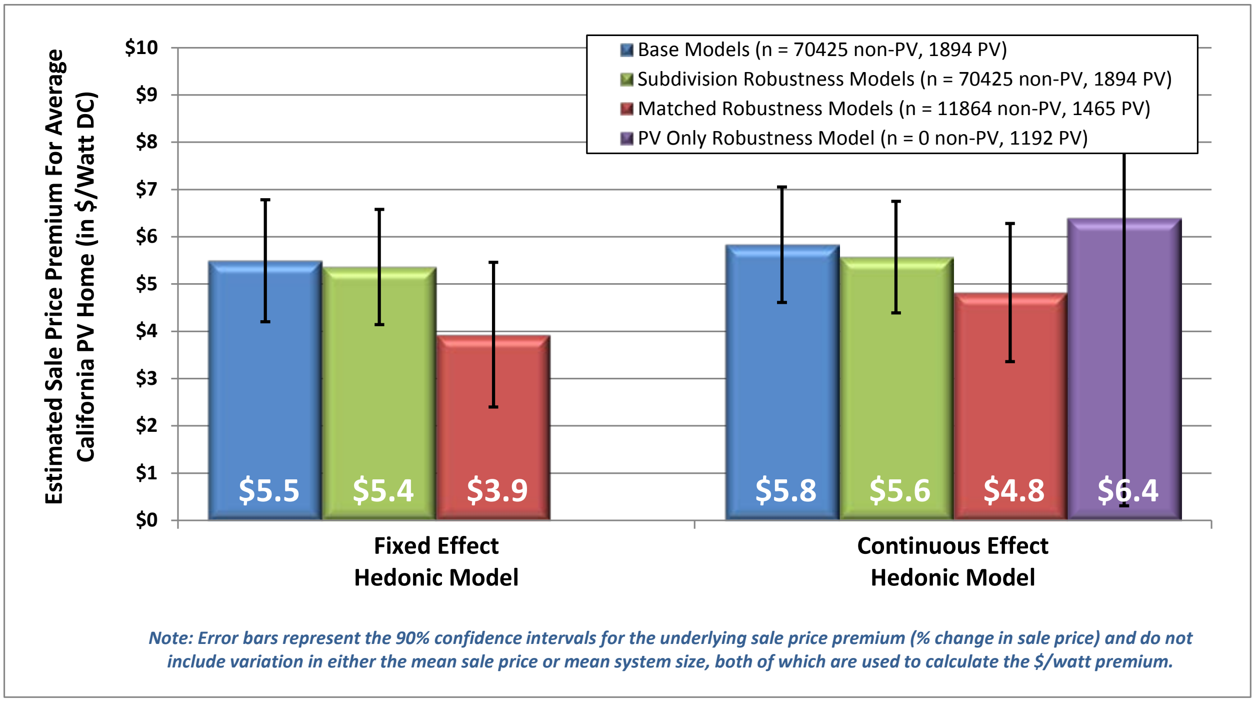
# 1. Background

Photovoltaic (PV) penetration in the United States is increasing rapidly, but challenges in properly valuing homes with PV systems remain a barrier to PV deployment. Solid empirical evidence shows that homes with PV garner a sales price premium (Farhar et al., 2004; Hoen et al., 2011; Dastrup et al., 2012; Desmarais, 2013; Hoen et al., 2013); Figure 1 shows a set of premium estimates from Hoen et al. (2011; 2013) derived from a variety of different hedonic models (e.g., "fixed" vs. "continuous"; "base" vs. "robustness").[1] Still, the banking, appraising, and assessment communities have been slow to establish a protocol for, and confidence in, valuing PV systems as part of appraising/assessing a home's value (Klise et al., 2013b). This is due in part to the difficulty in transferring the average results from large study samples to individual homes. Although appraisers might expect, because of the existing analyses, to find some PV premium in the market, they also would be expected to rely on "comparable sales" near any target home (the most common method used by appraisers) to corroborate that expectation and determine the level of the premium of the target home based on market conditions at the time of appraisal. Rarely is there a high enough density of "comparable" PV home transactions near target homes to enable such an analysis.

**Figure 1: Estimated Sale-Price Premiums for California PV Homes (Hoen et al., 2011, 2013)**




In part to fill this methodological gap, other valuation methods not typically used for residential properties have been proposed for PV homes, such as the *income approach* and the *replacement cost approach*, (referred to, for the remainder of the document, as simply the *cost approach*[2]) both of which are familiar techniques to appraisers, underwriters, and assessors and other valuers for use with commercial properties (Klise et al., 2013b). The *income approach* assumes that the value of an asset is developed using the

[1] The differences between these models are described in detail in Hoen et al., 2011.
[2] Actually the replacement cost approach is one of a few cost approaches that appraisers use, but for the purposes of this document it will simply be referred to as the *cost approach*.

discounted present value of the stream of income an asset produces over time. In the case of a PV system asset, this income is the avoided energy costs (i.e., energy cost savings). If a home costs less to "operate," it should be, all else being equal, assigned a higher value than similar homes (Eichholtz et al., 2009).

The *cost approach* assumes an asset should be worth approximately what the cost to replace it with a similar asset would be. Following this logic, a home with PV would enjoy a premium equal to what it would cost to install a PV system of similar age and size on a similar home without PV.

Intrinsic in both of these valuation approaches is the expectation that, under normal situations, buyers and sellers will respond to these "income" and "cost" signals to value the properties in the market. To date, however, little has been done to test that assumption with PV homes, though that has begun to change (e.g., Desmarais, 2013).

Using the income approach as a guide, Sandia National Laboratories and Energy Sense Finance created a Microsoft Excel-based downloadable worksheet that can be used by valuation professionals to predict the value a PV home might have in the market.[3] The PV Value® tool has been received favorably by the lending and appraisal community (Klise et al., 2013b), in part because of its ease of use, relative transparency, and conformance to well-understood appraisal techniques. To date, however, the tool has only just begun to be verified against actual sales data to determine if its predicted sale-price premiums are in line with actual premiums in the marketplace. A recent study looked at 30 Colorado homes using various appraisal methods to value the home, finding, in most cases, their results to be similar (Desmarais, 2013).

There is also evidence (in San Diego) that PV homes might experience a "green premium" that is above the amount that would be expected from energy savings alone (Dastrup et al., 2012), but this has not been explicitly investigated previously within a broader dataset of California PV homes. Further, there is evidence that the value of a PV system could be influenced by the age of the system (Hoen et al., 2011, 2013), with older systems receiving smaller premiums, all else being equal, but how sharply the market values of PV systems are influenced by age is not understood.

The present work seeks to help close these gaps in current knowledge by answering the following research questions:

1. Are there sensitivities to the size and age of PV systems in the California PV home *Premiums* found in the marketplace?
2. Are estimates using the income and cost approaches strongly correlated with the California PV home sales price *Premiums* found in the marketplace?
3. Do these results validate the PV Value® tool, and do they offer any insights for how to improve the income approach used in the PV Value® tool and/or to estimating algorithms based on the cost approach?

The paper relies on data collected in earlier work by Hoen et. al. (2011, 2013), including data on 1,894 PV homes sold in California from 2000 through 2009, and 70,425 non-PV homes sold over the same time frame and in the same neighborhoods as the PV homes. These same homes are re-analyzed here, and the estimated premiums for these homes are compared to predictions made using the income and cost valuation approaches.

The remainder of this report is structured as follows. Section 2 reviews the methodological approach for the analysis. Section 3 describes the data. Section 4 presents the results, and Section 5 provides discussion

[3] A web version of the tool is currently under development.

and concluding remarks. Two appendices provide additional detail on the calculations used and full sets of results.

# 2. Methodological Approach

The methods used in this analysis build on those used by Hoen and colleagues in what we refer to collectively as the "Lawrence Berkeley National Laboratory (LBNL) Report" (Hoen et al. (2011, 2013),which relied on hedonic price models.[4] The methods also build on Eichholtz et al. (2009), which investigated, among other things, the impact of estimated energy savings on the selling prices of commercial buildings. Section 2.1 presents the data-preparation methods. Section 2.2 describes the analytical methods.

## 2.1 Data-Preparation Methods

This section covers four sets of data-preparation methods: the LBNL Report methods overview; methods to extract a usable PV home premium from that dataset for the present research (*Premium*); methods to produce income approach estimates (*Income Estimates*); and, methods to produce cost approach estimates (*Cost Estimates*).[5]

### 2.1.1 LBNL Report Methods Overview

Because a similar model form as used in the LBNL Report is used to prepare the data for this research, the report's methods are briefly reviewed here. The LBNL Report investigated the *Premiums* that existed for a set of 1,894 California PV home sales in comparison to a set of 70,425 comparable non-PV home sales (that sold during the period of 2000-2009) in the surrounding neighborhoods using a "fixed effect" hedonic regression model as follows: [6]

$$\ln(\mathrm{P}_{\mathrm{itk}}) = \alpha + \beta_1\left(\mathrm{T}_{\mathrm{t}}\right) + \beta_2\left(\mathrm{N}_{\mathrm{k}}\right) + \sum_{\mathrm{a}} \beta_3\left(\mathrm{X}_{\mathrm{i}}\right) + \beta_4\left(\mathrm{PV}_{\mathrm{i}}\right) + \varepsilon_{\mathrm{itk}} \tag{1}$$

Where:

$P_{itk}$ represents the inflation-adjusted sale price for transaction *i*, in quarter *t*, in block group *k,*
$\alpha$ is the constant or intercept across the full sample,
$T_t$ is the quarter in which home sales transaction *i* occurred,
$N_k$ is the census block group in which transaction *i* occurred,
$X_i$ is a vector of home and site characteristics for transaction *i* (square feet, age of the home, age of the home squared, acres, acres less than 1, relative elevation of home in block group, number of bathrooms),
$PV_i$ is a fixed-effect variable indicating a PV system is installed on the home in transaction *i*,
$\beta_1$ is a parameter estimate for the quarter in which transaction *i* occurred,

[4] As described in detail in Hoen et al. (2011; 2013) hedonic pricing models are frequently used by real estate professionals and academics to assess the impacts of individual house and community characteristics on property values by investigating the sales prices of homes. When data from a large group of residential transactions are available, the average marginal contribution to the sales price of each characteristic of the homes (an additional bathroom, an extra 1000 square feet, a garage, etc.) can be estimated with a regression model. In this research, we use the hedonic model to estimate the contribution to the selling price of having a PV system on the home at the time of sale.

[5] From this point forward in the report, *Premium* or *Premiums* refer to the premiums found in the marketplace for the set of California PV homes over the set of non-PV homes. *Income Estimates* refer to the estimates generated by the PV Value algorithm that uses the present value of energy-cost savings based on the potential output of a PV system, while *Cost Estimates* refer to the "net" installed cost estimates produced from the Tracking the Sun V dataset. Each are described in detail below.

[6] For a full description of the motivation of this model and the data used for it and how they were derived see Hoen et al. (2011).

$\beta_2$ is a parameter estimate for the census block group in which transaction *i* occurred,
$\beta_3$ is a vector of parameter estimates for home and site characteristics *a*,
$\beta_4$ is a parameter estimate for the PV fixed-effects variable,
$\varepsilon_{itk}$ is a random disturbance term for transaction *i,* in quarter *t*, in block group *k*.

The coefficient of interest for the purposes of the LBNL Report is $\beta_4$, which represents the average effect of having PV installed on the home, as compared to all non-PV homes, all else being equal. This "fixed effect" is determined regardless of the size of the PV system.

This model is fully explored in the LBNL Report and therefore is not discussed further here.

### 2.1.2 Premiums for this Analysis

The model described above produces a single estimate of an average *Premium* across the dataset expressed as the log of adjusted sale price (in 2009 – the last year of the sample period - dollars), as was the goal of the LBNL Report. However, the present research aims to compare a set of *Premiums* to a set of *Income* and *Cost Estimates*, to examine how well they are correlated, and produce a set of standard deviations and p-values from those correlations allowing us to test various hypotheses. Moreover, because *Income* and *Cost Estimates* are in dollars, *Premiums* also must be expressed in dollars (i.e., be converted from log of dollars). Finally, because *Premiums* were calculated based on 2009 real dollars, *Income* and *Cost Estimates* must be adjusted for inflation to that period.[7]

To produce this set of *Premiums*, estimates are made for *Premiums* in each census block group in the dataset. The 1,894 homes in the 2011 sample span a total of 835 separate block groups, each of which has at least one PV sale in it. Each of these geographic delineations is considered an "island," in which at least one PV home is situated along with a set of other non-PV homes (similar to Eichholtz et al., 2009 green building "clusters"). Theoretically, a larger unit of analysis (e.g., a census tract or county) could have been used, but by enlarging the unit of aggregation important differences between premiums would have been subsumed, therefore allowing fewer analysis opportunities across other parameters such as age and size of the PV system. Alternatively, a smaller unit of analysis could have been used (e.g., a census block or individual homes themselves), but because only the census block group delineation was obtained from the data provider (as opposed to the x/y coordinates), matching these homes to comparable non-PV homes in the same neighborhood would have been difficult. Moreover, in many cases, more than one PV home was contained in the blockgroup therefore allowing some averaging of *Premiums* to occur, which, in turn, reduced some of the variability in *Premium* estimates. The census block group, therefore, was chosen to balance multiple empirical interests.

Because the set of non-PV homes varies considerably, and finding homes among this set that most closely match the PV home(s) can help minimize omitted-variable bias, a matching technique is employed that uses the predicted price based on all the home, site, and market characteristics not including whether the home has PV or not, as follows:

1. Using only non-PV homes, estimate a regression using Equation (1) (without the $PV_i$ variable) and predict the price for each non-PV home;
2. Using the PV home data, and the coefficients estimated in the above step, predict the price for each PV home (as if the home did not have PV);

[7] This inflation adjustment was done using the consumer price index (see: ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt).

3. For each PV home (and using that home's predicted price and sale date, as per step 2, without PV), select from the set of non-PV homes in the same block group (that sold within 1 year, either before or after, of the PV home's sale date) the five homes with the closest predicted prices.[8]

After matching, an estimate of a block-group-level *Premium* is produced using the following model, and including only the matched PV and non-PV homes:

$$\ln(P_{itk}) = \alpha + \beta_1(T_t) + \beta_2(N_k) + \sum_a \beta_3(X_i) + \beta_6(PV_i \cdot N_k) + \varepsilon_{itk} \quad (2)$$

Where

$\beta_6$ is a parameter estimate for the PV fixed-effects variable for the census block group N, and all other variables are as described in Equation (1).

This set of PV home *Premiums* (one for each census block group delineation) are expressed in log of sale price (as a percentage change in price based on the average PV home price in the block group) and therefore must be converted to dollars as is described below (which, then, also represents the premium – in dollars- itself not a percentage change in price).[9] Finally, to remove outlying premium estimates, only PV homes with a predicted price within three standard deviations of their actual price are included in the analysis.[10]

1. Using the data and coefficients from Equation (2), predict the log price for each PV home;
2. Calculate the average predicted log PV home price in each block group;
3. From the predicted log price of each PV home, subtract the PV block group coefficient to arrive at the predicted log price for each non-PV home;
4. Calculate the average predicted log non-PV home price in each block group;
5. Convert both PV and non-PV block-group-level average log prices to dollars by taking the anti-log;
6. Subtract one average price from the other to arrive at a block-group-level *Premium* in 2009 dollars (this *Premium* variable is entitled *bgaspprem*).

[8] This matching was done using the .geonear utility in Stata (version MP 12.1) (see, e.g., http://ideas.repec.org/c/boc/bocode/s457146.html), where the x-coordinate is fixed as the sale date and the y-coordinates are the predicted prices of PV and non-PV homes.

[9] Log of sale price is used in place of sale price to account for the skewed distribution of sale price, as is common in hedonic models (see e.g., Sirmans et al., 2005). Because the *Premium* (log of sale price) represents the percentage change in price for having PV installed on the home, it therefore requires a sale price of the full home to which the change refers (e.g., 2.7% increase over a base price of $627,182). Using the average price of non-PV homes in each block group is problematic because they are not perfectly representative of the PV home characteristics. Therefore a set of PV home prices is estimated without the effect of the PV system itself, to which the log of sale price can be compared, in order to arrive at a premium in dollars. A number of alternative approaches were explored to arrive at a premium in dollars, but the one presented here was the simplest.

[10] This screen is employed because the excluded homes are highly correlated with unusually large – both positive and negative - *Premiums* (i.e., they are outliers). This occurs because the set of non-PV homes that "match" each PV home, because they are drawn from a larger pool of over 70,000 transactions, are, on average, more likely to have their actual prices closer to their predicted prices (i.e., there is a lower chance that their prices will be outliers). Because premiums are derived from the differences between the actual prices of PV and non-PV homes, when the matched group of non-PV homes is compared with the PV homes' actual prices, as in the estimation described in Equation (2), large Premiums are estimated. That notwithstanding, when this screen is relaxed, the *Premiums* are, on average, larger and still highly significant. Finally, one reviewer noted that the ability to estimate accurate predicted prices could be tested using an "out-of-sample" test, but that was beyond the scope of this work.

### 2.1.3 Income Estimates using the PV Value® Algorithm

For each of the PV homes in the California sample, the estimated present value of energy savings data (*Income Estimates*) are prepared using the size of the system as well as the age of the system, the zip code of the home, and the estimated tilt and azimuth of the system.[11] These inputs are fed through the PV Value® algorithm (Klise et al., 2013b). The estimation procedure produces a set of low, average, and high estimates of the present value of the expected energy output, which are then adjusted to 2009 dollars.

The algorithm is based on the following: the average expected energy output of the PV system after the sale date and assuming a life span not greater than the warranty life of the panels (usually 25 years); an average electricity retail rate at the time of sale and an escalation of the rate similar to the historical escalation over the previous years; discount rates as of the time of sale, which for the purposes of this study, are equivalent to 50, 125, and 200 (high, average, and low *Income Estimates*, respectively) basis points above the 30-year, fixed mortgage, 60-day Fannie Mae lock-in rate at the time of sale[12]; a system DC-to-AC derate factor of 0.77%; a module degradation factor of 0.5% per year; and, finally, an expected inverter replacement at 15 years.

The full description of the income estimation procedure is contained in Appendix A and Klise and Johnson (2012).

### 2.1.4 Replacement Cost Estimates

The estimated replacement cost data (*Cost Estimates*) for the California PV homes in the sample are prepared using the set of Tracking the Sun V (TTSV) "net installed cost" data (Barbose et al., 2012) that span the years 2001 (as far back as the data go) through 2009 (the last year of the PV home data) across 41 California counties and encompassing systems of no larger than 10 kW. "Net installed costs" are defined as the cost of installing a PV system, less any available state or federal incentives. For a full description of how those data are prepared, see Appendix A and Appendix C in Barbose et al. (2012).

When PV homes are new and can be matched directly with the TTSV data, those data are used as the *Cost Estimates* because the net installed cost is also equal to the replacement cost at the time of sale. For retrofit applications, or if matching is not possible, a two-stage regression procedure is used to produce the *Cost Estimates*.[13] The TTSV "net installed cost" data total 47,770 in number and thus provide a robust dataset to produce *Cost Estimates*.

The first stage of the procedure estimates the following model:

$$C_{itsc} = \alpha + \beta_1 (T_t) + \beta_2 (S_s) + \beta_3 (N_i) + \beta_4 (C_c) + \varepsilon_{itsc} \tag{3}$$

where

- $C_{itsc}$ is the "net installed cost" of PV system *i* after state and federal incentives from the full TTSV dataset (i.e., all 47,770 PV homes),
- $T_t$ is a vector of variables representing the year *t* in which the system was installed,

[11] The age of the system is calculated by differencing the sale date from the operation date. Because tilt and azimuth for each PV home's system were not available (the data were not originally collected for the LBNL report), they were estimated by using the median tilt and azimuth for the same county using LBNL's extensive Tracking the Sun V "net installed cost" data (Barbose et al., 2012).

[12] These low, average and high estimates are by no means intended to bracket the estimates, but rather allow for three difference discount rates to be used, while the other inputs are held constant.

[13] Approximately 25% of the PV home data could not be matched to the TTSV dataset because IDs were not stored for them. All of those homes were from the Sacramento Municipal Utility District (SMUD) service area.

$S_s$ is a vector of variables representing the size *s* of the system in rounded kilowatts (e.g., 1 kW, 2 kW, 3 kW…),
$N_i$ is a fixed-effect variable indicating if the home was newly built when the system was installed,
$C_c$ is a vector of variables representing the county *c* in which the system was installed,
$\alpha$ is the constant,
$\beta_{1\text{-}4}$ are coefficients for the parameters,
$\varepsilon_{itsc}$ is the error term.

The model accounts for the different state incentives and system component prices over the study period (via $T_t$), economies of scale (via $S_s$), different seller motivations between new and existing homes ($N_i$), and the variety of rate structures, installer competitive prices, and market development (via $C_c$).

Using the predicted coefficients from this model and the data for the set of retrofit and/or unmatched PV homes (and substituting the sale year of the PV home for the install year *t*), the second stage of the procedure produces *Cost Estimates* for the remainder of the dataset, which are then combined with the other set, both of which are then adjusted back to 2009 dollars. Finally, to account for the underlying ages of the PV systems, all *Cost Estimates* are adjusted using a straight-line 20-year deprecation, which is expected to mimic the usable life of the system.[14]

## 2.2 Analysis Methods Used for This Research

The purpose of this research is threefold: 1) to explore sensitivities of California PV home (sales price) *Premiums* to the age and size of PV systems, 2) to compare the PV home *Premiums* to both the *Income* and *Cost Estimates* to better explain *Premium* levels, and 3) to validate the PV Value® tool's *Income Estimates* and possibly inform the estimation algorithm for that and other tools. Purpose 1 and 2 require different approaches, thus the following two subsections discuss the methods related to each purpose. These same methods are then also used for Purpose 3, and therefore require no further methodological discussion.

### 2.2.1 Exploring Sensitivities of PV Home Premiums

To explore the sensitivities of California PV home *Premiums* to the age and size of the systems, the following regression is estimated:

$$\widehat{\beta}_{6\text{n}} = \alpha + \beta_7(\text{SIZE}_\text{n}) + \beta_8(\text{AGE}_\text{n}) + \varepsilon_\text{n} \quad (4)$$

where

$\widehat{\beta}_{6n}$ is a parameter estimate in dollars (*bgaspprem*) for the PV fixed-effects variable for block group *n* derived from Equation (2) and as explained in Section 2.1.2,
$\text{SIZE}_n$ is a continuous variable for the average PV system size in the block group *n*,
$\text{AGE}_n$ is a continuous variable for the average PV system age in the block group *n*,
$\beta_7$ and $\beta_8$ are coefficients for the parameters, and all other variables are as described above.

[14] This 20-year depreciation period (and rate) was used to mimic that used for accounting purposes. One reviewer argued a better period might be the warranty period and also that the straight-line method does not account for "balloon" costs such as a new inverter (at 10 years). These differences, for systems in our data that are all relatively new (less than 10 years old) are minor, and therefore would not affect our results.

The expectation is that $\beta_7$ will be positive and that $\beta_8$ will be negative, indicating that as PV systems increase in size so too do their corresponding *Premiums* and, simultaneously, as systems age their *Premiums* decrease.

### 2.2.2 Comparing PV Home Premiums to Income and Cost Estimates

To compare PV home *Premiums* to the *Income* and *Cost Estimates* the following regressions are used:[15]

$$\widehat{\beta}_{6n} = \beta_9(\mathrm{INCOME_n}) + \varepsilon_n \tag{5}$$

$$\widehat{\beta}_{6n} = \beta_{10}(\mathrm{COST_n}) + \varepsilon_n \tag{6}$$

where

- $\mathrm{INCOME}_n$ is a continuous variable for the average estimated present value of theoretical energy savings for each PV system calculated at the time of sale for the block group *n* (low, average, and high *Income Estimates*),
- $\mathrm{COST}_n$ is a continuous variable for the average estimated replacement cost for the PV system at the time of sale for block group *n* (*Cost Estimate*),
- $\beta_9$ and $\beta_{10}$ are coefficients for the parameters.[16]

One regression is estimated for each of the low, average, and high *Income Estimates* and for the *Cost Estimates*. The expectation is that the coefficients will be highly significant because both *Income* and *Cost Estimates* and the *Premiums* are expected to be highly correlated to system size (Hoen et al., 2011; 2013). The more substantive question is whether the coefficients are greater or less than one. If greater than one, they indicate that the actual *Premium* as estimated in the California market is larger than the valuation *Estimates* (and therefore the income and cost approaches underestimate the premiums found in the marketplace for this dataset); if less than one, they indicate that the valuation *Estimates* are greater than the *Premiums* (and therefore the income and cost approaches overestimate the premiums found in the marketplace for this dataset).

[15] All of these regressions are estimated without an intercept because it is assumed that they converge at 0, for a system that has a size of 0 kW.

[16] Ideally we could estimate an equation where the effect of both INCOME and COST are estimated simultaneously, but, because of their high correlation (0.92), they are estimated separately.

## 3. Data Summary

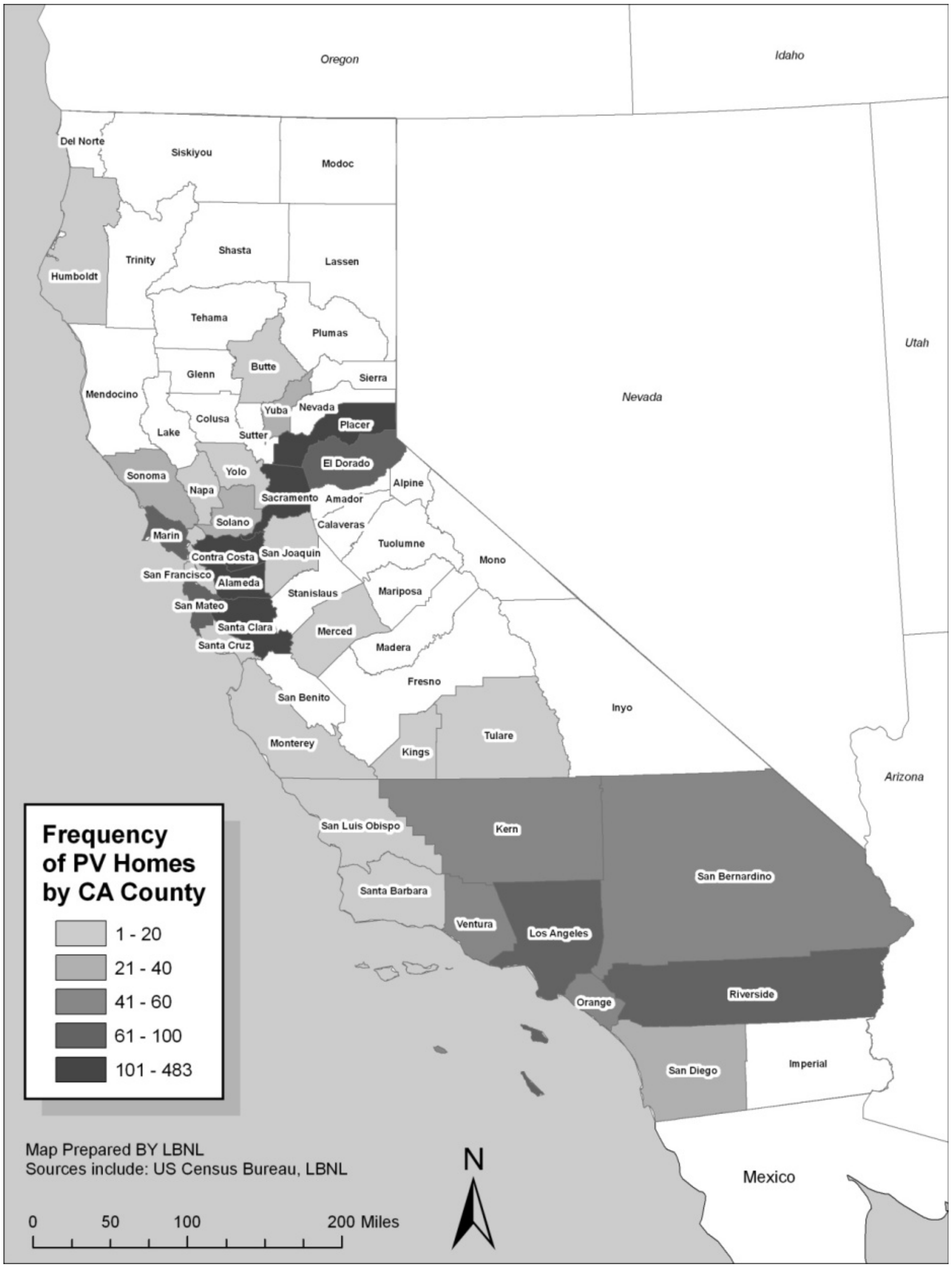
This section summarizes the underlying data used in this analysis, the preparation of which was described in Section 2.1. The LBNL Report uses data from California spanning the period from 1999 to mid-2009 and including 1,894 PV home sales and 70,425 non-PV home sales. All of the PV homes have PV systems that are homeowner owned as opposed to third party owned. These transactions are arrayed across the state as shown in Figure 2. After matching each PV home with a set of at most five non-PV homes (as discussed in Section 2.1.2), the dataset is reduced to 1,598 PV homes (Table 2) and 6,140 non-PV homes (Table 3) in 741 block groups.[17]

Because of the matching procedure, the PV and non-PV homes are extremely similar on many of the covariates (e.g., acre, age, baths, sqft) but not identical; the PV homes are slightly larger (sqft_1000: 2.42 for PV homes vs. 2.28 for non-PV homes), slightly newer (age: 19 vs. 23), on slightly larger parcels (acre: 0.34 vs. 0.30), with slightly more bathrooms (bath: 2.9 vs. 2.7), with slightly less acreage less than 1 (acrelt1: 0.21 vs. 0.24), and with a sale date approximately 2 months later (sd: 3/22/2007 vs. 1/19/2007). These characteristic differences are trivial, as is the difference in their predicted price absent the PV systems, which is identical to the second decimal (lasp_hat: PV homes 12.932 vs. non-PV homes 12.929, i.e., predicted prices differ by less than 0.003%). This similarity indicates that, at least with the included set of characteristics, these two groups are very similar and therefore are appropriate for producing *Premium* estimates.[18]

[17] A total of 196 PV homes could not be matched to non-PV homes because there were no non-PV homes in the block group that sold within a year of the PV home, or no non-PV homes that had a predicted log of sale price within three standard deviations (based on the mean of all PV homes) of the PV home's sale price, or both. Additionally, 100 PV homes were not included (as discussed earlier) because the difference between their predicted price and actual price was more than three times the standard deviation of the mean difference in predicted versus actual prices across the full sample.

[18] When these homes are included in a regression that is the same as in Hoen et al. (2011, 2013), the coefficient equals 0.034 (*p*-value 0.000) for having a PV system on the home, while the estimate for the LBNL Report is 0.036 (*p*-value 0.000).

**Figure 2: Frequency of PV Homes Analyzed, by California County**



## Table 1: Frequency of Block Groups Analyzed, by California County

| CA County | Blockgroup Count |
|---|---|
| Alameda | 80 |
| Butte | 7 |
| Contra Costa | 47 |
| El Dorado | 7 |
| Humboldt | 2 |
| Kern | 22 |
| Kings | 3 |
| Los Angeles | 67 |
| Marin | 32 |
| Merced | 1 |
| Monterey | 1 |
| Napa | 1 |
| Orange | 42 |
| Placer | 20 |
| Riverside | 47 |
| Sacramento | 52 |
| San Bernardino | 24 |
| San Diego | 22 |
| San Francisco | 11 |
| San Joaquin | 17 |
| San Mateo | 40 |
| Santa Barbara | 5 |
| Santa Clara | 102 |
| Santa Cruz | 1 |
| Solano | 17 |
| Sonoma | 29 |
| Tulare | 7 |
| Ventura | 32 |
| Yolo | 1 |
| Yuba | 2 |
| **Total** | **741** |

## Table 2: Summary Statistics of PV Homes in Final Dataset

| | | PV Homes | | | | |
|---|---|---|---|---|---|---|
| **Variable** | **Description** | ***n*** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| **acre** | size of the parcel (in acres) | 1598 | 0.34 | 0.89 | 0 | 21.6 |
| **acrelt1** | number of acres less than one | 1598 | 0.21 | 0.16 | 0 | 1 |
| **age** | age of home as of the date of sale (years) | 1598 | 19 | 25 | -1 | 104 |
| **agesqr** | age squared | 1598 | 1001 | 1886 | 0 | 11025 |
| **asp** | inflation adjusted sale price (in 2009 dollars) | 1598 | $ 531,154 | $ 375,748 | $ 90,790 | $ 2,419,214 |
| **bath** | number of bathrooms | 1598 | 2.9 | 1.0 | 1 | 7 |
| **bgre_100** | relative elevation to other homes in block group (in 100s of feet) | 1598 | 0.14 | 1.2 | -10.0 | 13.6 |
| **lasp** | natural log of asp | 1598 | 12.98 | 0.63 | 11.42 | 14.70 |
| **lasp_hat** | predicted natural log of asp (without pv effects) | 1598 | 12.93 | 0.62 | 11.47 | 15.01 |
| **pvage** | age of the PV system at the time of sale (in years) | 1598 | 1.7 | 2.1 | 0 | 9 |
| **sd** | sale date | 1598 | 3/22/2007 | 636 | 8/1/2000 | 6/29/2009 |
| **size** | size (in STC DC kW) of the PV system | 1598 | 3.1 | 1.5 | 0.6 | 10.0 |
| **sp** | sale price (not adjusted for inflation) | 1598 | $ 650,434 | $ 414,749 | $ 100,000 | $ 2,850,000 |
| **sqft_1000** | size of living area (in 1000s of square feet) | 1598 | 2.42 | 0.9 | 0.8 | 7.1 |
| **yrbuilt** | year the home was built | 1598 | 1988 | 25.2 | 1904 | 2009 |

### Table 3: Summary Statistics of Non-PV Homes in Final Dataset

| | | Non-PV Homes | | | | |
|---|---|---|---|---|---|---|
| **Variable** | **Description** | ***n*** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| **acre** | size of the parcel (in acres) | 6140 | 0.30 | 0.85 | 0 | 23.2 |
| **acrelt1** | number of acres less than one | 6140 | 0.24 | 0.20 | 0 | 1.0 |
| **age** | age of home as of the date of sale (years) | 6140 | 23 | 25 | -1 | 106 |
| **agesqr** | age squared | 6140 | 1209 | 1967 | 0 | 11449 |
| **asp** | inflation adjusted sale price (in 2009 dollars) | 6140 | $ 511,346 | $ 357,036 | $ 85,173 | $2,495,551 |
| **bath** | number of bathrooms | 6140 | 2.7 | 0.9 | 1 | 7 |
| **bgre_100** | relative elevation to other homes in block group (in 100s of feet) | 6140 | 0.06 | 1.0 | -17.7 | 13.7 |
| **lasp** | natural log of asp | 6140 | 12.94 | 0.63 | 11.35 | 14.73 |
| **lasp_hat** | predicted natural log of asp (without pv effects) | 6140 | 12.93 | 0.61 | 11.43 | 14.99 |
| **sd** | sale date | 6140 | 1/19/2007 | 675 | 1/31/2000 | 6/30/2009 |
| **sp** | sale price (not adjusted for inflation) | 6140 | $ 627,182 | $ 395,598 | $ 76,500 | $3,120,000 |
| **sqft_1000** | size of living area (in 1000s of square feet) | 6140 | 2.28 | 0.8 | 0.8 | 6.5 |
| **yrbuilt** | year the home was built | 6140 | 1984 | 25.5 | 1901 | 2009 |

These data span 741 different block groups in California. Table 4 summarizes the *Premiums* - based on Equation (2) and the conversion to 2009 dollars steps that followed - and *Cost* and *Income Estimates* for these block groups. When comparing PV homes to non-PV homes in these block groups, PV homes sell for an average of $24,705 more (median = $17, 609) in 2009 dollars than non-PV homes, which equates to $7.97/W of installed PV (median = $5.68/W) adjusted to 2009 dollars for average-sized (3.1-kW) systems. The distribution of those block group average *Premiums* is wide, with PV homes in some block groups selling for considerably less than their non-PV counterparts and some selling for considerably more. Turning to the *Income* and *Cost Estimates*, Table 4 shows that mean block group average *Income Estimates* range (in 2009 dollars) from $9,114 for the "low" estimate to $10,420 for the "high" estimate, while the "average" *Income Estimate* is $9,735. The average *Cost Estimate* for the sample is $15,244 (in 2009 dollars).

### Table 4: Summary Statistics for Block-Group-Level Premiums and Estimates

| | | PV Home Containing Census Blockgroups | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Description** | ***n*** | **Mean** | **Std. Dev.** | **Min** | **25th Pct.** | **Median** | **75th Pct.** | **Max** |
| bgaspprem | average blockgroup sale price *Premium* for PV homes (in 2009$) | 741 | $ 24,705 | $ 75,190 | $(247,597) | $ (16,561) | $ 17,609 | $ 56,475 | $ 538,389 |
| bglowinc09 | average blockgroup low *Income Estimate* (in 2009$) | 741 | $ 9,114 | $ 5,066 | $ 1,107 | $ 5,623 | $ 7,576 | $ 11,630 | $ 28,870 |
| bgavginc09 | average blockgroup average *Income Estimate* (in 2009$) | 741 | $ 9,735 | $ 5,405 | $ 1,175 | $ 5,991 | $ 8,082 | $ 12,436 | $ 30,904 |
| bghighinc09 | average blockgroup high *Income Estimate* (in 2009$) | 741 | $ 10,420 | $ 5,781 | $ 1,248 | $ 6,403 | $ 8,675 | $ 13,315 | $ 33,264 |
| bgcost09 | average blockgroup *Cost Estimate* (in 2009$) | 741 | $ 15,244 | $ 7,570 | $ 2,789 | $ 9,967 | $ 13,269 | $ 19,199 | $ 48,998 |

To explore further how both the size and age of the PV system affect *Premium* sizes, block groups are binned into the following groups in some of the analyses that follow:

- Based on average size of the PV systems in the block group (in kW):
  - 0.6–1 (meaning a size greater than or equal to 0.6 and less than 2 kW, or 0.6 ≤ size < 2)
  - 2 (2 ≤ size < 3)
  - 3 (3 ≤ size < 4)

- 4–5 (4 ≤ size < 6)
- 6–10 (6 ≤ size ≤ 10)

- Based on the average age of the PV systems in the block group (in years):
  - < 1 (meaning a system age less than 1 year, or age < 1)
  - 1–2 (1 ≤ age < 3)
  - 3–5 (3 ≤ age < 6)
  - 6–10 (6 ≤ age ≤ 10)

These groups are described in Table 5 and Table 6, which contain both the frequency of block groups falling into each group and the mean age and size for each of the respective size and age groups. These means indicate that the smaller systems are, in general, older, and the younger systems are, in general, larger. This distinction is important and reinforces the appropriateness of including both size and age in the regressions (see Equation 4).

Figure 3 and Figure 4 express the block group average *Income* and *Cost Estimates*, respectively, over PV system size, the year of sale, and the age of the PV system.[19] The left-most graph in each figure is expressed in dollars (2009), while all other graphs are expressed in dollars (2009) per watt. The left-most graphs show that both sets of estimates are strongly correlated with system size - the larger the system, the higher the estimates.[20] The two middle graphs show *Estimates* by the year of sale and identify important real-world impacts likely to be reflected in the market and therefore in PV home *Premiums*. For example, real (i.e., not nominal) average California retail electricity rates peaked between 2006 and 2007, which is reflected in the peak of *Income Estimates* during that period (Figure 3). A peak in the *Cost Estimates* in 2006 (Figure 4) reflects when incentives for PV systems in California were falling faster than overall PV system prices, causing the "net" installed costs to rise (see Barbose et al., 2011for a discussion of this occurance). Additionally, as shown in the right-most graphs in the figures, both sets of *Estimates* fall as the age of the PV system increases because of the decreasing remaining life.[21]

### Table 5: Count of Block Groups in Each PV System Size Group

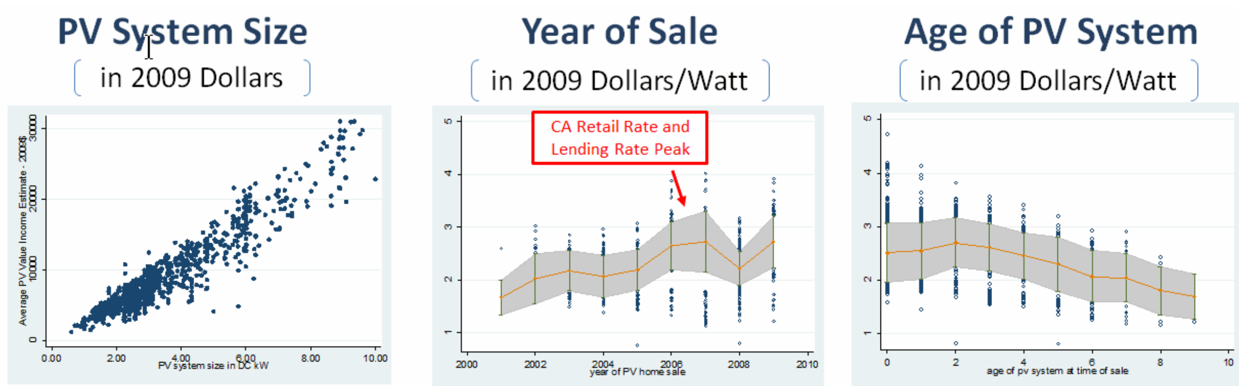
| Size Groups | *n* (number of blockgroups) | Mean Age of PV Systems in Group |
|---|---|---|
| 0.6-1kw | 89 | 3.2 |
| 2kw | 279 | 2.9 |
| 3kw | 128 | 2.7 |
| 4-5kw | 172 | 2.9 |
| 6-10kw | 73 | 2.7 |
| **Total** | **741** | **2.9** |

[19] Of course, the figures are very similar if either the low or high *Income Estimates* are used.
[20] The correlation coefficients for PV system size and the two sets of estimates (in 2009 dollars) are as follows: *Income* 0.94, *p*-value 0.000; *Cost* 0.91, *p*-value 0.000.
[21] The correlation coefficients for PV system age and the two sets of estimates (in 2009 dollars per watt) are as follows: *Income* -0.19, *p*-value 0.000; *Cost* -0.12, *p*-value 0.000.

**Table 6: Count of Block Groups in Each PV System Age Group**

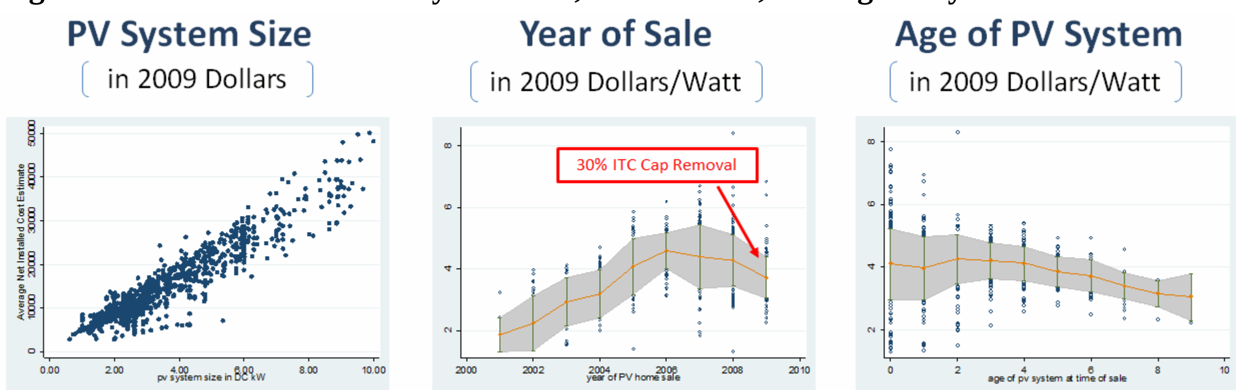
| Age Groups | *n* (number of blockgroups) | Mean Size of PV Systems in Group |
|---|---|---|
| <1year | 181 | 3.6 |
| 1-2year | 304 | 3.8 |
| 3-5year | 217 | 3.6 |
| 6-10year | 39 | 3.2 |
| **Total** | **741** | **3.7** |

**Figure 3: Average Income Estimates over System Size, Year of Sale, and Age of System**




*Note: In right two figures, the line represents mean values for each category; the shaded area represents one standard deviation from the mean, and the dots are values outside that range.*

**Figure 4: Cost Estimates over System Size, Year of Sale, and Age of System**




*Note: In right two figures, the line represents mean values for each category; the shaded area represents one standard deviation from the mean, and the dots are values outside that range.*

# 4. Results

As noted earlier, the purpose of this research is threefold: 1) to explore sensitivities of PV home *Premiums* to the age and size of PV systems, 2) to compare the PV home *Premiums* to both the *Income* and *Cost Estimates* to better explain *Premium* levels, and 3) to validate the PV Value® tool's *Income Estimates* and possibly inform the estimate algorithm for that and other tools. The results of the analyses related to these purposes are discussed below.[22]

## 4.1 Exploring Sensitivities of PV Home Premiums to System Age and Size

To explore sensitivities of PV home *Premiums* to the age and size of PV systems, Equation (3) is estimated; the results are shown in Table 7. Not surprisingly, the block group *Premiums* are strongly correlated with average PV system size in the block group, with each 1-kW increase in size equating to a $5,911 higher *Premium* (*p*-value 0.000). Age of the system is correlated negatively, and weakly, with the size of the *Premium*; for each year systems age, *Premiums* decrease by $2,411 (*p*-value 0.087).

Using these estimates enables forecasting of the effects on *Premiums* that might be evident across a variety of system sizes and ages (Table 8). For a system that is average across all block groups in terms of age (2.9 years) and size (3.7 kW), the estimated *Premium* is $24,851. In comparison, similarly aged systems of 1, 3, and 8 kW are estimated to have *Premiums* of $8,892, $20,714, and $47,312, respectively. Similarly sized systems (as the average) that are 1, 5, and 9 years old are estimated to have *Premiums* of $29,432, $19,789, and $10,146, respectively.

At a broader level, these results indicate that buyers and sellers of homes with PV systems seem to be cognizant of not only the size of the system, but also, at least weakly, the age of the system. Further, the market in the 2001 to 2009 timeframe seems to be discounting PV systems more quickly over time than the energy generated from the system is degrading (which affects the *Income Estimates*) or the system is depreciating in value (which affects the *Cost Estimates*). A degradation rate of 0.5% per year is considered normal for crystalline PV panels (which are on most all residential PV installations) and is what PV Value® uses for its algorithm (Osterwald et al., 2006), yet our results imply that the market might be discounting PV systems at approximately 9% per year.[23] Similarly, the *Cost Estimates* use a straight-line deprecation over 20 years, which equates to 5% per year, thus they too might underestimate the depreciation that should be applied.

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[22] All models are estimated using the .reg command in Stata with robust standard errors to correct for possible heteroskedasticity (White, 1980).

[23] The estimate of 9% per year is derived by comparing a system of 1.9 years old to that of 2.9 years old, which have estimated *Premiums* of $27,070 (not shown in table) and $24,851, respectively. An alternative theory for what might be driving age-related discounting is related to the fact that the older systems, which, in all cases, are early adopter systems, might have other qualities that are undesirable, such outdated aesthetic appeal, leaky roof mounting systems, power quality panels, and obsolete inverter technology, etc. Further research would be required to disentangle any of these individual effects.

**Table 7: Results from Regressions of Premiums on Size and Age of PV Systems (in 2009 $)**

| Model Results | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Description** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **intercept** | | $ 9,973 | $ 7,681 | 1.30 | 0.195 |
| **bgsize** | average PV system size in blockgroup | $ 5,911 | $ 1,565 | 3.78 | 0.000 |
| **bgage** | average PV system age in blockgroup | $ (2,411) | $ 1,407 | -1.71 | 0.087 |
| | | | | | |
| **Model Characteristics** | | | | | |
| ***n*** | | 741 | | | |
| **F** | | 8.93 | | | |
| **Prob > F** | | 0.0001 | | | |
| **Adjusted R-Squared** | | 0.021 | | | |
| **Dependent Variable** | | Blockgroup Premiums | | | |

**Table 8: Estimation of Size and Age Results across Vectors of Size and Age (in 2009$)**

| | **Average PV System Size (in kW) in Blockgroup** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Average PV System Age in Blockgroup** | 1 | 2 | 3 | **3.7** | 5 | 8 | 10 |
| 0 | $ 15,883 | $ 21,794 | $ 27,705 | **$ 31,842** | $ 39,526 | $ 54,303 | $ 69,080 |
| 1 | $ 13,473 | $ 19,383 | $ 25,294 | **$ 29,432** | $ 37,116 | $ 51,892 | $ 66,669 |
| 2 | $ 11,062 | $ 16,973 | $ 22,883 | **$ 27,021** | $ 34,705 | $ 49,482 | $ 64,258 |
| **2.9** | **$ 8,892** | **$ 14,803** | **$ 20,714** | **$ 24,851** | **$ 32,535** | **$ 47,312** | **$ 62,089** |
| 4 | $ 6,241 | $ 12,151 | $ 18,062 | **$ 22,199** | $ 29,883 | $ 44,660 | $ 59,437 |
| 5 | $ 3,830 | $ 9,740 | $ 15,651 | **$ 19,789** | $ 27,473 | $ 42,249 | $ 57,026 |
| 6 | $ 1,419 | $ 7,330 | $ 13,240 | **$ 17,378** | $ 25,062 | $ 39,839 | $ 54,615 |
| 7 | $ (992) | $ 4,919 | $ 10,830 | **$ 14,967** | $ 22,651 | $ 37,428 | $ 52,205 |
| 8 | $ (3,402) | $ 2,508 | $ 8,419 | **$ 12,556** | $ 20,240 | $ 35,017 | $ 49,794 |
| 9 | $ (5,813) | $ 98 | $ 6,008 | **$ 10,146** | $ 17,830 | $ 32,606 | $ 47,383 |
| 10 | $ (8,224) | $ (2,313) | $ 3,597 | **$ 7,735** | $ 15,419 | $ 30,196 | $ 44,972 |

*Note: The average PV system size in the 741 blockgroups is 3.7 kW, and the average age is 2.9 years. These are slightly different from the overall averages across all PV systems in the sample. The most reliable estimates (ones with the smallest margins of error) for premiums are those centered on those values - shown in bold.*

## 4.2 Comparing PV Home Premiums to Income and Cost Estimates

To compare PV home *Premiums* to the *Income* and *Cost Estimates*, Equation (5) (for low, average, and high *Income Estimates*) and Equation (6) (for *Cost Estimates*) are estimated; the results are summarized in Table 9. The full set of results from these regressions is included in Appendix B (Tables A3–A6). As expected, the *Premiums* are strongly correlated with both *Income and Cost Estimates*, because each are strongly correlated with system size. All of the coefficients, however, are larger than 1, indicating that, for each dollar increase of one of the *Estimates*, *Premiums* increase by more than a dollar. Another way to express this is by using percentages. For example, on average, *Cost Estimates* equate to approximately

65% of the *Premium*.[24] Similarly, low, medium, and high *Income Estimates* equate to 39%, 42%, and 45% of *Premiums*, respectively.

These results indicate that *Premiums* established in the California market from 2000 through 2009 appear to be larger than the expected values based on both sets of *Estimates*, thus buyers of PV homes were apparently willing to pay more than what might be expected. There are a number of plausible explanations for this disparity.

- **Green Cachet Boosts Market-Based PV Premium:** Premiums might be larger because buyers were willing to pay more for the PV system owing to its green cachet. As both Dastrup et al. (2012) and Eichholtz et al. (2009) found, there is some evidence that a green *Premium* or a "warm glow" might exist for PV homes, over and above that signaled by either the *Income* or *Cost Estimates*.[25]
- **Transactions Costs and Retail Rates Lead to Underestimates from Cost and Income Valuation:** Alternatively, there could be transaction costs that are avoided by purchasing a home with a PV system already installed that are not incorporated in the *Cost Estimates* (i.e., by purchasing a home with a PV system already installed the purchaser may avoid the time and difficulties of purchasing a separate PV system). Somewhat related, and perhaps more likely, the *Income Estimates*, which are derived from average utility-specific California residential electricity retail rates, could be lower than they should be because they underestimate the actual PV home electricity rate. In California, steeply tiered rates enable high-consumption households to offset retail rates that are higher than the average, implying the PV Value® income estimates will understate the actual energy value of average PV systems.[26] It is, of course, unclear whether home buyers and sellers account for such complexity in establishing PV premiums. It also deserves note that this effect of rate tiers is somewhat unique to the California market.
- **Market-Based Premium Estimates Could be Incorrect:** Another possibility is that the market-based *Premium* estimates could contain effects from omitted variables such as the age of the roof or energy efficiency upgrades. It has been postulated that PV homes might have newer roofs, because homeowners are unlikely to install PV on a home with an old roof, but the effects that those age differences have on market values is likely relatively small.[27] This same scenario exists for possible energy-efficiency (EE) upgrades that a PV homeowner might select in addition to the PV system installation, which also is likely to be affecting prices in a relatively small manner.[28]

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[24] This percentage is estimated by dividing 1 by the coefficient: 1/1.54 = 0.65

[25] This "warm glow" might also be conflated with a desire to lock in a fixed energy cost, i.e., a hedge against future price increases.

[26] For example, a recent analysis found that average California PV customers have electricity rates that are between 3% and 30% more than average non-PV customers, depending on the utility service area (E3, 2013). (Rate classes are determined by electricity consumption, and PV customers consume considerably more electricity on average than non-PV customers.)

[27] A few appraisers that we spoke to about this argued that roof age does not have an effect on value unless the roof is nearing its usable life. Moreover, often roof age is strongly correlated with the home's age and therefore our selection of comparable non-PV homes, which includes roof age as one of the parameters, would have controlled for this in part. Finally, the appraisers contended often homes in the same neighborhood have similarly aged roofs, and, of course, the comparable non-PV homes used in this analysis are from the same neighborhood (i.e., blockgroup). Further, other research indicates that major renovations, including roofs, do not impact the level of *Premiums* (Dastrup et al., 2012). Taken together we believe this is likely not affecting our results in a significant way.

[28] Though, other research indicates that smaller EE upgrades that are more common to PV system owners (versus non-PV system owners), such as new light bulbs and appliances (CPUC, 2010), are likely not a powerful driver of home value. Further, larger EE upgrades that might be conducted on PV homes, assuming they are accompanied by a permit for construction, do not appear to influence estimated PV premiums (Dastrup et al., 2012).

**Table 9: Results from Regressions of Premiums on Cost and Low, Medium, and High Income Estimates**

| Model Results (for four models) | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Description** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **bglowinc09** | average blockgroup low *Income Estimate* | 2.54 | 0.26 | 9.67 | 0.000 |
| **bgavginc09** | average blockgroup average *Income* | 2.38 | 0.25 | 9.67 | 0.000 |
| **bghighinc09** | average blockgroup high *Income Estimate* | 2.22 | 0.23 | 9.67 | 0.000 |
| **bgcost09** | average blockgroup *Cost Estimate* | 1.54 | 0.16 | 9.58 | 0.000 |

| Average Model Characteristics (for four models - see note) | |
|---|---|
| ***n*** | 741 |
| **F** | 93.06 |
| **Prob > F** | 0.000 |
| **Adjusted R-Squared** | 0.111 |
| **Dependent Variable** | Blockgroup Premiums |

*Note: These characteristics are averages from four separate models. Differences between the four sets of characteristics are de minimis. The full set of results are included in Appendix B*

## 4.3 Comparing Income and Cost Estimates Across Size and Age Bins

To array the data differently, three regressions are estimated using both size (see Table 5) and age (see Table 6) bins in place of the continuous size and age variables (see Equation 4), with one regression for *Premiums*, one for *Cost Estimates*, and a third for average *Income Estimates*.[29] The results are summarized in Table 10 and Table 11 and Figure 5 and Figure 6, while the full set of results appears in Appendix B (Tables A7–A9).[30]

Table 10 shows the results from each of the three models expressed over the five PV system size groups, while Figure 5 plots these values. They show the monotonic arrangement of the three sets of estimates, with coefficient sizes increasing as system size increases. *Cost Estimates* range from 43% to 61% of *Premiums*, while average *Income Estimates* range from 25% to 41%, with smaller percentages for smaller systems. Therefore, both sets of *Estimates* appear to be closer to the *Premiums* found in the marketplace for larger systems and, conversely, further away for smaller systems. It should be noted that these results are also consistent with the green cachet, transaction cost, and omitted variable theories presented above, as these might impact smaller systems more than larger systems on a dollar pet watt basis.

When the results are arrayed across age groups (Table 11 and Figure 6), a different story emerges, which echoes what was discovered in the regressions with the full sample (e.g., see Table 7 and Table 8). As PV system age increases, *Premiums* decrease, even after controlling for the size of the system. These figures imply a relatively large decrease after 6 years, but, because of the relatively small sample size in the 6–10 years group, and the correspondingly large confidence intervals, it is not clear by how much. Although this seems to indicate that age of a PV system influences *Premiums*, alternative theories are possible (see footnote 23). *Cost* and *Income Estimates* respectively range from 43% to 73% and 25% to 43% of

[29] Low and high *Income Estimate* regression results are similar and therefore are not included.

[30] By breaking the sets of estimates across these discrete bins, some explanatory power is lost, and margins or errors increase. The tables and figures derived from these regressions, therefore, appear to show that in some cases there is no statistical difference between the *Premiums* and *Cost* and *Income Estimates*; more importantly, in some cases the *Premiums* are not statistically different from zero. A more reliable test is to use the full set of (continuous) estimates, all of which show strongly statistically significant differences.

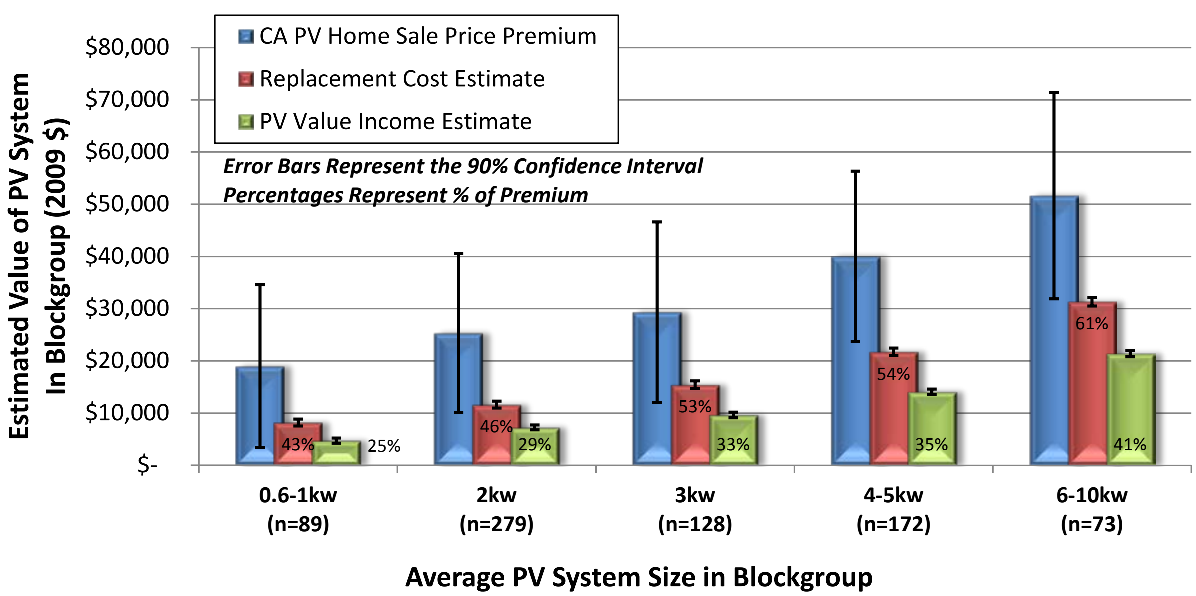
*Premiums* as PV systems age up to 5 years, but jump to more than 800% and 400%, respectively, beyond 6 years of age.

### Table 10: Summarized Regression Results of Premium, Cost, and Income Estimates across PV System Size Groups (results in 2009 dollars)

| Model Results (for three models - see note) | | | |
|---|---|---|---|
| **Size Groups** | **Premiums** | **Cost Estimates** | **Income Estimates** |
| **0.6-1kw** | $ 18,998 ** | $ 8,212 *** | $ 4,729 *** |
| **2kw** | $ 25,293 *** | $ 11,621 *** | $ 7,263 *** |
| **3kw** | $ 29,328 *** | $ 15,423 *** | $ 9,651 *** |
| **4-5kw** | $ 40,008 *** | $ 21,735 *** | $ 14,074 *** |
| **6-10kw** | $ 51,643 *** | $ 31,335 *** | $ 21,409 *** |

*Results shown above are derived from three separate regressions, which are included in Appendix B. Values in this table are determined by adding the 2, 3, 4-5 and 6-10kW coefficients to the omitted 0.6-1 kW coefficient. Significance levels are calculated by comparing these coefficients to 0, rather than the omitted category, which is what is shown in the full set of results. Significance symbols are as follows: p-value < * 0.10, ** 0.05, *** 0.01.*

### Figure 5: Regression Results of Premium, Cost, and Income Estimates across PV System Size Groups



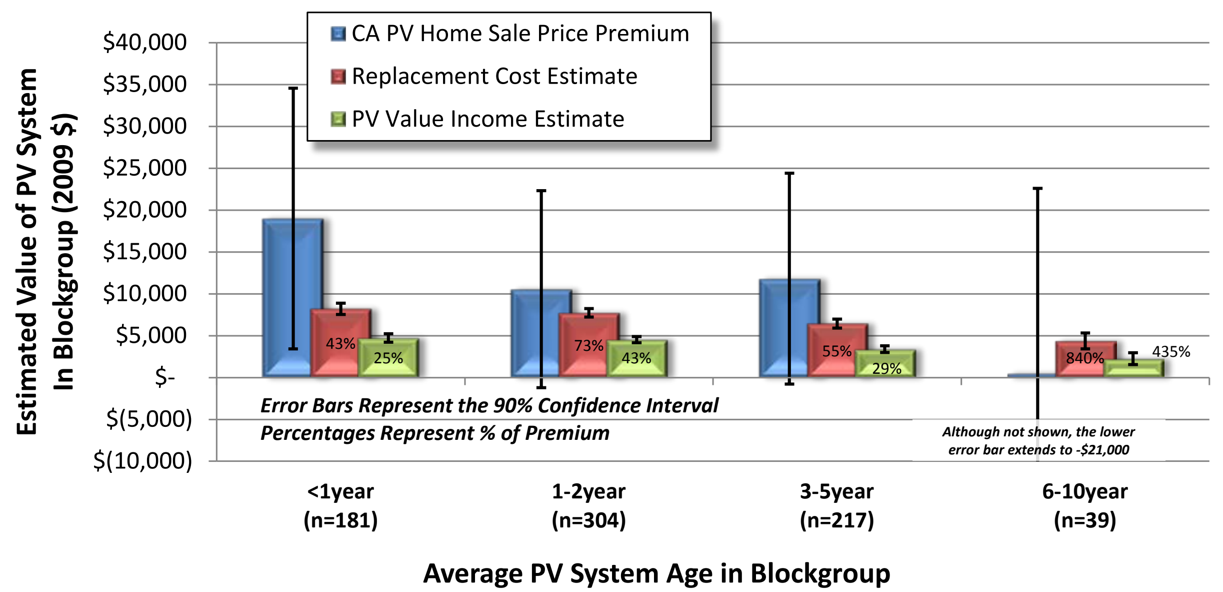

*Estimates are derived for each census blockgroup (n=741), each of which contains at least one PV home and at least one non-PV home. n (in labels above) represents the number of block groups with average PV system size in that range. Although Premium and Cost and Income estimates do not appear to statistically significantly different, that is a result of the discreet bin sample sizes. When regressed as continuous variables they are.*

**Table 11: Summary Regression Results of Premium, Cost, and Income Estimates across PV System Age Groups (results in 2009 dollars)**

| Model Results (for three models - see note) | | | |
|---|---|---|---|
| **Age Groups** | **Premiums** | **Cost Estimates** | **Income Estimates** |
| **<1year** | $ 18,998 *** | $ 8,212 *** | $ 4,729 *** |
| **1-2year** | $ 10,557 | $ 7,734 *** | $ 4,523 *** |
| **3-5year** | $ 11,811 | $ 6,452 *** | $ 3,378 *** |
| **6-10year** | $ 520 | $ 4,364 *** | $ 2,258 *** |

*Results shown above are derived from three separate regressions, which are included in Appendix B. Values in this table are determined by adding the 1-2, 3-5 and 6-10 year coefficients to the omitted 0-1 year coefficient. Significance levels are calculated by comparing these coefficients to 0, rather than the omitted category, which is what is shown in the full set of results. Significance symbols are as follows: p-value < * 0.10, ** 0.05, *** 0.01.*

**Figure 6: Regression Results of Premium, Cost, and Income Estimates across PV System Age Groups**




*Estimates are derived for each census blockgroup (n=741), each of which contains at least one PV home and at least one non-PV home. n (in labels above) represents the number of block groups with average PV system age in that range. Although Premium and Cost and Income estimates do not appear to statistically significantly different, that is a result of the discreet bin sample sizes. When regressed as continuous variables they are.*

## 4.4 Assessing PV Home Valuation Tools

We now turn to the final research question: Based on California PV home sales from 2000 through 2009, *do these results validate the PV Value® tool, and do they offer any guidance to the income approach used in the PV Value® tool or to other estimating algorithms (including those based on the cost approach)?*

First, our analysis offers clear support that a premium exists in the marketplace; thus, PV systems have value, and their contribution to home values must be assessed.[31]

Second, as noted elsewhere (e.g., Klise et al., 2013b), in many communities few PV home sales exist, and finding comparable PV home sales is therefore difficult. This is borne out in our data with many counties showing less than a handful of PV home transactions (see Table 1). Consequently, tools are needed that can estimate the premium for an average PV home without a set of comparable sales. PV Value® is just such a tool.

Third, the market-based California PV homes premiums show increases with systems size, and decreases with PV system age. These relationships are both logical and conform, directionally, with the estimates made by PV Value, providing some validation to the basic methods used in the tool.

Fourth, because PV Value® is only beginning to be used, prudence suggests that it should err on the side of conservative (i.e., low) estimates of the contribution of PV systems to home values. The analysis presented in this paper shows that, at least for California PV homes sold between 2000 and 2009, PV Value's *Income Estimates* are, in fact, conservative, being well below the estimated market-indicated *Premiums*. For the full sample of California PV homes analyzed, PV Value® *Income Estimates* account for approximately 39% to 45% of the estimated *Premiums* found in the marketplace, depending on whether the low, medium, or high *Income Estimate* is examined.

Fifth, the source of the discrepancy between PV Value® estimates and estimated market-based premiums for California PV homes is an area where further research is warranted, but this initial research tentatively suggests some areas of *possible* improvement in PV Value® estimates. For example, as discussed earlier, one possible partial source for the discrepancy for California PV homes is that the actual retail electricity rates that PV home customers face could be substantially higher than were estimated by PV Value. This is due to the steep rate tiers that are a feature of the California market, and revisions to PV Value® to account for such tiers might be worth further investigation. That said, one must acknowledge that such steep tiers are largely limited to California, and it is unclear whether they are considered in home sales transactions. Moreover, retail rate complexity in other states, including the existence of fixed customer charges, means that PV Value® estimates of energy savings may be biased high in other markets. As such, if additional retail rate complexity is to be added to PV Value® estimates, that complexity may increase energy savings estimates in some locations, but decrease energy savings estimates in others.

Sixth, when focusing on older systems, PV Value's *Income Estimates* appear not to be conservative. Instead, the market seems to indicate that *Premiums* for PV homes erode faster than would be predicted from energy savings alone (e.g., for systems that are older than six to ten years). Therefore, in future iterations, the tool might include either higher degradation factors or higher discount rates as PV systems age, especially for systems older than six to ten years and beyond. Additional validation research may, however, be prudent before altering PV Value® estimates along these lines, as the reliability of the California PV home premium age-degradation results is not clear.

[31] This may seem obvious, but there are many anecdotal accounts of appraisers, underwriters, assessors, and other valuers not placing any value on an installed PV system.

Seventh, it is possible that the source of the difference between *Premium* and *Income Estimates* might be because *Premiums* are overestimated and include the value of, for example, a new roof or other features. In that case, *Income Estimates* might be less conservative when those features are considered, and changing PV Value® estimates might be inappropriate. Related, the preliminary validation presented here focuses on California homes sales from 2000 through 2009; a more complete validation would include more recent sales, and PV homes sales in states beyond California. Any revisions to PV Value® estimates based on validation efforts should, arguably, await a more complete validation using additional data.

Finally, similar conclusions apply to replacement cost algorithms. The market seems to indicate higher values for PV homes than the *Cost Estimates* predict, possibly owing to transaction-cost avoidance. In addition, using a 20-year depreciation rate might not be aggressive enough, as the market seems to show a steeper discount as systems age beyond six to ten years, which might be related to additional costs that are not incorporated in our estimates such as inverter replacement.

# 5. Conclusion

Although PV penetration in the United States is increasing rapidly, and previous studies have found that market premiums exist for PV homes, the drivers of those premiums have not been explored adequately. Moreover, developing solid techniques for predicting PV premiums for individual homes has only begun, with little validation of the accuracy of those predictions. This study helps fill both of those gaps by analyzing PV home premiums from a large dataset of California PV homes, exploring the sensitivities of those premiums to the size and age of the installed system at the time of sale, and comparing those premiums to two commonly used techniques for predicting the value of a PV system, using either the income or cost approach. The estimates using the income approach are derived using the PV Value® tool (Klise et al., 2013b), while the cost approach estimates use a replacement cost approach.

Our analysis offers clear support that a premium exists in the marketplace; thus, PV systems have value, and their contribution to home values must be assessed. We find that premiums in California are strongly correlated with PV system size and weakly correlated with PV system age, in other words larger systems garner larger premiums and older systems garner smaller premiums. We estimate that each 1-kW increase in size equates to a $5,911 higher Premium (*p*-value 0.000) and each year systems age equates to a $2,411 lower premium (*p*-value 0.087).

Additionally, the actual California premiums appear to erode over time (estimated to be approximately 9% per year), more quickly than either the income (approximately 0.5% per year) or cost approaches (5% per year) predict and thus the premiums for homes with older systems (e.g., between 6 and 10 years old) appear to be substantially smaller than predicted.

Further, premiums appear to be substantially larger than predicted using the income (42% of premiums when the average income estimate is used, *p*-value 0.000) and cost approaches (65% of premiums, *p*-value 0.000). There are a number of plausible explanations for this disparity including: premiums might be larger because buyers were willing to pay more for the PV system owing to its green cachet; there could be transaction costs that are avoided by purchasing a home with a PV system already installed that are not incorporated in the cost estimates; the average utility-specific California residential electricity retail rates, which are used for the income estimates, might be lower than they should be in CA where steeply tiered rates are commonplace; and, the market-based premium estimates could contain effects from omitted variables and therefore potentially overestimate the actual premiums.

A number of areas might be considered for future study: investigate premiums in other markets outside of California and across a broader set of PV homes and over a more recent period, including the recent market crash and recovery; investigate how premiums vary between customer owned and third-party owned PV systems; further explore the impact of system age, "green cachet", and retail electricity rates on PV premiums; and, explore how these and other relationships change over time as the market for PV homes develops. These further investigations will help improve our collective understanding of PV premiums, and will help further tune the income and cost based valuation tools that develop to predict the impact of PV systems on homes prices.

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# 7. Appendix A: Calculating the Present Value of Energy Savings (Income) Estimates

This appendix outlines the steps made to calculate the expected income value of the PV system at the date the home was sold (*Income Estimates*). These *Estimates* are determined utilizing a modified discounted cash flow that accounts for the many components and configurations that impact the amount of energy the PV system can produce. The installed cost, either gross or net, is not necessary for analyzing the system in this manner. In order to make this calculation, the PV Value® tool is utilized to determine a range of values for each of the 1,894 PV homes in the LBNL database.[32]

The use of a discounted cash flow tool to calculate the present value of the energy produced by a PV system requires many inputs, including the following:

- Age of PV system and remaining lifetime under warranty
- First-year energy production in kWh, which requires:
  - Zip code
  - Size of PV system (direct current [DC] nameplate capacity)
  - Derate factor (NREL, 2013)
  - Module-degradation rate
  - Array type (fixed or tracking)
  - Array tilt (in degrees)
  - Array azimuth (in degrees)
- Discount rate
- Average electricity rate
- Utility escalation rate
- Estimated operations and maintenance (O&M) expenses

These parameters represent the minimum set of data needs for this analysis; data are not available on roof age or condition, energy savings realized by the homeowner with the PV system, the condition of the system, and whether there is any partial shading that can reduce the PV system's output. These additional factors would be used by a real property appraiser to adjust the market value to account properly for added "risks" that can reduce production and encompass future liabilities (roof replacement).

## 7.1 Age of PV System and Remaining Lifetime

The LBNL dataset has two date fields: the age of the PV system and the date of sale for the house. New date fields were added to aid in determining the discount rate, the proper utility escalation rate, and the remaining energy lifetime. First, to pick a date which could be used for the discount rate, 30 days are subtracted from each "date sold." This helps approximate the lock-in period for the mortgage interest rate. Second, the remaining lifetime of the PV system is determined from the existing age of the PV system. For this analysis, it is assumed that the module power production warranty, typically 25 years, will define the timeframe for the present value analysis. Finally, the start and end year for the utility escalation rate are determined using the 30-day prior "date sold" field and the remaining lifetime of the PV system (see below for more detail).

[32] For more information on the methodology behind and the use of the PV Value tool, see Klise and Johnson (2012), Klise et al. (2013b, a), and http://www.pvvalue.com.

## 7.2 First-Year Energy Production

To calculate the first-year energy production, PV Value® utilizes the PVWatts Application Programming Interface (API) call available from developer.nrel.gov. Many inputs are necessary to make this calculation, and the assumptions made are described below.

The zip code of the house is available from LBNL along with the DC nameplate capacity of the PV system. To be consistent with the default assumptions in the current version of the PV Value® tool, the default derate factor of 0.77 is utilized. This is a default used by the National Renewable Energy Laboratory with the PVWatts program, and, without evidence to support a higher or lower derate factor for this dataset, this default value was used. The PV Value® user manual has a discussion on how the derate factor can be changed with proper supporting documentation.

Module degradation rate is assumed at 0.5% per year, which is consistent with the default value used in PV Value® for crystalline-silicon PV modules. This type of technology is prevalent in most residential installations, and studies have determined this rate to be somewhat consistent with crystalline PV modules installed before and after the year 2000 (Jordan and Kurtz, 2013).

Array type for all systems is assumed to be fixed, because these are small residential PV systems installed on either pitched or flat roofs. LBNL provided information on array tilt and azimuth for each PV system, but based on county-level averages rather than knowledge about specific systems.

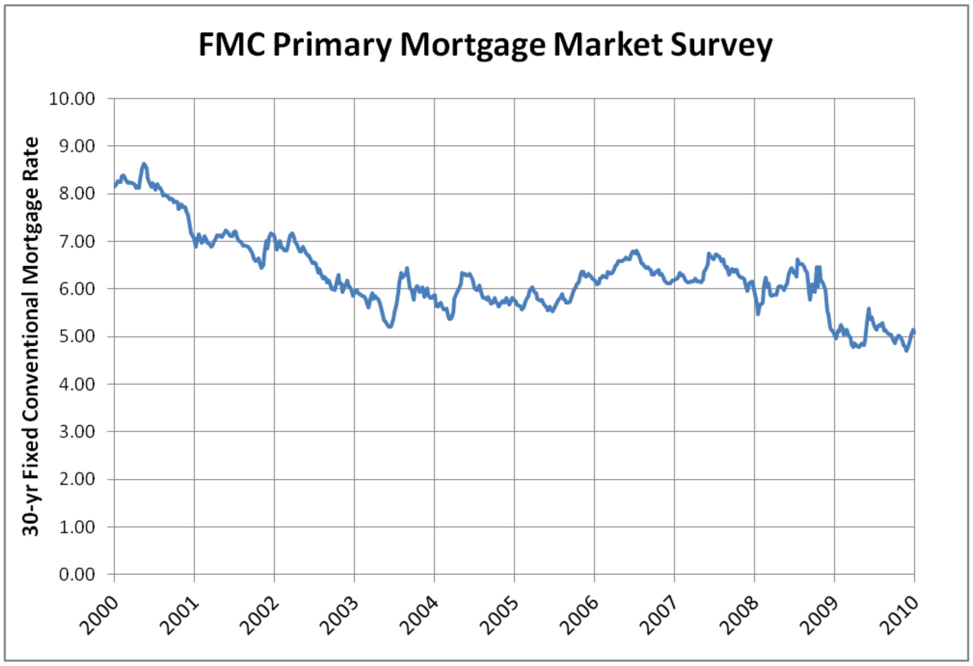
These data were then run through PV Value, which accesses the PVWatts API, to calculate the first-year energy production in kWh. This value is then used to determine production estimates for the remaining years through a discounted cash flow analysis.

## 7.3 Discount Rate

The discount rate in this analysis is a function of a risk-free rate plus an additional predefined basis point spread to account for risk. As the PV Value® tool ties the residential discount rate to the cost of borrowing money at the time of the home sale, the goal is to determine the historic rate that would have applied at the time the house was sold. The Freddie Mac Primary Mortgage Survey (Freddie Mac, 2013) monthly-averaged 30-year fixed, conventional rate is used to determine the rates that would have been available to the home purchaser 30 days before the home sold, which reflects a somewhat average commitment period to complete the entire transaction. The basis point spread is added on top of these rates, ranging between 50 and 200 basis points (0.5% to 2.00%) with an average of 125 (1.25%). This spread is the current default in PV Value® and is used in this analysis. Figure A - 1 shows the trend of data from the mortgage survey used for the risk-free rate.

A discount rate model is in development by Sandia National Laboratories and Energy Sense Finance to refine discount rates and risk premium spreads further for renewable energy transactions. It is anticipated to be available in 2014. In its absence, a default range of 50–200 basis points is used.

**Figure A - 1: Rates Obtained from the Freddie Mac (FMC) Primary Mortgage Market Survey from 2000 through 2009**




## 7.4 Average Electricity Rate and Utility Escalation Rate

The PV Value® tool utilizes an average electricity rate as supplied from the U.S. Energy Information Administration (EIA), from Form EIA-861, to approximate the value of the energy produced (EIA, 2013). For years after the home sale, this rate is escalated using a utility-specific percentage that is calculated using a compound annual growth rate (CAGR), based on growth in rates in previous years. Figure A – 2 and Table A - 1 represent the EIA-861data for the four utilities that service all but two of the houses in the LBNL PV home dataset.

**Figure A - 2: Rates from EIA 861 Calculated for the Four Main Utility Service Areas**

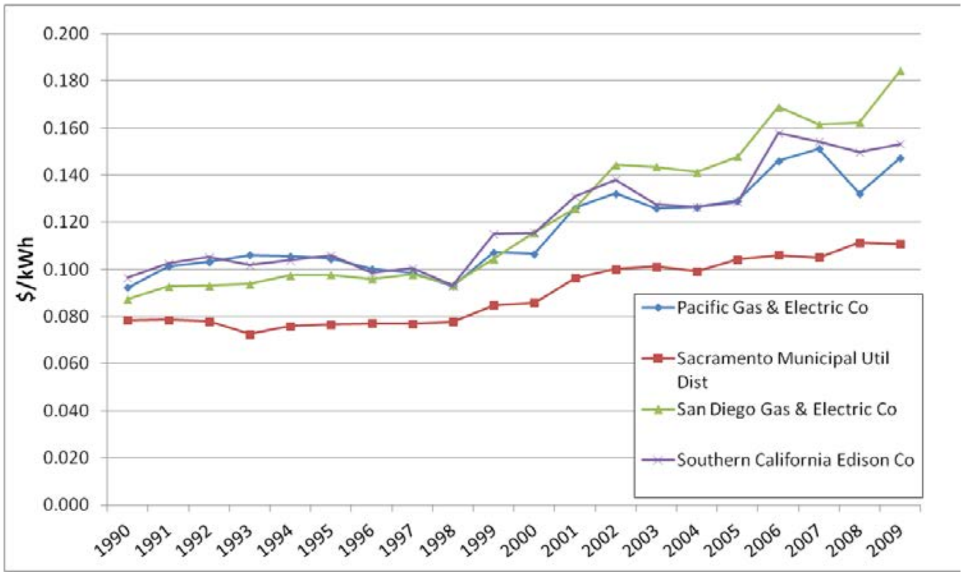


**Table A - 1: Rates from EIA 861 Calculated for the Four Main Utility Service Areas**

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pacific Gas & Electric Co** | 0.092 | 0.101 | 0.103 | 0.106 | 0.106 | 0.105 | 0.100 | 0.099 | 0.093 | 0.107 |
| **Sacramento Municipal Util Dist** | 0.078 | 0.079 | 0.078 | 0.073 | 0.076 | 0.077 | 0.077 | 0.077 | 0.078 | 0.085 |
| **San Diego Gas & Electric Co** | 0.087 | 0.093 | 0.093 | 0.094 | 0.097 | 0.098 | 0.096 | 0.098 | 0.093 | 0.105 |
| **Southern California Edison Co** | 0.097 | 0.103 | 0.105 | 0.102 | 0.104 | 0.106 | 0.099 | 0.100 | 0.093 | 0.115 |
| | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
| **Pacific Gas & Electric Co** | 0.107 | 0.126 | 0.132 | 0.126 | 0.127 | 0.129 | 0.146 | 0.151 | 0.132 | 0.147 |
| **Sacramento Municipal Util Dist** | 0.086 | 0.096 | 0.100 | 0.101 | 0.099 | 0.104 | 0.106 | 0.105 | 0.111 | 0.111 |
| **San Diego Gas & Electric Co** | 0.116 | 0.126 | 0.144 | 0.143 | 0.141 | 0.148 | 0.169 | 0.161 | 0.162 | 0.184 |
| **Southern California Edison Co** | 0.116 | 0.131 | 0.138 | 0.128 | 0.127 | 0.129 | 0.158 | 0.154 | 0.150 | 0.153 |

*Note: Data obtained from* [*http://www.eia.gov/electricity/data/eia861/*](http://www.eia.gov/electricity/data/eia861/)

These average annual utility rates were determined by dividing the residential revenues by the residential sales for bundled service. This is an average of what customers paid for that particular year, and the resulting value from the table above that matches the year the house was sold is used in the analysis. Two of the 1,894 houses had different utility providers than the four listed above: the City of Palo Alto and the City of Healdsburg. Utility rates for these two providers were obtained in the same way as above, although they are not shown in Figure A - 2.

Utility escalation rates were developed from the data above using a CAGR formula:

$$CAGR = \frac{(starting\ electricity\ rate)^{\left(\frac{1}{\#\ of\ years}\right)}}{(ending\ electricity\ rate)} - 1 \qquad \text{(A1)}$$

The remaining lifetime of the PV system is a function of the module power production warranty, which for this study is assumed to be 25 years, which matches most module power production warranties on the market. The CAGR is used to escalate retail rates from the date of home sale to the end of the remaining lifetime of the PV system. To calculate the appropriate CAGR to apply, historical rate escalation data from EIA are used. Those data only go back to 1990, however, leading to different periods of historical rate data being used to estimated appropriate CAGRs, depending on the year of home sale. For example, a home sold in 2002 with a 2-year-old PV system has 23 years remaining for the module power production warranty lifetime. The CAGR used over the 23 years is the one calculated based on available data back to 1990 and through the home sale in 2002: 13 years. Table A - 2 shows the different rates utilized along with the year for the starting rate, which is used in the numerator of the CAGR calculation. There are only 10 years shown below, because these match the range of years the homes sold in the LBNL database.

**Table A - 2: Utility escalation rates in % calculated from Table 1 using Equation A1**

| *Year for Starting Rate* | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
|---|---|---|---|---|---|---|---|---|---|---|
| *Number of Years* | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| **Pacific Gas & Electric Co** | 1.45 | 2.89 | 3.04 | 2.43 | 2.28 | 2.27 | 2.92 | 2.95 | 2.02 | 2.50 |
| **Sacramento Municipal Util Dist** | 0.91 | 1.88 | 2.07 | 1.98 | 1.69 | 1.91 | 1.90 | 1.73 | 1.96 | 1.83 |
| **San Diego Gas & Electric Co** | 2.86 | 3.37 | 4.27 | 3.89 | 3.50 | 3.57 | 4.21 | 3.68 | 3.50 | 4.01 |
| **Southern California Edison Co** | 1.81 | 2.80 | 3.03 | 2.16 | 1.95 | 1.93 | 3.11 | 2.79 | 2.47 | 2.46 |

## 7.5 Estimated O&M Expenses

The PV Value® Tool accounts for O&M costs at the beginning of year 16 (out of the 25-year warranty lifetime) to determine the potential cost for an inverter replacement. For example, the anticipated O&M expenses are $0.55/W in year 16.[33] For a 5-kW PV system, the future value to replace the inverters at the

[33] See Klise and Johnson (2012) for more information on O&M rates.

end of the 15th year (beginning of 16th) would be $2,750. This amount has to be discounted back to today's dollars to determine the present value of that replacement cost. For a new PV system valued today, the replacement cost 16 years into the future, discounted back to today's dollars, is $962.44 with a discount rate of 7.25%. If the system is 5 years old and valued today, then the replacement cost 10 years into the future, discounted back to today's dollars, is $1,365.71. The PV Value® tool has the ability to look at replacement cost after the 15th year, which essentially gives the user the choice to state whether the inverter has or has not been replaced up until the end of the 15th year. This will reduce the value, especially if it has not been replaced before the end of the 15th year, assuming that it is out of warranty. For this analysis, the oldest PV system is 9 years, so this extra level of analysis is not required.

## 7.6 Appraisal Range of Value Calculation

The details of each PV system were entered into the PV Value® tool. Results were returned for the high, average, and low appraisal range of value. This range differs by discount rate range with the 50, 125, and 200 basis points added to the risk-free rate, respectively.

The calculation made in the tool for determining the present value of the energy produced is presented in Equations A2 and A3, where the Appraisal Value is the sum of the energy value over the 25-year module power production warranty lifetime:

$$EiVal = AC_{Ei} \times (1 - 0.05i) \times U_r \times \left(1 + U_{er}\right)^{0,1,2,..(i-1)} \times \left(1 + D_r\right)^{0,-1,-2,..-(i-1)} \qquad \text{(A2)}$$

$$Appraisal\ Value = \begin{cases} \sum_i EiVal_i & for\ i = 1..15 \\ \sum_i EiVal_i - O\&M_{i=16} & for\ i = 16..25 \end{cases} \qquad \text{(A3)}$$

Where: EiVal = energy value in $

$AC_{Ei}$ = alternating-current energy in kWh

$U_r$ = utility rate in $/kWh

$U_{er}$ = utility escalation rate in %

$D_r$ = discount rate in %

## 8. Appendix B: Premium, Cost, and Income Regressions over Size and Age Bins

### Table A - 3: Results from Regression of Premiums on Low Income Estimates

| **Model Results** | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Description** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **bglowinc09** | average blockgroup low *Income Estimate* | 2.54 | 0.26 | 9.67 | 0.000 |
| | | | | | |
| **Model Characteristics** | | | | | |
| ***n*** | | 741 | | | |
| **F** | | 93.44 | | | |
| **Prob > F** | | 0.000 | | | |
| **Adjusted R-Squared** | | 0.1109 | | | |
| **Dependent Variable** | | Blockgroup Premiums | | | |

### Table A - 4: Results from Regression of Premiums on Average Income Estimates

| **Model Results** | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Description** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **bgavginc09** | average blockgroup average *Income Estimate* | 2.38 | 0.25 | 9.67 | 0.000 |
| | | | | | |
| **Model Characteristics** | | | | | |
| ***n*** | | 741 | | | |
| **F** | | 93.5 | | | |
| **Prob > F** | | 0.000 | | | |
| **Adjusted R-Squared** | | 0.111 | | | |
| **Dependent Variable** | | Blockgroup Premiums | | | |

### Table A - 5: Results from Regression of Premiums on High Income Estimates

| **Model Results** | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Description** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **bghighinc09** | average blockgroup high *Income Estimate* | 2.22 | 0.23 | 9.67 | 0.000 |
| | | | | | |
| **Model Characteristics** | | | | | |
| ***n*** | | 741 | | | |
| **F** | | 93.57 | | | |
| **Prob > F** | | 0.000 | | | |
| **Adjusted R-Squared** | | 0.1111 | | | |
| **Dependent Variable** | | Blockgroup Premiums | | | |

**Table A - 6: Results from Regression of Premiums on Cost Estimates**

| Model Results | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Description** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **bgcost09** | average blockgroup *Cost Estimate* | 1.54 | 0.16 | 9.58 | 0.000 |

| Model Characteristics | |
|---|---|
| ***n*** | 741 |
| **F** | 91.73 |
| **Prob > F** | 0.000 |
| **Adjusted R-Squared** | 0.1091 |
| **Dependent Variable** | Blockgroup Premiums |

**Table A - 7: Results from Regression of Premiums on Size and Age Bins**

| Model Results | | | | |
|---|---|---|---|---|
| **Variable** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **Intercept** | $ 18,998 | $ 9,325 | 2.04 | 0.042 |
| **Size Groups** | | | | |
| **0.6-1kw** | Omitted | - | - | - |
| **2kw** | $ 6,295 | $ 9,110 | 0.69 | 0.490 |
| **3kw** | $ 10,330 | $ 10,349 | 1.00 | 0.319 |
| **4-5kw** | $ 21,010 | $ 9,785 | 2.15 | 0.032 |
| **6-10kw** | $ 32,645 | $ 11,827 | 2.76 | 0.006 |
| **Age Groups** | | | | |
| **<1year** | Omitted | - | - | - |
| **1-2year** | $ (8,441) | $ 7,050 | -1.20 | 0.232 |
| **3-5year** | $ (7,187) | $ 7,537 | -0.95 | 0.341 |
| **6-10year** | $ (18,478) | $ 13,224 | -1.40 | 0.163 |

| Model Characteristics | |
|---|---|
| ***n*** | 741 |
| **F** | 2.12 |
| **Prob > F** | 0.04 |
| **Adjusted R-Squared** | 0.01 |
| **Dependent Variable** | Blockgroup Premiums |

**Table A - 8: Results from Regression of Cost Estimates on Size and Age Bins**

| **Model Results** | | | | |
|---|---|---|---|---|
| **Variable** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **Intercept** | $ 8,212 | $ 400 | 20.51 | 0.000 |
| **Size Groups** | | | | |
| **0.6-2kw** | Omitted | - | - | - |
| **2-3kw** | $ 3,408 | $ 391 | 8.71 | 0.000 |
| **3-4kw** | $ 7,211 | $ 444 | 16.23 | 0.000 |
| **4-6kw** | $ 13,523 | $ 420 | 32.19 | 0.000 |
| **6-10kw** | $ 23,123 | $ 508 | 45.54 | 0.000 |
| **Age Groups** | | | | |
| **0-1year** | Omitted | - | - | - |
| **1-3year** | $ (478) | $ 303 | -1.58 | 0.114 |
| **3-6year** | $ (1,760) | $ 324 | -5.44 | 0.000 |
| **6-10year** | $ (3,848) | $ 568 | -6.78 | 0.000 |

| **Model Characteristics** | |
|---|---|
| ***n*** | 741 |
| **F** | 482.73 |
| **Prob > F** | 0.00 |
| **Adjusted R-Squared** | 0.82 |
| **Dependent Variable** | Cost Estimates |

**Table A - 9: Results from Regression of Average Income Estimates on Size and Age Bins**

| **Model Results** | | | | |
|---|---|---|---|---|
| **Variable** | **Coef** | **SE** | ***t*** | ***p*-value** |
| **Intercept** | $ 4,729 | $ 296 | 16.00 | 0.000 |
| **Size Groups** | | | | |
| **0.6-1kw** | Omitted | - | - | - |
| **2kw** | $ 2,534 | $ 289 | 8.77 | 0.000 |
| **3kw** | $ 4,921 | $ 328 | 15.00 | 0.000 |
| **4-5kw** | $ 9,344 | $ 310 | 30.13 | 0.000 |
| **6-10kw** | $ 16,680 | $ 375 | 44.49 | 0.000 |
| **Age Groups** | | | | |
| **<1year** | Omitted | - | - | - |
| **1-2year** | $ (206) | $ 223 | -0.92 | 0.356 |
| **3-5year** | $ (1,352) | $ 239 | -5.66 | 0.000 |
| **6-10year** | $ (2,471) | $ 419 | -5.90 | 0.000 |

| **Model Characteristics** | |
|---|---|
| ***n*** | 741 |
| **F** | 444.81 |
| **Prob > F** | 0.00 |
| **Adjusted R-Squared** | 0.81 |
| **Dependent Variable** | Average Income Estimates |