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Do PV Systems Increase Residential Selling Prices? If So, How Can Practitioners Estimate This Increase?

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***Abstract* - Relatively little research exists estimating the marginal impacts of photovoltaic (PV) energy systems on home sales prices. Using a large dataset of California homes that sold from 2000 through mid-2009, we find strong evidence, despite a variety of robustness checks, that existing homes with PV systems sold for a premium over comparable homes without PV systems, implying a near full return on investment. Premiums for new homes are found to be considerably lower than those for existing homes, implying, potentially, a tradeoff between price and sales velocity. The results have significant implications for homeowners, builders, appraisers, lenders, and policymakers. Some new tools have emerged which can be used to estimate premiums for PV homes.**

***Index Terms* – photovoltaic, PV, home values, resale, premiums, new homes, existing homes.**

I. BACKGROUND

The market for photovoltaic (PV) energy systems is expanding rapidly in the U.S. Almost 100,000 PV systems have been installed in California alone, more than 90% of which are residential [1]. Some of those "PV homes" have sold, yet little research exists estimating if those homes sold for significantly more than similar non-PV homes. A clearer understanding of these effects might influence the decisions of homeowners considering installing PV on their home or selling their home with PV already installed, of home buyers considering purchasing a home with PV already installed, and of new home builders considering installing PV on their production homes.

Previous literature indicates that a premium might exist, but relatively small samples were used. Farhar et al. [2-3] tracked repeat sales of 15 "high performance" energy efficient homes with PV installed from one subdivision in San Diego and found evidence of higher appreciation rates, using simple averages, for these homes over comparable homes (*n*=12). More recently, Dastrup et al. [4] used a hedonic analysis to investigate the selling prices of 329 homes with PV installed in the San Diego and Sacramento, California metropolitan areas, finding evidence of PV premiums that averaged approximately 3% of the total sales price of non-PV homes. In the absence of applicable empirical research investigating PV home premiums, practitioners have relied on analogous, work that investigated premiums related to energy efficiency using a sales comparison approach [5-6], while separately using estimates for premiums based an income valuation approach [e.g., 7].

To provide a more robust estimate as to whether PV homes sell for significantly more than comparable non-PV homes, Berkeley Lab analyzed a dataset of approximately 72,000 California homes, almost 2,000 of which had PV systems installed at the time of home sale. The study also investigated whether premiums for PV installed on new homes were different than those for PV installed as a retrofit on existing, and whether the age or the size of the PV system impacted premiums.

II. METHODOLOGY

Several empirical model specifications, with a high reliance on the hedonic pricing model [8-9], are used in this paper to disentangle and control for the potentially competing influences of home, site and neighborhood characteristics in order to determine whether and to what degree PV homes sell for a premium. A set of "base" models are estimated, along with robustness models, including a variant of the hedonic model, a difference-in-difference (DD) model [10].

Formally, the "base" hedonic model is as follows:

$$\ln(P_{itk}) = \alpha + \beta_1 (T_i) + \beta_2 (N_i) + \sum_a \beta_3 (X_i) + \beta_4 (PV_i \cdot SIZE_i) + \varepsilon_{itk} \tag{1}$$

where:

P_{itk} represents the inflation adjusted sale price for transaction *i*, in quarter *t*, in block group *k*,

α is the constant or intercept across the full sample,
T_i is the quarter in which transaction *i* occurred,
N_i is the census block group in which transaction *i* occurred,
X_i is a vector of *a* home characteristics for transaction *i* (e.g., acres, square feet, age, etc.),
PV_i is a fixed (i.e., dummy) effect variable indicating a PV system is installed on the home in transaction *i*,
$SIZE_i$ is a continuous variable for the size (in kW) of the PV system installed on the home prior to transaction *i*,
β_1 is a parameter estimate for the quarter in which transaction *i* occurred,
β_2 is a parameter estimate for the census block group in which transaction *i* occurred,
β_3 is a vector of parameter estimates for home characteristics *a*,
β_4 is a parameter estimate for the percentage change in sale price for each additional kW added to a PV system and
ε_{itk} is a random disturbance term for transaction *i*, in quarter *t*, in block group *k*.

Similar "base" models were estimated for the sample subsets consisting of new PV homes and existing PV homes. For each of the base models, robustness models were estimated using: 1) a coarsened exact matched set of PV and non-PV homes [11]; and 2) a fixed effect variable to account for the subdivision in which the PV home was situated; and, for the existing PV home base model, additionally a difference-in-difference model using repeat home sales was estimated.

III. DATA

The dataset of 72,319 California homes, 1,894 of which had PV systems installed at the time of home sale: (1) are from 31 of the 58 counties in California; (2) are approximately 60% existing homes (that received a "retrofit" PV installation) and 40% new homes (that received a PV system as it was being built); (3) occurred over eleven years (1998-2009), with the largest concentration of PV sales occurring in 2007 and 2008; and (4) are located primarily within four major utility service areas (Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, and Sacramento Municipal Utility District), with the largest concentration in the Pacific Gas & Electric territory.

IV. RESULTS

The research finds strong evidence that homes with PV systems in California have sold for a premium over comparable homes without PV systems. More specifically, estimates for average PV premiums among a large number of different model specifications coalesced near $17,000 for a relatively new (approximately 2.5 years old) "average-sized" - based on the sample of homes studied - PV system of 3,100 watts (DC). This corresponds to an average home sales price premium of $5.5/watt (DC), with the range of results across various models being $3.9 to $6.4/watt (see fig. 1).

The average sale price premiums appear to be comparable to the investment that homeowners had made to install PV systems in California (after applicable state and federal incentives), which from 2001-09 averaged approximately $5/watt (DC) (Barbose et al., 2010), and homeowners also benefited from electricity cost savings after PV system installation and prior to home sale, implying a near full-return on their investment.

When the dataset is split between new and existing homes, PV system premiums are found to be markedly affected (see fig. 1), with new homes with PV demonstrating average premiums of $2.3 to 2.6/watt, while the average premium for existing homes with PV being more than $6/watt. There are a number of possible explanations for why this disparity might exist, including: differences in the underlying net installation costs for PV systems between new and existing homes; a lower emphasis of "up selling" the PV system as compared to other aspects of the home; and, a lack of familiarity with the specifics of the system [12]. Additionally, new home builders may gain value from PV as a market differentiator, and therefore have tended to sell PV as a standard (as opposed to an optional) product on their homes [13], and perhaps had been willing in this sample to accept a lower premium in return for faster sales velocity and decreased carrying costs [13-14].

The research also finds that, as PV systems age, the premium enjoyed at the time of home sale decreases, indicating that buyers and sellers of PV homes may be accounting for the decreased efficiency and remaining expected life of older PV systems.

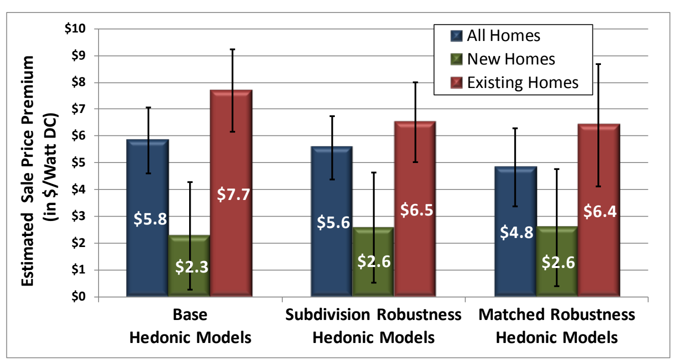
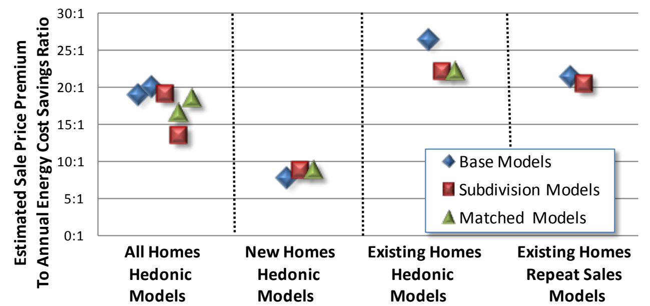


Fig. 1: CA PV home sale price premiums expressed in dollars per installed watt (DC) hover near $5/watt for average homes, and lower for new homes, yet higher for existing (retrofit) PV homes.

When the results are expressed as a ratio of the sales price premium to estimated annual electricity cost savings associated with PV they are consistent with those of the moreextensive existing literature on the impact of energy efficiency on home sales prices; the present research (see fig. 2) finds an average range from 7:1 to 31:1, with most models coalescing near 20:1, as had been found with previous research [e.g., 6].



The following assumptions were used for this calculation: 1,425 kWh AC are produced by each kW DC of PV. Energy cost savings equal $0.20/kWh AC.

Fig. 2: Using conservative assumptions for PV system energy output and a fixed price of energy, sale price premium to energy savings (in dollars) ratios coalesce near 20:1.

V. Discussion

These results have potentially significant implications for stakeholders in the PV arena, including homeowners, builders, appraisers, lenders, and even state and federal policymakers. Solar PV investments are sizable, and must be made under uncertainty, as future electricity rates, electrical output, and on-going maintenance requirements cannot be known with precision. Given the possibility that a homeowner might not reside in their home for long enough to experience the full returns of electricity bill savings from their PV investment, uncertainty over the impact of PV on home resale value could further dissuade investment in PV and thereby slow solar deployment. State and federal policymakers, meanwhile, have developed a variety of incentive programs to try to overcome these barriers and to increase solar deployment.

Our results strongly suggest that, on average at least, PV systems have substantial value upon home sale, thereby reducing this source of uncertainty for buyers, sellers, and developers, and potentially facilitating increased deployment of solar systems. If popularized, these results could reduce the amount of state and federal incentives that might otherwise be needed to support a given amount of solar deployment. To make such an outcome possible, however, homeowners would need to include resale value considerations when making investment decisions, which requires more-comprehensive life-cycle costing approaches rather than the simple payback calculations that are often used but that ignore resale value.

Finally, though our results suggest that new home builders can also expect a premium for solar homes, the average premium has not – to this point – been sufficient to cover the net cost of the installation of the PV systems. Encouraging greater uptake of solar in new homes may therefore require higher state and federal incentive levels and/or greater customer education, or for homebuilders to more-fully recognize the other possible benefits of PV in the form of sales velocity and other considerations.

VI. New Tools

Acceptance by appraisers and lenders of the resale value of PV could further reinforce to homeowners that impacts - as was found herein - are real, and such changes seem to be underfoot [e.g., 15]. Moreover, in 2011, two new tools were unveiled which might be used to help clarify likely sales price premiums for this group of stakeholders: 1) The California Energy Commission Solar Advantage Value Estimator (SAVE) tool, that is available online (http://www.gosolarcalifornia.org/tools/save.php); and, 2) Sandia National Laboratory's Photovoltaic System Valuation Model – PV Value™ [16], also available online (http://pv.sandia.gov/pvvalue).

Building on the past work of others [e.g., 7], both of these tools use a present value calculation of a estimated stream of energy savings over time. The more prominent differences between the two tools are that SAVE is: focused on CA; is web-based; uses tiered rate structures; cannot accommodate operations and maintenance (O&M) expenses related to inverter replacement; and, uses one fixed discount rate (3%). Alternatively, PV Value: can accommodate addresses from anywhere in the US; is a downloadable spreadsheet; uses utility average rates; can accommodate O&M expenses for inverter replacement; and, uses three discount rates (based on the Fannie Mae 30-year fixed rate and a high-middle-low risk spread).

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