Summary

How much is solar worth?

Because using electricity is not an option, a solar system should not be treated like other amenities in a home. A solar electric system has a uniquely quantifiable benefit: electricity that powers the home. A solar electric system can significantly reduce the cost of ownership. These saved costs should be valued with the home (and the mortgage). In addition, rising utility rates mean that savings, or avoided costs, will increase in the future. Thus, purchasing a rooftop solar system is an economic home-investment. Recent studies show that a solar system increases the property value by a substantial amount, often recovering 100% of the original cost. It is therefore important to give the solar system an accurate value. This may not always be easy to do, especially since solar homes are still relatively new in the real estate market.

Calculators

There are free tools—provided by state and federal governments—to help you accurately calculate the value of a PV rooftop solar system.

- Sandia and Solar Power Electric offer the PV Value™ tool: http://energy.sandia.gov/?page_id=8047
- NREL offers the PVWatts™ calculator: http://www.nrel.gov/rredc/pvwatts/

Read on for more detailed information.

Contents

- Solar & How it Works
- Electricity 101
- Solar Economics
- Market Valuation Studies
- Calculator Tools

Solar systems are measured in DC kW (kilowatts). Roughly 1 kW = 1,500 kWh/year
How Solar Works

Solar Electric System
Not all solar cells are the same. There is a wide range of efficiency and performance based on the cells used to make the solar panel. Solar electric systems constructed of high-efficiency cells, modules, and inverters will generate more power and thereby delivery greater financial benefits.

The Panels & Inverter
The solar electric system—also called a PV or photovoltaic system—produces electricity for in-home consumption. The solar system turns on automatically in the morning and turns off automatically at night. From sunrise to sunset, the system converts sunlight into electricity. Solar cells within the panels produce direct current (DC) electricity that flows into an inverter typically located on the inside wall of the garage. The inverter converts DC electricity into alternating current (AC), which is required for residential use to power appliances and fixtures, and instantly delivers the converted electricity to the home’s electric service panel.

Grid-Connected Solar Systems
The electric service panel first uses the solar electricity to supply all of the power required by the home. When the solar system generates more energy than the home consumes, surplus electricity travels through the meter and into the local power grid. The electric meter spins backward and the electric bill decreases (known as “net metering”).

Over the course of the month, if the solar system produces more electricity than the home consumes, the electric bill will be credited for the surplus electricity. Homeowners will be credited at the same rate as if they had purchased the electricity from their local utility.

Life Expectancy of a Solar System
Most solar systems today come with a 20 or 25-year warranty for power performance. Expected useful life is likely to be 40 to 50 years. The best evidence we have for expected useful life is the existence of several hundred systems that were installed 30 to 40 years ago and still operate today. With the technological advancements made in performance and reliability, it would be safe to assume that today’s systems would last at least as long. In general, solar systems are expected to last 30 years or more if the modules and inverters are qualified and certified products, installation and testing was properly done, and the system is well maintained (inverter replaced after 12-18 years, production monitoring is continued, and the panels are kept clean from excessive dust and debris).

What’s the science behind the solar panel?
A solar panel is made up of a number of photovoltaic cells. Photovoltaic (PV) is a method of generating electricity by converting solar energy into direct (DC) current. The PV cells are generally made from thin wafers of silicon, the second most abundant substance on Earth—the same substance that makes up sand. To make the wafers, the silicon is heated to extreme temperatures, and chemicals, usually boron and phosphorous, are added. The addition of these chemicals makes the silicon atoms unstable (their electrons become less tightly held). When photons of sunlight hit a solar panel, some are absorbed into the solar cells, where their energy knocks loose some of the modified silicon’s electrons. These loose electrons flow to wires that have been placed within the cells. This flow of electrons through the wires is electricity, which flows to the inverter for conversion to AC power.
So how much solar will a system produce? Solar system sizes are measured in kW (kilowatts). A 1 kW solar system will produce roughly 1,500 kWh (kilowatt-hours) per year.

**Rule of Thumb:**

1 kW = 1,500 kWh/yr

**Electricity Measurement**

Electricity is measured in kilowatt-hours. A watt is a unit of power that measures the rate of energy conversion. A typical household incandescent light bulb uses electrical energy at a rate of 25 to 100 watts.

A typical household incandescent light bulb uses electrical energy at a rate of 25 to 100 watts.

Ten 100-watt bulbs are equal to 1,000 watts, which is equal to 1 kilowatt. A kilowatt-hour is a measure of how many kilowatts are being used in one hour. If you turn on those ten bulbs for one hour, that would equal one kilowatt-hour.

**Electricity Consumption**

How many kilowatt-hours do you think most families consume each month? This is actually a very difficult question to answer because people live such different lifestyles. A large family with several big-screen televisions, computer equipment, and a pool or spa will use much more energy compared to a family with fewer of those items. Also, everyone’s home is different, and some are more energy efficient than others.

The U.S. Energy Information Administration (EIA) 2010 census for the US average residential electricity use per household is 958 kWh per month (or 11,496 kWh per year). [Source: “Residential Average Monthly Bill by Census Division, and State 2010.” EIA. 3 November 2011. Web. 11 May 2012.] Every utility is different, but many charge for power using a tiered system, where everyone starts out buying electricity at a baseline rate at the beginning of the billing cycle. Once a home goes over the baseline, homeowners move into a higher tier with a higher rate. High energy users can get up to the highest tier, which, in Table 1, is $0.29 per kilowatt hour.

For demonstration purposes, we will use the consumption pattern for the average California household which uses 567 kilowatt hours per month; their electricity bill would be $74. They went up to Tier 3 charges [Table 2].

If this family were to install a 2.5 kilowatt system on their home, producing an average of 313 kilowatt hours per month, they could get their bill down to as low as $27 a month. They could opt to buy a larger solar system and wipe out their bill altogether, but it’s not always the best financial choice, because a larger system may be more than what it costs to buy power at the baseline rate.

**Electricity savings with solar:**

- **Monthly savings:** $47
- **Annual savings:** $564
- **Lifetime savings:** $23,488*

* Based on annual savings of $564 over 25 years with an estimated 4% electricity rate increase per year.

Table 1 - Avg. tier rates & baselines of CA investor-owned utilities (May 2012)

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
<th>Tier 4</th>
<th>Tier 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-376 kWh</td>
<td>377-489 kWh</td>
<td>490-752 kWh</td>
<td>753-1128 kWh</td>
<td>1129+ kWh</td>
</tr>
<tr>
<td>$0.11</td>
<td>$0.13</td>
<td>$0.25</td>
<td>$0.28</td>
<td>$0.29</td>
</tr>
</tbody>
</table>

Table 2 - Average CA household energy bill (broken down in tiers)

<table>
<thead>
<tr>
<th>kWh</th>
<th>Baseline</th>
<th>Tier 2</th>
<th>Tier 3</th>
<th>Tier 4</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average monthly consumption</td>
<td>562</td>
<td>$41</td>
<td>$15</td>
<td>$18</td>
<td>$0</td>
</tr>
<tr>
<td>Average monthly solar production (2.5 kW)</td>
<td>313</td>
<td>$27</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Remainder purchased from Utility</td>
<td>249</td>
<td>$27</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
</tbody>
</table>
How much is solar worth?

The total amount of money that can be saved with solar power depends on several factors.

- System size
- System production
  - Efficiency of system
  - Orientation of system
  - Roof pitch
- System cost (less rebates/incentives)
- Electricity consumption

Saving Money

As utility companies continue to raise their rates, the solar system can keep energy bills low. Nationally, utilities have increased electricity rates an average of about 3-6% per year for the last 30 years. These rates will only continue to increase. With a solar home, homeowners can lock in lower rates for their solar electricity, and purchase less power from the utility. While the cost of electricity increases with time, the cost of home solar power remains low and constant.

Solar Incentives

Local and Federal incentives exist for renewable energy, including solar. The federal tax credit is the most significant. If the system costs $20,000, for example, homeowners would get $6,000 back. This program expires at the end of 2016. The solar system also qualifies for property tax exemption, meaning the value of the solar system is subtracted from the total property value for tax purposes.

Lower Ownership Cost

Compared with standard homes, energy-efficient solar homes use substantially less energy for heating, cooling, and water heating. That’s a savings of almost $140 a month. Over the lifetime of the system, the homeowner can save more than $80,000. Financing the home purchase using an energy efficient mortgage could lead to even greater savings.

Increasing Property Value

The Appraisal Journal: More Evidence of Rational Market Values for Home Energy Efficiency

Solar and energy efficient homes tend to sell for a higher resale price. According to a study funded by the Department of Housing and Urban Development, for every $1 in reduced energy costs, homes sell for approximately $20 more. Therefore, if you had a home that saved $1,000 a year on energy, the home could sell for $20,000 more on the resale market. In comparison to many other home renovations, solar can often recover more than 100% of the original cost (see Table 3). On the same note, value of the home increases over time, as well; as electricity prices continue to rise, the energy savings will also increase.

Berkeley Lab Report: An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California

In a more recent study, Berkeley Lab analyzed nearly 72,000 homes that resold, with 2,000 of these homes including solar. The research found that the solar homes sold for an average home sales price premium of approximately $17,000 for a relatively new 3.1 kW PV system (the average size of PV systems in the Berkeley Lab dataset), or $5.5/watt (DC). When expressed as a ratio, an average California home with PV installed equates to a 14:1 to 22:1 sale price to energy savings ratio respectively. This is comparable to the investment that homeowners have made to install PV systems in California (after applicable state and federal incentives).

Table 3: 2009-10 National Average of Cost Recovery for Midrange Remodeling Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Project Cost</th>
<th>Resale Value</th>
<th>% of Cost Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Addition</td>
<td>$10.6K</td>
<td>$8.6K</td>
<td>80.6%</td>
</tr>
<tr>
<td>Bathroom Remodel</td>
<td>$16.1K</td>
<td>$11.5K</td>
<td>71.0%</td>
</tr>
<tr>
<td>Window Upgrade</td>
<td>$10.7K</td>
<td>$8.2K</td>
<td>76.6%</td>
</tr>
<tr>
<td>Kitchen Remodel</td>
<td>$57.2K</td>
<td>$41.2K</td>
<td>72.1%</td>
</tr>
</tbody>
</table>


1 See www.eia.gov/electricity/data.cfm#sales for more information on electricity usage and rates.
2 Based on home in San Diego, CA, with $150 per month electric bill. System financed with 25-yr home loan at 3% interest.


Calculators

There are free tools provided by the federal government to help you accurately calculate the value of a PV rooftop solar system.

**PV Value™**

This spreadsheet tool developed by Sandia National Laboratories and Solar Power Electric™ is intended to help determine the value of a new or existing photovoltaic (PV) system installed on residential and commercial properties. It is designed to be used by real estate appraisers, mortgage underwriters, credit analysts, real property assessors, insurance claims adjusters and PV industry sales staff.

PV Value is a free Microsoft Excel® spreadsheet which values a PV solar system using an income capitalization approach. Download tool and user manual here: [http://energy.sandia.gov/?page_id=8047](http://energy.sandia.gov/?page_id=8047)

**PV Watts™**

NREL's PV Watts is an online grid data calculator which determines energy production and cost savings of grid-connected PV solar systems throughout the world, easily estimating the hypothetical performance. It works by creating hour-by-hour performance simulations that provide estimated monthly and annual energy production in kW and energy value. [http://www.nrel.gov/rredc/pvwatts/](http://www.nrel.gov/rredc/pvwatts/)

Additional Information

The Appraisal Institute is a good start for resources and information. For information on solar valuation specific to your state, try searching “[your state] solar valuation for appraiser” in your web browser.

The Appraisal Institute
[http://www.appraisalinstitute.org](http://www.appraisalinstitute.org)

Papers & Studies

Here are some helpful papers and studies, which can easily be found by doing a Web search of the title.


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CONSTRUCTION AND THE APPRAISER

More Evidence of Rational Market Values for Home Energy Efficiency

Rick Nevin, Christopher Bender, and Heather Gazan

The article, “Evidence of Rational Market Values for Home Energy Efficiency,” which appeared in the October 1998 issue of The Appraisal Journal, presented the results of research indicating that market values for energy-efficient homes reflect a rational trade-off between homebuyers’ fuel savings and their after-tax mortgage interest costs. This research estimated implicit values for the number of rooms in a house, the square footage of living space, lot size, location, and other home characteristics, including the annual utility bill. We performed separate regression analyses for attached and detached homes based on the 1991, 1993, and 1995 American Housing Survey (AHS) national data and AHS metropolitan statistical area (MSA) data for 1992 through 1996. Table 1 shows that the results of these separate regression analyses were remarkably consistent, indicating that home value increases by about $20 for every $1 reduction in annual utility bills, reflecting after-tax mortgage interest rates of about 5% from 1991 through 1996.

To demonstrate the “real world” validity of this research, the regression results have been compared with the collective judgment of real estate agents participating in “cost versus value” surveys conducted by Remodeling Magazine (RM). Each year, the RM survey asks agents throughout the United States to estimate the amount that popular remodeling projects would add to the value of a home in their area if the home were sold within a year of project completion. This sur-
vey reflects estimates from about 300 agents familiar with diverse neighborhoods in 60 metropolitan areas. (Between three and seven agents are surveyed in each area.) The remodeled home for which these estimates are made is a “mid-priced house in an established neighborhood in each city.” These value estimates are then compared with cost estimates for each MSA (derived from estimating manuals and from experts in unit cost analysis).

As will be explained, the RM survey value estimates for home additions are consistent with the overall ICF regression model for home value. A window replacement project in the 1993 RM survey1 also supports the estimate for the value of energy efficiency, and further analysis of the RM cost and value estimates suggests that increased home value can fully recover the cost of window replacement in many existing homes. Detailed calculations of home additions, the assumptions on which the window replacement analysis was based, and the results obtained for individual cities are available from the authors.

**RM Home Additions Survey**

Table 2 compares value estimates for four home additions from the 1992 through 1996 RM survey with the regression model estimates. In particular, the regression values from the MSA detached home sample were used in the comparison because this regression was taken of the largest AHS sample and showed the highest measures of statistical significance in our study. The value estimates in table 2 reflect changes in the following regression variables:

- The number of rooms and square footage of living space (as specified in the RM survey);
- The estimated change in utility bills (based on the project’s addition to living space relative to the average size and utility bills for detached homes in the MSA sample); and
- The living space and utility interaction measures in the ICF regression model (utility bill multiplied by number of rooms, and utility bill multiplied by square footage of living space).

Other variables in the model (lot size, age of unit, and location) are not reflected in table 2 because these variables would not be affected by an addition to an existing home.

The average RM survey value estimates for all four home additions are within 7.4% of the model estimates. The similarity of these estimates is especially striking in light

| TABLE 1 Reduction in Home Value per One-Dollar Increase in Annual Utility Bill |
|-----------------------------------------------|------------------|-----------------|-----------------|
| Detached homes | | $24 | $20 | $21 | $18 |
| Attached homes | | $20 | $12 | $19 | $23 |

**TABLE 2 Comparison of Remodeling Magazine Survey and ICF Model Estimates for Resale Value for Home Additions**

<table>
<thead>
<tr>
<th>Remodeling Magazine Survey</th>
<th>Family Room</th>
<th>Master Suite</th>
<th>Two-Story Addition</th>
<th>Attic Bedroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>$24,681</td>
<td>NA</td>
<td>NA</td>
<td>$18,001</td>
</tr>
<tr>
<td>1994</td>
<td>$24,019</td>
<td>$24,744</td>
<td>$42,438</td>
<td>$18,199</td>
</tr>
<tr>
<td>1995</td>
<td>$26,451</td>
<td>$29,252</td>
<td>$43,004</td>
<td>$17,933</td>
</tr>
<tr>
<td>1996</td>
<td>$26,483</td>
<td>$30,530</td>
<td>$46,236</td>
<td>$20,624</td>
</tr>
</tbody>
</table>

RM survey, 1993–1996 average
$25,408 $28,175 $43,893 $18,689

ICF model estimates
$23,655 $26,104 $46,582 $18,715

Difference in dollars
$1,754 $2,071 -$2,689 -$26

Percentage difference 6.9% 7.4% -6.1% -0.1%

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of the detail provided in the RM survey questions that could not be reflected in the model estimates. For example, the master suite described in the 1994 RM survey is “a 24-foot-by-16-foot master bedroom with walk-in closet, dressing area, master bath, whirlpool tub, separate ceramic tile shower and double-bowl vanity.” The model estimate, by contrast, reflects only the value of adding any 382-square-foot room, and the associated change in the home’s annual utility bill. In spite of the generic nature of the model, there is actually more variation between the annual RM survey estimates than there is between the average RM estimates and the model estimates.

Window Replacement Comparison
In 1993 Remodeling Magazine did a survey on the value of window replacement. The RM window replacement project would “replace 16 existing 3-foot-by-5-foot windows with energy-efficient vinyl or vinyl-clad aluminum double-pane windows.” To determine whether the RM value estimates for this project were largely attributable to the energy savings, we performed an analysis that included the following four steps:

1. Specifying model home energy use characteristics consistent with the RM survey question for windows
2. Estimating pre-project utility bills using the (Department of Energy’s) DOE2 energy analysis program, and validating these estimates against actual bills reported in the AHS
3. Estimating post-project utility bills and calculating utility bill savings for different types of windows
4. Multiplying annual utility savings times the model value for utility bill, and comparing these window replacement value estimates with RM survey value estimates

These four steps were repeated for every MSA included in both the RM survey and in the AHS MSA sample. In all, 25 MSAs were included, providing a range of geographic and climate scenarios to test the regression estimate for the value of energy efficiency. The MSAs were:

• **East**: Boston, Providence, Pittsburgh, Baltimore/Washington, D.C., and Hartford
• **South**: New Orleans, Dallas, Birmingham, Charlotte, and Atlanta
• **Midwest**: Columbus, Kansas City, Milwaukee, St. Louis, Minneapolis, Detroit, Cleveland, and Indianapolis
• **West**: San Diego, Denver, Salt Lake City, Phoenix, Seattle, San Francisco, and Portland

Model home specifications for this analysis were designed to approximate historical construction practices and reflect the description of remodeled homes in the RM survey. The model home in each city was assumed to have floor space equal to the AHS median square footage for single-family detached homes in that MSA, reflecting the RM survey description of a “mid-priced house.” The analysis also specifies 240 square feet of windows, based on the RM description of replacing sixteen 3-foot-by-5-foot windows. The model home is assumed to have relatively little wall insulation because the RM survey describes a home in an “established neighborhood” and agents responding to the survey are likely to think about older homes when asked about window replacement. Older homes and especially those built before the oil shocks of 1973 and 1979 are likely to have less insulation than newer homes. Ceilings are assumed to have somewhat more insulation because ceiling insulation has been added to many older homes since the 1973 and 1979 spikes in fuel prices.

To reflect somewhat different regional construction practices, homes in the South and West were assumed to have a 28% duct loss, whereas homes in the East and Midwest were assumed to have a 20% duct loss. Energy efficiency assumptions for heating and cooling were based on estimates from the Home Energy Rating Systems Council. The DOE2 energy analysis program was used to estimate model home energy demand with and without air conditioning, and with each of four heating system types (electric resistance, heat pump, natural gas furnace, and oil furnace). Weighted average energy demand for each city was calculated based on AHS data showing the percentage of pre-1980 single-family detached homes in each MSA with air conditioning and each type of heating system. Data from the 1993 Residential Energy Consumption Survey (RECS), presented in table 3, show that pre-1980 homes account for practically all of the homes that reported replacement of all original windows. Therefore, real estate agents responding to the 1993 RM Survey must have made value estimates for window replacements.
based on their experience with pre-1980 homes.

Energy consumption associated with hot water was estimated to reflect typical units in the AHS MSA data for single-family detached homes built before 1980. Energy consumption for other uses of electricity was based on estimates from the Home Energy Ratings Systems Council.

Table 4 presents the model home specifications that would change as a result of the window replacement project. Separate DOE2 model estimates for homes before window replacement were developed to illustrate the significant difference in energy use for homes with wood-frame windows versus homes with metal-frame windows. The pre-project specifications reflect RECS data indicating that most pre-1980 homes in the East and Midwest have storm windows, but most homes in the West and South do not. The RECS data also show that single-pane windows are the norm for pre-1980 homes in all regions. The infiltration rate in homes before window replacement was assumed to be one air change per hour, and the window replacement project was expected to reduce the infiltration rate to 0.7 air changes per hour.

Post-project double-pane windows with clear glass were expected to be the basis for value estimates in the RM survey because high-performance low-emissivity (low-e) windows were not widely used before the 1990s. RECS data show that low-e windows account for less than 5% of all replacement windows installed before 1993. Therefore, this analysis examines whether the energy savings with clear-glass, double-pane windows can substantially explain the RM survey value estimates. The additional energy savings with low-e windows are then calculated to show how additional home value can be realized with the choice of high-performance windows. Two different high-performance windows were examined to yield the best performance in warm or cold climates.

The model home specifications just described were used to estimate annual energy consumption for homes before window replacement in each MSA, and these estimates were multiplied by 1993 energy prices to estimate utility bills before window replacement. MSA energy prices were approximated with available data on 1993 statewide averages for residential prices from the Energy Information Administration. Table 5 shows AHS average utility bills and the estimated utility bills for two pre-project model homes in each region, with wood- and metal-frame windows.

The regional average for DOE2 model utility bills in homes with wood-frame windows are within 14% of the average utility bills reported in the AHS MSA data. The RECS

<table>
<thead>
<tr>
<th>TABLE 3 Age Distribution of Homes with All Original Windows Replaced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Home Construction</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Pre-1940</td>
</tr>
<tr>
<td>1940–1949</td>
</tr>
<tr>
<td>1950–1959</td>
</tr>
<tr>
<td>1960–1969</td>
</tr>
<tr>
<td>1970–1979</td>
</tr>
<tr>
<td>Post-1980</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Percentage of all homes with all windows replaced</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>TABLE 4 Model Home Specifications for Window Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>East and Midwest windows (DOE2 glass values)</td>
</tr>
<tr>
<td>South and West windows</td>
</tr>
<tr>
<td>Infiltration rate</td>
</tr>
</tbody>
</table>

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The data in Table 6 show that non-metal frames are most common in older homes, and are therefore more likely to be the basis for the RM survey estimates. The DOE2 model bills should be somewhat higher than the AHS average because the model home bills reflect the average for pre-1980 homes with single-pane windows. Although RECS data indicate that about 70% of pre-1980 homes have single-pane glass in most windows, the 30% that report double-pane glass in most windows would tend to reduce the average utility bills in the AHS data. The DOE2 model bills in the South are somewhat lower than the actual AHS bills, indicating that the DOE2 model home specifications for this analysis may slightly overstate the energy efficiency of average homes in the South.

Table 7 presents the DOE2 estimated annual utility bill savings from the window replacement project described in the 1993 RM survey. Four estimates were calculated for each region, showing the annual savings associated with replacing wood- or metal-frame, single-pane windows with clear-glass, double-pane windows or high-performance low-e windows.

The 25 MSA average shows that the energy savings from replacing wood-frame, single-pane windows with clear-glass, double-pane windows is $200 per year, and the energy savings from replacing metal-frame, single-pane windows is $310 per year. Using high-performance low-e replacement windows increases annual savings by an additional $114 per year.

Table 8 compares the RM survey estimates for window replacement value with the ICF model estimates for clear-glass, double-pane replacement windows. The ICF estimates reflect the savings in the annual utility bill resulting from clear-glass, double-pane windows (from Table 7) multiplied by $20 (based on the ICF conclusion that home
value increases by $20 for every dollar reduction in annual utility bills).

The 25 MSA average shows that the energy savings from replacing wood-frame, single-pane windows with clear-glass, double-pane windows explains 73% of the RM survey value estimates for this project. The energy savings from replacing metal-frame, single-pane windows with clear-glass, double-pane windows could increase home value by 113% of the RM survey value estimates. As noted before, the RM survey primarily should reflect the experience of real estate agents with the value of replacing wood-frame windows because older homes account for most of the homes that have replaced all original windows, and older homes are more likely to have wood-frame windows.

The results in table 9 indicate that the RM survey value estimates for window replacement can be substantially explained by the market value of energy efficiency estimated by ICF. The 25 MSA average values indicate that about $4,000 of the RM survey window replacement value may be due to energy efficiency, and about $1,500 to the value ascribed to the ease of use and the appearance of new windows.

The difference between the model value (for wood frame) and the RM survey value is only $435 in the South, but this may reflect limitations of the RM survey data. RECS data indicate that only 7% of homes in the South report that all their original windows have been replaced so that real estate agents responding to the RM survey in this region may have relatively little experience with the market value of window replacement. Further, AHS data show that the percentage of pre-1980, single-family detached homes in the South with central air conditioning increased from 49% in 1985 to 66% in 1995. Therefore, the response of real estate agents in the South who estimate the value of window replacement based on their career experience may reflect the lesser value of energy-efficient homes associated with years when fewer homes had central air conditioning.

The 1993 RM survey concludes that window replacement only recovers about 70% of project costs, on average, but the data in table 8 suggest that RM value estimates may represent only the value of replacing wood-frame windows with clear-glass, double-pane windows. Significantly greater energy-efficiency value could be realized by replacing metal-frame windows, and even greater energy savings would be realized with high-performance low-e windows. Therefore, the RM survey may accurately reflect the historical cost recovery percentage for window replacement but may underestimate the potential cost recovery with more efficient windows.

Table 9 compares the RM estimates for window replacement cost with our energy value estimates for high-performance windows (based on annual utility savings with high-efficiency windows multiplied by $20). The 25-MSA average shows that the value associated with energy savings from high-efficiency windows could recover more than 85% of the cost of replacing wood-frame, single-pane windows and 115% of the cost of replacing metal-frame windows.

Although older homes with wood-frame windows account for most of the homes that have already replaced all original windows, RECS data indicate that about half of all existing homes have metal-frame windows. Table 9 suggests that replacing metal-frame windows with high-performance windows could result in an energy-efficient home value that exceeds the cost of window replacement.

In the case of wood-frame windows, table 9 indicates that the average cost of window replacement is about $1,100 more than the ICF model value for high-performance windows. RM cost estimates in table 9 may also under-

### Table 8

<table>
<thead>
<tr>
<th></th>
<th>ICF Model Values for Clear-Glass Double-Pane</th>
<th>RM Survey Value Estimates</th>
<th>ICF Model Percentage of RM Survey Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metal frame</td>
<td>Wood frame</td>
<td>Metal frame</td>
</tr>
<tr>
<td>East</td>
<td>$6,744</td>
<td>$4,048</td>
<td>$6,372</td>
</tr>
<tr>
<td>South</td>
<td>$6,248</td>
<td>$4,160</td>
<td>$4,595</td>
</tr>
<tr>
<td>Midwest</td>
<td>$6,035</td>
<td>$3,718</td>
<td>$5,118</td>
</tr>
<tr>
<td>West</td>
<td>$5,989</td>
<td>$4,149</td>
<td>$5,469</td>
</tr>
<tr>
<td>25-MSA average</td>
<td>$6,206</td>
<td>$3,993</td>
<td>$5,469</td>
</tr>
</tbody>
</table>

Source: Remodeling Magazine.
state the higher cost of low-e windows by about $240 (an additional dollar per square foot of window area). On the other hand, the ICF model values in table 9 reflect only the value of energy efficiency, and the analysis of table 8 concluded that the appearance value of new windows makes up about $1,500 of the value of energy efficiency. The net effect of these factors suggests that the total value of new high-performance low-e windows may also fully recover the cost of window replacement in homes with wood-frame windows.

### CONCLUSION

The validity of the overall model for home value is substantiated by the comparison with value estimates of home additions provided by real estate agents participating in the “cost versus value” survey by *Remodeling Magazine*. Detailed analysis of the RM survey on a window replacement project also indicates that the value estimates from window replacement can be substantially explained by the market value of energy efficiency, as estimated in the regression analysis. This analysis also indicates that the RM survey appears to reflect the historical recovery of window replacement cost, but may understate the potential cost recovery with more efficient windows. In fact, this analysis shows that the value associated with high-performance low-e windows could fully recover the cost of replacing wood-frame, single-pane windows and may well exceed the cost of replacing metal-frame windows.
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. 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.

To determine 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 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 homes, and whether the age or the size of the PV system impacted premiums.

A large number of hedonic pricing and difference-in-difference models (see sidebar on next page) were used to ensure that the results were robust.

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 “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.

These results are similar to the average increase for PV homes found by Dastrop et al. (2010), which used similar methods but focused on homes in the San Diego area. The average sales price premiums also appear to be comparable to the investment that homeowners have made to install PV systems in California (after applicable state and federal incentives), which from 2001-2009 averaged approximately $5/watt (DC) (Barbose et al., 2010), and homeowners with PV also benefit from electricity cost savings after PV system installation and prior to home sale.

When the dataset is split between new and existing homes, PV system premiums are found to be markedly affected (see figure on back), 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. The report offers 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. Additionally, new home builders may gain value from PV as a market differentiator, and have therefore often tended to sell...
PV as a standard (as opposed to an optional) product on their homes and perhaps been willing to accept a lower premium in return for faster sales velocity and decreased carrying costs.

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.

When the results are expressed as a ratio of the sales price premium to estimated annual electricity cost savings associated with PV (see figure below) they are consistent with those of the more extensive existing literature on the impact of energy efficiency on home sales prices; the present research finds an averages range from 7:1 to 31:1, with models coalescing near 20:1.

**Applicability**

Although this research finds strong evidence that homes with PV systems in California have sold, on average, for a significant premium over comparable homes without PV systems, the authors recommend that extrapolation of these results to different locations or market conditions be done with care.

**Further Research Warranted**

The report outlines a number of additional questions that warrant further research, such as investigating more-recent home sales (the report’s dataset spanned 1999 thru 2009) from a broader geographic area (the dataset included only California homes), and further investigating the difference in premium between new and existing PV homes.

### What Is a Hedonic Pricing Model?

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. A house can be thought of as a bundle of characteristics (e.g., number of square feet). When a price is agreed upon between a buyer and a seller there is an implicit understanding that those characteristics have value. When data from a large group of residential transactions are available, the average marginal contribution to the sales price of each characteristic can be estimated with a regression model. The contribution to the selling price of having a PV system can be thus be estimated, if other important housing market influences are adequately controlled for.

### What Is a Difference-in-Difference Model?

A variant of the hedonic model, a difference-in-difference model compares inflation adjusted selling prices of homes that have sold twice, both before a condition exists (e.g., having a PV system installed) and after.

### What Are Robustness Models?

Because models are built on assumptions, practitioners often test those assumptions by trying multiple model forms. In this research, “base” models, which used the full dataset and controlled for “neighborhood” effects at the census block group level, were compared with “robustness” models. Examples include models that controlled for “neighborhood” at the subdivision level (a potentially better proxy than the block group), models that only evaluated PV homes.

The general consistency in results across all of the models demonstrates the robustness of the study’s findings.

### References


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Ben Hoen, Ryan Wiser, Peter Cappers and Mark Thayer

Environmental Energy Technologies Division

April 2011


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Prepared for the
Office of Energy Efficiency and Renewable Energy
Solar Energy Technologies Program
U.S. Department of Energy

and the
National Renewable Energy Laboratory

and the
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Abstract

An increasing number of homes with existing photovoltaic (PV) energy systems have sold in the U.S., yet relatively little research exists that estimates the marginal impacts of those PV systems on home sales prices. 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. This research analyzes a large dataset of California homes that sold from 2000 through mid-2009 with PV installed. Across a large number of hedonic and repeat sales model specifications and robustness tests, the analysis finds strong evidence that California homes with PV systems have sold for a premium over comparable homes without PV systems. The effects range, on average, from approximately $3.9 to $6.4 per installed watt (DC) of PV, with most coalescing near $5.5/watt, which corresponds to a home sales price premium of approximately $17,000 for a relatively new 3,100 watt PV system (the average size of PV systems in the study). These average sales price premiums appear to be comparable to the investment that homeowners have made to install PV systems in California, which from 2001 through 2009 averaged approximately $5/watt (DC), and homeowners with PV also benefit from electricity cost savings after PV system installation and prior to home sale. When expressed as a ratio of the sales price premium to estimated annual electricity cost savings associated with PV, an average ratio of 14:1 to 22:1 can be calculated; these results are consistent with those of the more-extensive existing literature on the impact of energy efficiency (and energy cost savings more generally) on home sales prices. The analysis also finds - as expected - that sales price premiums decline as PV systems age. Additionally, when the data are split between new and existing homes, a large disparity in premiums is discovered: the research finds that new homes with PV in California have demonstrated average premiums of $2.3-2.6/watt, while the average premium for existing homes with PV has been more than $6/watt. One of several possible reasons for the lower premium for new homes is that new home builders may also gain value from PV as a market differentiator, and have therefore often tended to sell PV as a standard (as opposed to an optional) product on their homes and perhaps been willing to accept a lower premium in return for faster sales velocity. Further research is warranted in this area, as well as a number of other areas that are highlighted.
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1. Introduction

In calendar year 2010, approximately 880 megawatts (MW)\(^1\) of grid-connected solar photovoltaic (PV) energy systems were installed in the U.S. (of which approximately 30% were residential), up from 435 MW installed in 2009, yielding a cumulative total of 2,100 MW (SEIA & GTM, 2011). California has been and continues to be the country’s largest market for PV, with nearly 1000 MW of cumulative capacity. California is also approaching 100,000 individual PV systems installed, more than 90% of which are residential. An increasing number of these homes with PV have sold, yet to date, relatively little research has been conducted to estimate the existence and level of any premium to sales prices that the PV systems may have generated. One of the primary incentives for homeowners to install a PV system on their home, or for home buyers to purchase a home with a PV system already installed, is to reduce their electricity bills. However, homeowners cannot always predict if they will own their home for enough time to fully recoup their PV system investment through electricity bill savings. The decision to install a PV system or purchase a home with a PV system already installed may therefore be predicated, at least in part, on the assumption that a portion of any incremental investment in PV will be returned at the time of the home’s subsequent sale through a higher sales price. Some in the solar industry have recognized this potential premium to home sales prices, and, in the absence of having solid research on PV premiums, have used related literature on the impact of energy efficiency investments and energy bill savings on home prices as a proxy for making the claim that residential PV systems can increase sales prices (e.g., Black, 2010).

The basis for making the claim that an installed PV system may produce higher residential selling prices is grounded in the theory that a reduction in the carrying cost of a home will translate, \textit{ceteris paribus}, into the willingness of a buyer to pay more for that home. Underlying this notion is effectively a present value calculation of a stream of savings associated with the

\(^{1}\) All references to the size of PV systems in this paper, unless otherwise noted, are reported in terms of direct current (DC) watts under standard test conditions (STC). This convention was used to conform to the most-common reporting conventions used outside of California. In California, PV systems sizes are often referred to using the California Energy Commission Alternating Current (CEC-AC) rating convention, which is approximately a multiple of 0.83 of the DC-STC convention, but depends on a variety of factors including inverter efficiency and realistic operating efficiencies for panels. A discussion of the differences between these two conventions and how conversions can be made between them is offered in Appendix A of Barbose et al., 2010.
reduced electricity bills of PV homes, which can be capitalized into the value of the home. Along these lines, a number of studies have shown that residential selling prices are positively correlated with lower energy bills, most often attributed to energy related home improvements, such as energy efficiency investments (Johnson and Kaserman, 1983; Longstreth et al., 1984; Laquatra, 1986; Dinan and Miranowski, 1989; Horowitz and Haeri, 1990; Nevin and Watson, 1998; Nevin et al., 1999). The increased residential sales prices associated with lower energy bills and energy efficiency measures might be expected to apply to PV as well. Some homeowners have stated as much in surveys (e.g., CEC, 2002; McCabe and Merry, 2010), though the empirical evidence supporting such claims is limited in scope. Farhar et al. (2004a; 2008) 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, Dastrop et al. (2010) used a hedonic analysis to investigate the selling prices of 279 homes with PV installed in the San Diego, California metropolitan area, finding clear evidence of PV premiums that averaged approximately 3% of the total sales price of non-PV homes, which translates into $4.4 per installed PV watt (DC).

In addition to energy savings, higher selling prices might be correlated with a “cachet value” based on the “green” attributes that come bundled with energy-related improvements (e.g., helping combat global warming, impressing the neighbors, etc.). A number of recent papers have investigated this correlation. Eichholtz et al. (2009, 2011) analyzed commercial green properties in the U.S, and Brounen and Kok (2010) and Griffin et al. (2009) analyzed green labeled homes in the Netherlands and Portland, Oregon, respectively, each finding premiums, which, in some cases, exceeded the energy savings (Eichholtz et al., 2009, 2011; Brounen and Kok, 2010). Specifically related to PV, Dastrop et al. (2010) found higher premiums in communities with a greater share of Toyota Prius owners and college grads, indicating, potentially, the presence of a cachet value to the systems over and above energy savings. It is therefore reasonable to believe that buyers of PV homes might price both the energy savings and the green cachet into their purchase decisions.
Of course there is both a buyer and a seller in any transaction, and the sellers of PV homes might be driven by different motivations than the buyers. Specifically, recouping the net installed cost of the PV system (i.e., the cost of PV installation after deducting any available state and federal incentives) might be one driver for sellers. In California, the average net installed cost of residential PV hovered near $5/watt (DC) from 2001 through 2009 (Barbose et al., 2010). Adding slightly to the complexity, the average net installed cost of PV systems has varied to some degree by the type of home, with PV systems installed on new homes in California enjoying approximately a $1/watt lower average installed cost than PV systems installed on existing homes in retrofit applications (Barbose et al., 2010). Further, sellers of new homes with PV (i.e., new home developers) might be reluctant to aggressively increase home sale prices for installed PV systems because of the burgeoning state of the market for PV homes and concern that more aggressive pricing might slow home sales, especially if PV is offered as a standard (not optional) product feature (Farhar and Coburn, 2006). At the same time, the possible positive impact of PV on product differentiation and sales velocity may make new home developers willing to sell PV at below the net installed cost of the system. After all, some studies that have investigated whether homes with PV (often coupled with energy efficient features) sell faster than comparable homes without PV have found evidence of increased velocity due to product differentiation (Dakin et al., 2008; SunPower, 2008). Finally, as PV systems age, and sellers (i.e., homeowners) recoup a portion of their initial investment in the form of energy bill savings (and, related, the PV system’s lifespan decreases), the need (and ability) to recoup the full initial investment at the time of home sale might decrease. On net, it stands to reason that premiums for PV on new homes might be lower than those for existing homes, and that older PV systems might garner lower premiums than newer PV systems of the same size.

Though a link between selling prices and some combination of energy cost savings, green cachet, recouping the net installed cost of PV, seller attributes, and PV system age likely exists, the existing empirical literature in this area, as discussed earlier, has largely focused on either energy efficiency in residential and commercial settings, or PV in residential settings but in a limited geographic area (San Diego), with relatively small sample sizes. Therefore, to date, establishing a reliable estimate for the PV premiums that may exist across a wide market of homes has not
been possible. Moreover, establishing premiums for *new versus existing* homes with PV has not yet been addressed.

Additionally, research has not investigated whether there are increasing or decreasing returns on larger PV systems, and/or larger homes with the same sized PV systems, nor has research been conducted that investigates whether older PV systems garner lower premiums. In the case of returns to scale on larger PV systems, it is not unreasonable to expect that any increase in value for PV homes may be non-linear as it relates to PV system size. For example, if larger PV systems push residents into lower electricity price tiers\(^2\), energy bill savings could be diminished on the margin as PV system size increases. This, in turn, might translate into smaller percentage increases in residential selling prices as PV systems increase in size, and therefore a decreasing return to scale. Larger PV systems might also enjoy some economies of scale in installation costs, which, in turn, might translate into lower marginal premiums at the time of home sale as systems increase in size – a decreasing return to scale. Additionally, “cachet value”, to the degree that it exists, is likely to be somewhat insensitive to system size, and therefore might act as an additional driver to decreasing returns to scale. Somewhat analogously, PV premiums may be related to the number of square feet of living area in the home. Potentially, as homes increase in size, energy use can also be expected to increase, leading homeowners to be subjected to higher priced electricity rate tiers and therefore greater energy bill savings for similarly sized PV systems. Finally, as discussed previously, as PV systems age, and both a portion of the initial investment is recouped and the expected life and operating efficiency of the systems decrease, home sales price premiums might be expected to decline.

To explore these possible relationships, we investigate the residential selling prices across the state of California of approximately 2,000 homes with existing PV systems against a comparable set of approximately 70,000 non-PV homes. The sample is drawn from 31 California counties, with PV home sales transaction dates of 2000 through mid-2009. We apply a variety of hedonic pricing (and repeat sales) models and sample sets to test and bound the possible effects of PV on residential sales prices and to increase the confidence of the findings. Using these tools, we also

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\(^2\) Many California electric utilities provide service under tiered residential rates that charge progressively higher prices for energy as more of it is used.
explore whether the effects of PV systems on home prices are impacted by whether the home is new or existing, by the size of either the PV system or the home itself, and finally by how old the PV system is when the home sells.\textsuperscript{3} It should be stated that this research is not intended to disentangle the specific effects of energy savings, green cachet, recovery of the cost of installation, or seller motivations, but rather to establish credible estimates of aggregate PV residential sales price effects.

The paper begins with a discussion of the data used for the analyses (Section 2). This is followed by a discussion of the empirical basis for the study (Section 3), where the variety of models and sample sets are detailed. The paper then turns to a discussion of the results and their potential implications (Section 4), and finally offers some concluding remarks with recommendations for future research (Section 5).

\textsuperscript{3} Due to the limited sample of PV home sales in many individual years, the results presented in this report reflect average impacts over the entire 2000-09 period (after controlling for housing market fluctuations).
2. Data Overview

To estimate the models described later, a dataset of California homes is used that joins the following five different sets of data: (1) PV home addresses and system information from three organizations that have offered financial incentives to PV system owners in the state; (2) real estate information that is matched to those addresses and that also includes the addresses of and information on non-PV homes nearby; (3) home price index data that allow inflation adjustments of sale prices to 2009 dollars; (4) locational data to map the homes with respect to nearby neighborhood/environmental influences; and (5) elevation data to be used as a proxy for “scenic vista.” Each of these data sources is described below, as are the data processing steps employed, and the resulting sample dataset.

2.1. Data Sources

The California Energy Commission (CEC), the California Public Utilities Commission (CPUC), and the Sacramento Municipal Utility District (SMUD) each provide financial incentives under different programs to encourage the installation of PV systems in residential applications, and therefore have addresses for virtually all of those systems, as well as accompanying data on the PV systems. 4 Through these programs, Berkeley Laboratory was provided information on approximately 42,000 homes where PV was installed, only a fraction of which (approximately 9%) subsequently sold with the PV system in place. The data provided included: address (street, street number, city, state and zip); incentive application and PV system install and operational dates; PV system size; and delineations as to whether the home was new or existing at the time the PV system was installed (where available).

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4 The CEC and CPUC have both been collecting data on PV systems installed on homes in the utility service areas of investor owned utilities (e.g., PG&E, SCE, SDG&E) for which they have provided incentives, as have some of California’s publicly owned utilities (e.g., SMUD) that offer similar incentives. The CEC began administering its incentive program in 1998, and provided rebates to systems of various sizes for both residential and commercial customers. The CPUC began its program in 2001, initially focusing on commercial systems over 30 kW in size. In January 2007, however, the CEC began concentrating its efforts on new residential construction through its New Solar Home Partnership program, and the CPUC took over the administration of residential retrofit systems through the California Solar Initiative program. Separately, SMUD has operated a long-standing residential solar rebate program, but of smaller size than the efforts of the CEC and CPUC.
These addresses were then matched to addresses as maintained by Core Logic (CL)\(^5\), which they aggregate from both the California county assessment and deed recorder offices. Once matched, CL provided real estate information on each of the California PV homes, as well as similar information on approximately 150,000 non-PV homes that were located in the same (census) block group and/or subdivision as the matched PV homes. The data for both of these sets of homes included:

- address (e.g., street, street number, city, state and zip+4 code);
- most recent (“second”) sale date and amount;
- previous (“first”) sale date and amount (if applicable);
- home characteristics (where available) (e.g., acres, square feet of living area, bathrooms, and year built);
- assessed value;
- parcel land use (e.g., commercial, residential);
- structure type (e.g., single family residence, condominium, duplex);
- housing subdivision name (if applicable)\(^6\); and
- census tract and census block group.

These data, along with the PV incentive provider data, allowed us to determine if a home sold after a PV system was installed ("second" sale). 3,657 such homes were identified in total, and these homes, therefore, represent the possible sample of homes on which our analysis focused. A subset of these data for which "first" sale information was available and for which a PV system had not yet been installed as of this “first” sale, were culled out. These “repeat sales” were also used in the analysis, as will be discussed in Section 3.

In addition to the PV and real estate data, Berkeley Laboratory obtained from Fiserv a zip-code-level weighted repeat sales index of housing prices in California from 1970 through mid-2009, by quarter. These indices, where data were available, were differentiated between low, middle, \(^5\) More information about this product can be obtained from [http://www.corelogic.com/](http://www.corelogic.com/). Note that Core Logic, Inc. was formerly known as First American Core Logic.
\(^6\) In some cases the same subdivisions were referred to using slightly different names (e.g., “Maple Tree Estates” & “Maple Trees Estates”). Therefore, an iterative process of matching based on the names, the zip code, and the census tract were used to create “common” subdivision names, which were then used in the models, as discussed later.
and high home price tiers, to accommodate the different appreciation/depreciation rates of market segments. Using these indices, all sale prices were adjusted to Q1, 2009 prices.7

From Sammamish Data, Berkeley Laboratory purchased x/y coordinates for each zip+4 code, which allowed the mapping of addresses to street level accuracy.8 Additionally, Berkeley Laboratory obtained from the California Natural Resources Agency (via the California Environmental Resources Evaluation System, CERES) a 30 meter level Digital Elevation Map (DEM) for the state of California.9 Combining these latter two sets of data, a street level elevation could be obtained for each home in the dataset, which allowed the construction of a variable defined as the elevation of a home relative to its (census) block group. This relative elevation served as a proxy for “scenic vista”, a variable used in the analysis.

2.2. Data Processing

Data cleaning and preparation for final analysis was a multifaceted process involving selecting transactions where all of the required data fields were fully populated, determining if sales of PV homes occurred after the PV system was installed, matching the homes to the appropriate index, ensuring the populated fields were appropriately coded, and finally, eliminating obviously suspicious observations (e.g., not arms length transactions, outliers, etc.). Initially provided were a total of 150,000 detached single family residential sale records without PV and a total of 3,657 with PV. These totals, however, were substantially reduced (by approximately 65,000 records, 1,400 of which were PV sales) because of missing/erroneous core characteristic data (e.g., sale date, sale price, year built, square feet).10 Additionally, the final dataset was reduced (by approximately 14,000 records, 300 of which were PV sales) because some sales occurred outside the range of the index that was provided (January 1970 to June 2009). Moreover, to focus our analysis on more-typical California homes and minimize the impact of outliers or potential data-

7 The inflation adjustment instrument used for this analysis is the Fiserv Case-Shiller Index. This index is a weighted repeat sales index, accumulated quarterly at, optimally, the zip code level over three home price tiers (e.g., low, middle and high prices). More information can be found at: http://www.caseshiller.fiserv.com/indexes.aspx
8 More information about this product can be obtained from http://www.sammdata.com/
9 More information about this product can be obtained from http://www.ceres.ca.gov/
10 Examples of “erroneous” data might include a year built or sale date that is in the future (e.g., “2109” or “Jan 1, 2015”, respectively), or large groups of homes that were listed at the same price in the same year in the same block group that were thought to be “bulk” sales and therefore not valid for our purposes.
entry errors on our results, observations not meeting the following criteria were screened out (see Table 1 for variable descriptions):

- the inflation adjusted most recent (second) sale price ($asp2$) is between $85,000 and $2,500,000;\textsuperscript{11}
- the number of square feet ($sqft$) is greater than 750;
- $asp2$ divided by $sqft$ is between $40$ and $1,000$;
- the number of acres is less than 25 and greater than $sqft$ divided by 43,560 (where one acre equals 43,560 $sqft$);\textsuperscript{12}
- the year the home was built ($yrbuilt$) is greater than 1900;
- the age of the home (in years) at the time of the most recent sale ($ages2$) is greater than or equal to negative one;
- the number of bathrooms ($baths$) is greater than zero and less than ten;
- the size of the PV system ($size$) is greater than 0.5 and less than 10 kilowatts (kW);
- each block group contains at least one PV home sale and one non-PV home sale; and
- the total assessed value ($avtotal$), as reported by the county via Core Logic, is less than or equal to the predicted assessed value ($pav$), where $pav = sp2*1.02^{(2010-year of sale)}$.\textsuperscript{13}

In addition, the repeat sales used in the analysis had to meet the following criteria:

- the difference in sale dates ($sddif$) between the most recent (second) sale date ($sd2$) and the previous (first) sale date ($sd1$) is less than 20 years;
- PV is not installed on the home as of $sd1$; and
- the adjusted annual appreciation rate ($adjaar$) is between -0.14 and 0.3 (where $adjaar = \ln(asp2/asp1)/(sddif/365)$), which corresponds to the 5th and 95th percentile for the distribution of $adjaar$.\textsuperscript{14}

\textsuperscript{11} An alternative screen was tested that limited the data to homes under $1 million (leaving 90% of the data) and $600,000 (leaving 75%), with no significant change to the results.
\textsuperscript{12} An alternative screen that incorporated the number of stories for the home along with the number of square feet in calculating the “footprint”, and therefore allowed smaller parcels to be used, was also explored, with no significant change in results.
\textsuperscript{13} This screen was intended to help ensure that homes that had significant improvements since the most recent sale, which would be reflected in a higher assessed value than would otherwise be the maximum allowable under California property tax law, were removed from the dataset. The screen was not applied to homes that sold in 2009, however, because, in those cases, assessed values often had not been updated to reflect the most recent sale.
\textsuperscript{14} This final screen was intended to remove homes that had unusually large appreciation or depreciations between sales, after adjusting for inflation, which could indicate that the underlying home characteristics between the two sales changed (e.g., an addition was added, the condition of the home dramatically worsened, etc.), or the data were erroneous.
Table 1: Variable Descriptions

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<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>acre</td>
<td>size of the parcel (in acres)</td>
</tr>
<tr>
<td>acregt1</td>
<td>number of acres more than one</td>
</tr>
<tr>
<td>acrelt1</td>
<td>number of acres less than one</td>
</tr>
<tr>
<td>adjaar</td>
<td>adjusted annual appreciation rate</td>
</tr>
<tr>
<td>ages2</td>
<td>age of home as of sd2</td>
</tr>
<tr>
<td>ages2sqr</td>
<td>ages2 squared</td>
</tr>
<tr>
<td>asp1</td>
<td>inflation adjusted sp1 (in 2009 dollars)</td>
</tr>
<tr>
<td>asp2</td>
<td>inflation adjusted sp2 (in 2009 dollars)</td>
</tr>
<tr>
<td>avtotal</td>
<td>total assessed value of the home</td>
</tr>
<tr>
<td>bath</td>
<td>number of bathrooms</td>
</tr>
<tr>
<td>bgre_100</td>
<td>relative elevation to other homes in block group (in 100s of feet)</td>
</tr>
<tr>
<td>elev</td>
<td>elevation of home (in feet)</td>
</tr>
<tr>
<td>lasp1</td>
<td>natural log of asp1</td>
</tr>
<tr>
<td>lasp2</td>
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</tr>
<tr>
<td>pav</td>
<td>predicted assessed value</td>
</tr>
<tr>
<td>ppage</td>
<td>age of the PV system at the time of sale</td>
</tr>
<tr>
<td>sdl</td>
<td>first sale date</td>
</tr>
<tr>
<td>sd2</td>
<td>second sale date</td>
</tr>
<tr>
<td>sddif</td>
<td>number of days separating sd1 and sd2</td>
</tr>
<tr>
<td>size</td>
<td>size (in STC DC kW) of the PV system</td>
</tr>
<tr>
<td>sp1</td>
<td>first sale price (not adjusted for inflation)</td>
</tr>
<tr>
<td>sp2</td>
<td>second sale price (not adjusted for inflation)</td>
</tr>
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<td>sqft</td>
<td>size of living area</td>
</tr>
<tr>
<td>sqft_1000</td>
<td>size of living area (in 1000s of square feet)</td>
</tr>
<tr>
<td>yrbuilt</td>
<td>year the home was built</td>
</tr>
</tbody>
</table>

2.3. Data Summary

The final full dataset includes a total of 72,319 recent sales, 1,894 of which are PV homes and 70,425 of which are non-PV (see Table 2). The homes with PV systems are distributed evenly between new (51%) and existing (49%) home types, while the non-PV homes are weighted toward existing homes (62%) over new (38%) (see Table 5). The final repeat sales dataset of homes selling twice total 28,313 homes, of which 394 are PV and 27,919 are non-PV (see Table 3).

As indicated in Table 2, the average non-PV home in the full sample (not the repeat sales sample) sold for $584,740 (unadjusted) in late 2005, which corresponds to $480,862 (adjusted)
in 2009 dollars. This “average” home is built in 1986, is 19 years old at the time of sale, has 2,200 square feet of living space, has 2.6 bathrooms, is situated on a parcel of 0.3 acres, and is located at the mean elevation of the other homes in the block group. On the other hand, the average PV home in the full sample sold for $660,222 in early 2007, which corresponds to $537,442 in 2009 dollars. Therefore, this “average” PV home, as compared to the “average” non-PV home, is higher in value. This difference might be explained, in part, by the fact that the average PV home is slightly younger at the time of sale (by two years), slightly bigger (by 200 square feet), has more bathrooms (by 0.3), is located on a parcel that is slightly larger (by 0.06 acres), and, of course, has a PV system (which is, on average, 3,100 watts and 1.5 years old).

The repeat sale dataset, as summarized in Table 3, shows similar modest disparities between PV and non-PV homes, with the “average” PV homes selling for more (in 2009 $) in both the first and second sales. Potentially more telling, though, non-PV homes show a slight depreciation (of -1.4%) between sales after adjusting for inflation, while PV homes show a modest appreciation (of 3.2%). Average PV homes in the sample are found to be slightly bigger (by 100 square feet), occupy a slightly larger parcel (by 0.2 acres), older (by 10 years), and, of course, have a PV system (which is, on average, 4,030 watts and 2.5 years old).

Focusing on the full dataset geographically (see Table 4 and Figure 1), we find that it spans 31 counties with the total numbers of PV and non-PV sales ranging from as few as nine (Humboldt) to as many as 11,991 (Placer). The dataset spans 835 separate (census) block groups (not shown in the table), though only 162 (18.7%) of these block groups contain subdivisions with at least one PV sale. Within the block groups that contain subdivisions with PV sales there are 497 subdivision-specific delineations. As shown in Table 5, the data on home sales are fairly evenly split between new and existing home types, are located largely within four utility service areas,

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15 The adjusted values, which are based on a housing price index, demonstrate the large-scale price collapse in the California housing market post 2005; that is, there has been significant housing price depreciation.
16 Age of PV system at the time of sale is determined by comparing the sale date and ideally an “installation date”, which corresponds to the date the system was operational, but, in some cases, the only date obtained was the “incentive application date”, which might precede the installation date by more than one year. For this reason the age of the system reported for this research is lower than the actual age.
with the largest concentration in PG&E’s territory, and occurred over eleven years, with the largest concentration of PV sales occurring in 2007 and 2008.

In summary, the full dataset shows higher sales prices for the average PV home than the average non-PV home, while the repeat sales dataset shows positive appreciation between sales for PV homes, but not for non-PV homes. Though these observations seem to indicate that a PV sales price premium exists, these simple comparisons do not take into account the other underlying differences between PV and non-PV homes (e.g., square feet), their neighborhoods, and the market conditions surrounding the sales. The hedonic and difference-in-difference statistical models discussed in the following section are designed to do just that.

Table 2: Summary Statistics of Full Dataset

<table>
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<tr>
<th>Variable</th>
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<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
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<td>70425</td>
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<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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Table 3: Summary Statistics of Repeat Sale Dataset

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<th>Min</th>
<th>Max</th>
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</tr>
<tr>
<td>avtotal</td>
<td>394</td>
<td>$682,459</td>
<td>$478,768</td>
<td>$51,737</td>
<td>$3,433,320</td>
</tr>
<tr>
<td>bath</td>
<td>394</td>
<td>2.6</td>
<td>0.9</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>bgre 100</td>
<td>394</td>
<td>0.1</td>
<td>1.6</td>
<td>-5.5</td>
<td>17.9</td>
</tr>
<tr>
<td>elev</td>
<td>394</td>
<td>479</td>
<td>581</td>
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<td>3687</td>
</tr>
<tr>
<td>lasp1</td>
<td>394</td>
<td>13.2</td>
<td>0.6</td>
<td>11.6</td>
<td>14.7</td>
</tr>
<tr>
<td>lasp2</td>
<td>394</td>
<td>13.2</td>
<td>0.6</td>
<td>11.4</td>
<td>14.7</td>
</tr>
<tr>
<td>page</td>
<td>394</td>
<td>2.5</td>
<td>1.6</td>
<td>-1.0</td>
<td>9.0</td>
</tr>
<tr>
<td>sd1</td>
<td>394</td>
<td>11/22/1999</td>
<td>1792 days</td>
<td>11/30/1984</td>
<td>1/7/2008</td>
</tr>
<tr>
<td>sddif</td>
<td>394</td>
<td>2605</td>
<td>1686</td>
<td>387</td>
<td>7280</td>
</tr>
<tr>
<td>size</td>
<td>394</td>
<td>4.03</td>
<td>1.94</td>
<td>0.89</td>
<td>10</td>
</tr>
<tr>
<td>sp1</td>
<td>394</td>
<td>$492,368</td>
<td>$351,817</td>
<td>$81,500</td>
<td>$2,500,000</td>
</tr>
<tr>
<td>sp2</td>
<td>394</td>
<td>$800,359</td>
<td>$489,032</td>
<td>$121,000</td>
<td>$3,300,000</td>
</tr>
<tr>
<td>sqft 1000</td>
<td>394</td>
<td>2.2</td>
<td>0.8</td>
<td>0.8</td>
<td>5.3</td>
</tr>
<tr>
<td>vrbuilt</td>
<td>394</td>
<td>1972</td>
<td>26</td>
<td>1904</td>
<td>2008</td>
</tr>
</tbody>
</table>
Table 4: Frequency Summary by California County

<table>
<thead>
<tr>
<th>CA County</th>
<th>Non-PV</th>
<th>PV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
<td>4,826</td>
<td>153</td>
<td>4,979</td>
</tr>
<tr>
<td>Butte</td>
<td>457</td>
<td>12</td>
<td>469</td>
</tr>
<tr>
<td>Contra Costa</td>
<td>5,882</td>
<td>138</td>
<td>6,020</td>
</tr>
<tr>
<td>El Dorado</td>
<td>938</td>
<td>85</td>
<td>1,023</td>
</tr>
<tr>
<td>Humboldt</td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Kern</td>
<td>2,498</td>
<td>53</td>
<td>2,551</td>
</tr>
<tr>
<td>Kings</td>
<td>134</td>
<td>5</td>
<td>139</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>3,368</td>
<td>82</td>
<td>3,450</td>
</tr>
<tr>
<td>Marin</td>
<td>1,911</td>
<td>61</td>
<td>1,972</td>
</tr>
<tr>
<td>Merced</td>
<td>48</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Monterey</td>
<td>10</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Napa</td>
<td>36</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>Orange</td>
<td>1,581</td>
<td>44</td>
<td>1,625</td>
</tr>
<tr>
<td>Placer</td>
<td>11,832</td>
<td>159</td>
<td>11,991</td>
</tr>
<tr>
<td>Riverside</td>
<td>4,262</td>
<td>87</td>
<td>4,349</td>
</tr>
<tr>
<td>Sacramento</td>
<td>10,928</td>
<td>483</td>
<td>11,411</td>
</tr>
<tr>
<td>San Bernardino</td>
<td>2,138</td>
<td>50</td>
<td>2,188</td>
</tr>
<tr>
<td>San Diego</td>
<td>1,083</td>
<td>30</td>
<td>1,113</td>
</tr>
<tr>
<td>San Francisco</td>
<td>407</td>
<td>16</td>
<td>423</td>
</tr>
<tr>
<td>San Joaquin</td>
<td>1,807</td>
<td>20</td>
<td>1,827</td>
</tr>
<tr>
<td>San Luis Obispo</td>
<td>232</td>
<td>1</td>
<td>233</td>
</tr>
<tr>
<td>San Mateo</td>
<td>2,647</td>
<td>92</td>
<td>2,739</td>
</tr>
<tr>
<td>Santa Barbara</td>
<td>224</td>
<td>7</td>
<td>231</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>6,127</td>
<td>157</td>
<td>6,284</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>90</td>
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<td>91</td>
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<tr>
<td>Solano</td>
<td>2,413</td>
<td>39</td>
<td>2,452</td>
</tr>
<tr>
<td>Sonoma</td>
<td>1,246</td>
<td>32</td>
<td>1,278</td>
</tr>
<tr>
<td>Tulare</td>
<td>774</td>
<td>14</td>
<td>788</td>
</tr>
<tr>
<td>Ventura</td>
<td>1,643</td>
<td>42</td>
<td>1,685</td>
</tr>
<tr>
<td>Yolo</td>
<td>16</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Yuba</td>
<td>860</td>
<td>23</td>
<td>883</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>70,425</td>
<td>1,894</td>
<td>72,319</td>
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</tbody>
</table>
Figure 1: Map of Frequencies of PV Homes by California County
Table 5: Frequency Summary by Home Type, Utility and Sale Year

<table>
<thead>
<tr>
<th>Home Type *</th>
<th>Non-PV</th>
<th>PV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Home</td>
<td>26,938</td>
<td>935</td>
<td>27,873</td>
</tr>
<tr>
<td>Existing Home</td>
<td>43,487</td>
<td>897</td>
<td>44,384</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utility **</th>
<th>Non-PV</th>
<th>PV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Gas &amp; Electric (PG&amp;E)</td>
<td>36,137</td>
<td>1,019</td>
<td>37,156</td>
</tr>
<tr>
<td>Southern California Edison (SCE)</td>
<td>14,502</td>
<td>337</td>
<td>14,839</td>
</tr>
<tr>
<td>San Diego Gas &amp; Electric (SDG&amp;E)</td>
<td>8,191</td>
<td>35</td>
<td>8,226</td>
</tr>
<tr>
<td>Sacramento Municipal Utility District (SMUD)</td>
<td>11,393</td>
<td>498</td>
<td>11,891</td>
</tr>
<tr>
<td>Other</td>
<td>202</td>
<td>5</td>
<td>207</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sale Year</th>
<th>Non-PV</th>
<th>PV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>110</td>
<td>0</td>
<td>110</td>
</tr>
<tr>
<td>2000</td>
<td>379</td>
<td>1</td>
<td>380</td>
</tr>
<tr>
<td>2001</td>
<td>1,335</td>
<td>10</td>
<td>1,345</td>
</tr>
<tr>
<td>2002</td>
<td>6,278</td>
<td>37</td>
<td>6,315</td>
</tr>
<tr>
<td>2003</td>
<td>8,783</td>
<td>63</td>
<td>8,846</td>
</tr>
<tr>
<td>2004</td>
<td>10,888</td>
<td>153</td>
<td>11,041</td>
</tr>
<tr>
<td>2005</td>
<td>10,678</td>
<td>168</td>
<td>10,846</td>
</tr>
<tr>
<td>2006</td>
<td>9,072</td>
<td>173</td>
<td>9,245</td>
</tr>
<tr>
<td>2007</td>
<td>8,794</td>
<td>472</td>
<td>9,266</td>
</tr>
<tr>
<td>2008</td>
<td>9,490</td>
<td>642</td>
<td>10,132</td>
</tr>
<tr>
<td>2009</td>
<td>4,618</td>
<td>175</td>
<td>4,793</td>
</tr>
</tbody>
</table>

* A portion of the PV homes could not be classified as either new or existing and therefore are not included in these totals

** Non-PV utility frequencies were estimated by mapping block groups to utility service areas, and then attributing the utility to all homes that were located in the block group
3. Methods and Statistical Models

3.1. Methodological Overview

The data, as outlined above, not only show increased sales values and appreciation for PV homes (in 2009 $) over non-PV homes, but also important differences between PV and non-PV homes as regards other home, site, neighborhood and market characteristics that could, potentially, be driving these differences in value and appreciation. A total of 21 empirical model specifications, with a high reliance on the hedonic pricing model, are used in this paper to disentangle these potentially competing influences in order to determine whether and to what degree PV homes sell for a premium.

The basic theory behind the hedonic pricing model starts with the concept that a house can be thought of as a bundle of characteristics. When a price is agreed upon between a buyer and seller there is an implicit understanding that those characteristics have value. When data from a number of sales transactions are available, the average individual marginal contribution to the sales price of each characteristic can be estimated with a hedonic regression model (Rosen, 1974; Freeman, 1979). This relationship takes the basic form:

\[ \text{Sales price} = f(\text{home and site, neighborhood, and market characteristics}) \]

“Home and site characteristics” might include, but are not limited to, the number of square feet of living area, the size of the parcel of land, and the presence of a PV system. “Neighborhood” characteristics might include such variables as the crime rate, the quality of the local school district, and the distance to the central business district. Finally, “market characteristics” might include, but are not limited to, temporal effects such as housing market inflation/deflation.

A variant of the hedonic model is a repeat sales model, which holds constant many of the characteristics discussed above, and compares inflation adjusted selling prices of homes that have sold twice, both before a condition exists (e.g., before a PV system is installed on the home) and after the condition exists (e.g., after a PV system is installed on the home), and across PV
and non-PV homes. This repeat sales model, in the form used in this paper, is referred to as a difference-in-difference (DD) model, and is discussed in more detail later.

To test for the impact of PV systems on residential selling prices, a series of “base” hedonic models, a “base” difference-in-difference model, a series of robustness models, and two “other” models are estimated for this research.\(^{17}\) As discussed later, these models are used to test for fixed (whether the home has a PV system) and continuous (the size of the PV system) effects using the full dataset of PV homes. They are also used to test for any differences that exist between new and existing PV homes and between homes with PV systems of different ages, and to test for the possibility of non-linear returns to scale based on the size of the PV system or the home itself. Before describing these models in more detail, however, a summary of the variables to be included in the models is provided.

### 3.2. Variables Used in Models

In each base model, be it hedonic or difference-in-difference, four similar sets of parameters are estimated, namely coefficients on the variables of interest and coefficients for three sets of controls that include home and site characteristics, neighborhood (census block group) fixed effects, and temporal (year and quarter) fixed effects. The variables of interest are the focus of the research, and include such variables as whether the home has a PV system installed or not, the size of the PV system, and interactions between these two variables and others, such as the size of the home or the age of the PV system. To accurately measure these variables of interest (and their interactions) other potentially confounding variables need to be controlled for in the models. The base models differ in their specification and testing of the variables of interest, as discussed later, but use the same three sets of controls.

The first of these sets of control variables accounts for differences across the dataset in home and site-specific characteristics, including the age of the home (linear and squared), the total square feet of living area, and the relative elevation of the home (in feet) to other homes in the block group; the latter variable serves as a proxy for “scenic vista,” a value-influencing characteristic

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\(^{17}\) As will be discussed later, each of the “base” models is coupled with a set of two or three robustness models. The “other” models are presented without “robustness” models.
Additionally, the size of the property in acres was entered into the model in spline form to account for different valuations of less than one acre and greater than one acre.

The second set of controls, the geographic fixed effects variables, includes dummy variables that control for aggregated “neighborhood” influences, which, in our case, are census block groups. A census block group generally contains between 200 and 1,000 households and is delineated to never cross boundaries of states, counties, or census tracts, and therefore, in our analysis, serves as a proxy for “neighborhood.” To be usable, each block group had to contain at least one PV home and one non-PV home. The estimated coefficients for this group of variables capture the combined effects of school districts, tax rates, crime, distance to central business district and other block group specific characteristics. This approach greatly simplifies the estimation of the model relative to determining these individual characteristics for each home, but interpreting the resulting coefficients can be difficult because of the myriad of influences captured by the variables. Because block groups are fairly small geographically, spatial autocorrelation is also, to some degree, dealt with through the inclusion of these variables.

Finally, the third set of controls, the temporal fixed effect variables, includes dummy variables for each quarter of the study period to control for any inaccuracies in the housing inflation adjustment that was used. A housing inflation index is used to adjust the sales prices throughout the study period to 2009 prices at a zip code level across as many as three price tiers. Although

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18 Other home and site characteristics were also tested, such as the condition of the home, the number of bathrooms, the number of fireplaces, and if the home had a garage and/or a pool. Because these home and site characteristics were not available for all home transactions (and thus reduced the sample of homes available), did not add substantial explanatory power to the model, and did not affect the results substantively, they were not included in the model results presented in this paper.

19 For a portion of the dataset, a common subdivision name was identified, which, arguably, serves as a better proxy for neighborhood than block group. Unfortunately, not all homes fell within a subdivision. Nonetheless, a separate combined subdivision-block group fixed effect was tested and will be discussed later.

20 Census block groups generally contain between 600 and 3,000 people, and the median household size in California is roughly 3.

21 Spatial Autocorrelation - a correlation between neighbors' selling prices - can produce unstable coefficient estimates, yielding unreliable significance tests in hedonic models if not accounted for. One reason for this spatial autocorrelation is omitted variables, such as neighborhood characteristics (e.g., distance to the central business district), which affect all properties within the same area similarly. Having micro-spatial controls, such as block groups or subdivisions, helps control for such autocorrelation.
this adjustment is expected to greatly improve the model - relative to using just a temporal fixed effect with an unadjusted price - it is also assumed that because of the volatility of the housing market, the index may not capture price changes perfectly and therefore the model is enhanced with the additional inclusion of these quarterly controls.\textsuperscript{22}

3.3. Fixed and Continuous Effect Hedonic Models

The analysis begins with the most basic model comparing prices of all of the PV homes in the sample (whether new or existing) to non-PV homes across the full dataset. As is common in the literature (Malpezzi, 2003; Sirmans et al., 2005b; Simons and Saginor, 2006), a semi-log functional form of the hedonic pricing model is used where the dependent variable, the (natural log of) sales price (P), is measured in zip code-specific inflation-adjusted (2009) dollars. To determine if an average-sized PV system has an effect on the sale price of PV homes (i.e., a fixed effect) we estimate the following base fixed effect model:

\[
\ln(P_{ik}) = \alpha + \beta_1 (T_i) + \beta_2 (N_k) + \sum_a \beta_3 (X_i) + \beta_4 (PV_i) + \varepsilon_{itk}
\]

where

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

\textsuperscript{22} A number of models were tested both with and without these temporal controls and with a variety of different temporal controls (e.g., monthly) and temporal/spatial controls (e.g., quarter and tract interactions). The quarterly dummy variables were the most parsimonious, and none of the other approaches impacted the results substantively.
The parameter estimate of primary interest in this model is $\beta_4$, which represents the marginal percentage change in sale price with the addition of an average sized PV system. If differences in selling prices exist between PV and non-PV homes, we would expect the coefficient to be positive and statistically significant.

An alternative to equation (1) is to interact the PV fixed effect variable ($PV_i$) with the size (in kW) of the PV system as installed on the home at the time of sale ($SIZE_i$), thereby producing an estimate for the differences in sales prices as a function of size of the PV system. This base continuous effect model takes the form:

$$
\ln(P_{ith}) = \alpha + \beta_1 (T_i) + \beta_2 (N_k) + \sum \beta_3 (X_i) + \beta_4 (PV_i \cdot SIZE_i) + \epsilon_{ith}
$$

(2)

where

$\text{SIZE}_i$ is a continuous variable for the size (in kW) of the PV system installed on the home prior to transaction $i$,

$\beta_4$ is a parameter estimate for the percentage change in sale price for each additional kW added to a PV system, and all other terms are as were defined for equation (1).

If differences in selling prices exist between PV and non-PV homes, we would expect the coefficient to be positive and statistically significant, indicating that for each additional kilowatt added to the PV system the sale price increases by $\beta_4$ (in % terms).

This continuous effect specification may be preferable to the PV fixed effect model because one would expect that the impact of PV systems on residential selling prices would be based, at least partially, on the size of the system, as size is related to energy bill savings. Moreover, this specification allows for a direct estimate of any PV home sales premium in dollars per watt ($/watt), which is the form in which other estimates – namely average net installed costs – are reported. With the previous fixed effects specification, a $/watt estimate can still be derived, but

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23 Ideally, the energy bill savings associated with individual PV systems could be entered into the model directly, but these data were not available. Moreover, estimating the savings accurately on a system-by-system basis was not possible because of the myriad of different rate structures in California, the idiosyncratic nature of energy use at the household level, and variations in PV system designs and orientations.
not directly. Therefore, where possible in this paper, greater emphasis is placed on the continuous effect specification than on the fixed effect estimation.

As mentioned earlier, for each base model we explore a number of different robustness models to better understand if and to what degree the results are unbiased. In the present research, two areas of bias are of particular concern: omitted variable bias and sample selection bias.

The omitted variables that are of specific concern are any that might be correlated with the presence of PV, and that might affect sales prices. An example is energy efficiency (EE) improvements, which might be installed contemporaneously with a PV energy system. If many homes with PV have EE improvements, whereas the comparable non-PV homes do not, then estimates for the effects of PV on selling prices might be inclusive of EE effects and, therefore, may be inappropriately high. Any other value-influencing home improvements (e.g., kitchen remodels, new roofs, etc.), if correlated with the presence of PV, could similarly bias the results if not carefully addressed.

With respect to selection bias, the concern is that the distribution of homes that have installed PV may be different from the broad sample of homes on which PV is not installed. If both sets of homes are assumed to have similar distributions but are, in point of fact, dissimilar due to selection, then the estimates for the effects of PV on the selling price could be inclusive of these underlying differences but attributed to the existence of PV, thereby also potentially biasing the results.

To mitigate the issue of omitted variable bias, one robustness model uses the same data sample as the base model but a different model specification. Specifically, a combined subdivision-block group fixed effect variable can be substituted, where available, in place of the block group fixed effect variable as an alternative proxy for “neighborhood.” Potentially omitted variables are likely to be more similar between PV and non-PV homes at the subdivision level than at the
block group level, and therefore this model may more-effectively control for such omitted variables.\textsuperscript{24}

To mitigate the issue of selection bias, one robustness model uses the same model specification as the base model but with an alternative (subset) of the data sample. Specifically, instead of using the full dataset with equations (1) and (2), a “coarsened exact matched” dataset is used (King et al., 2010).\textsuperscript{25} This matching procedure results in a reduced sample of homes to analyze, but the PV and non-PV homes that remain in the matched sample are statistically equal on their covariates after the matching process (e.g., PV homes within a block group are matched with non-PV homes such that both groups are similar in the number of bathrooms, date of sale, etc.). As a result, biases related to selection are minimized.

Finally, specific to equation (2), a robustness model to mitigate both omitted variable and selection bias is constructed in which the sample is restricted to include only PV homes (in place of the full sample of PV and non-PV homes). Because this model does not include non-PV “comparable” homes, sales prices of PV homes are “compared” against each other based on the size of the PV systems, while controlling for the differences in the home via the controlling characteristics (e.g., square feet of living space). PV system size effects are therefore estimated without the use of non-PV homes, providing an important comparison to the base models, while also directly addressing any concerns about the inherent differences between PV and non-PV homes (e.g., whether energy efficient upgrades were made contemporaneously with the PV) and therefore omitted variable and sample selection bias.

\textsuperscript{24} Subdivisions are often geographically smaller than block groups, and therefore more accurately control for geographical influences such as distance to central business district. Moreover, homes in the same subdivision are often built at similar times using similar materials and therefore serve as a control for a variety of house specific characteristics that are not controlled for elsewhere in the model. For example, all homes in a subdivision will often be built using the same building code with similar appliances being installed, both of which might control for the underlying energy efficiency (EE) characteristics of the home. For homes not situated in a subdivision, the block group delineation was used, and therefore these fixed effects are referred to as “combined subdivision-block group” delineations.

\textsuperscript{25} The procedure used, as described in the referenced paper, is coarsened exact matching (cem) in Stata, available at: \url{http://ideas.repec.org/c/boc/bocode/s457127.html}. The matching procedure creates statistically matched sets of PV and non-PV homes in each block group, based on a set of covariates, which, for this research, include the number of square feet, acres, and baths, as well as the age of the home, its elevation, and the date at which it sold. Because this matching process excludes non-PV homes that are without a statistically similar PV match (and vice versa), a large percentage of homes (approximately 80% non-PV and 20% PV) are not included in the resulting dataset.
3.4. New and Existing Home Models

Although equations (1) and (2) are used to estimate whether a PV system, on average, effects selling prices across the entire data sample, they do not allow one to distinguish any such effects as a function of house type, specifically whether the home is new or existing. As discussed earlier, new homes with PV might have different premiums than existing homes. To try to tease out these possible differences, two base hedonic models are estimated using equation (2), one with only new homes and the other with only existing homes. Comparing the coefficient of the variable of interest ($\beta_4$) between these two models allows for an assessment of the relative size of the impact of PV systems across the two home types.

Additionally, two sets of robustness models that were discussed earlier are also applied to the new and existing home models, one using the coarsened exact matched datasets and the other using the combined subdivision-block group delineations. These models test the robustness of the results for selection and omitted variable bias, respectively. Although it is discussed separately as a base model in the following subsection, the difference-in-difference model, using repeat sales of existing homes, also doubly serves as a robustness test to the existing homes base model.

3.4.1. Difference-in-Difference Models

One classic alternative to estimating a hedonic model, as briefly discussed earlier, is to estimate a difference-in-difference (DD) model (Wooldridge, 2009). This model (see Table 1) uses a set of homes that have sold twice, both with and without PV, and provides estimates of the effect of adding PV to a subset of those homes as of the second sale (“DD” as noted in Table 1), while simultaneously accounting for both the inherent differences in the PV and non-PV groups and the trend in housing prices between the first and second sales of non-PV homes. Repeat sales models of this type are particularly effective in controlling for selection and certain types of

---

26 New and existing homes were determined in an iterative process. For PV homes, the type of home was often specified by the data provider. It was also discovered that virtually all of the new PV homes (as specified by the PV data providers) had ages, at the time of sale, between negative one and two years, inclusive, whereas the existing PV homes (as specified by the PV data providers) had ages greater than two years in virtually every case. The small percentage (3%) of PV homes that did not fit these criteria were excluded from the models. For non-PV homes, no data specifying the home type were available, therefore, groupings were created following the age at sale criteria used for PV homes (e.g., ages between negative one and two years apply to new non-PV homes).
omitted variable bias. In the former case, any underlying difference in home prices between PV and non-PV homes prior to the addition of PV is controlled for. In the latter case, PV and non-PV homes are assumed to have undergone mostly similar changes (e.g., home improvements) between sales. Any changes to the home that are coincident with the installation of a PV system (or the PV system household), on the other hand, are not directly controlled for in this model, though there is reason to believe that any such remaining influences are not imposing substantial bias in the present study.27

The set of PV homes that are used in the DD model are, by default, existing homes (i.e., the home was not new when the PV system was installed). Estimates derived from this model, therefore, apply to - while also serving as a robustness tests for - the existing home models as specified above.

Table 6: Difference-in-Difference Description

<table>
<thead>
<tr>
<th></th>
<th>Pre PV</th>
<th>Post PV</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Homes</td>
<td>PV₁</td>
<td>PV₂</td>
<td>ΔPV = PV₂ - PV₁</td>
</tr>
<tr>
<td>Non-PV Homes</td>
<td>NPV₁</td>
<td>NPV₂</td>
<td>ΔNPV = NPV₂ - NPV₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DD = ΔPV - ΔNPV</td>
</tr>
</tbody>
</table>

1 and 2 denote time periods

The base DD model is estimated as follows:

$$\ln(P_{itk}) = \alpha + \beta_1(T_{it}) + \beta_2(N_k) + \sum_{a} \beta_3(X_{ai}) + \beta_4(PVH_i) + \beta_5(SALE2_i) + \beta_6(PVS_i) + \epsilon_{itk}$$ (3)

where

PVHᵢ is a fixed effect variable indicating if a PV system is or will be installed on the home in transaction i,

27 Support for this assumption comes from two sources. Although surveys (e.g., CPUC, 2010) indicate that PV homeowners install energy efficient “measures” with greater frequency than non-PV homeowners, the differences are relatively small and largely focus on lighting and appliances. The former is not expected to substantially impact sales prices, while the latter could. The surveys also indicate that PV homeowners tend to install other larger EE measures, such as building shell, water heating and cooling improvements, with greater frequency than non-PV homes. Additionally, it might also be hypothesized that PV homeowners may be more-likely to have newer roofs (perhaps installed at the time of PV installation). Dastrop et al. (2010), however, investigated whether home improvements that might require a permit affect PV home sales premium estimates, and found they did not. It should be noted that the PV Only model, discussed previously, directly addresses the concern of omitted variable bias for this analysis.
SALE2, is a fixed effect variable indicating if transaction i is the second of the two sales, PVS is a fixed effect variable (an interaction between PVH and SALE2) indicating if transaction i is both the second of the two sales and contained a PV system at the time of sale, α is the constant or intercept across the full sample, β4 is a parameter estimate for homes that have or will have PV installed (i.e., from Table 6 “PV1 – NPV1”), β5 is a parameter estimate if transaction i occurred as of the second sale (i.e., “ΔNPV”), β6 is a parameter estimate if transaction i occurred as of the second sale and the home contained PV (i.e., “ΔPV – ΔNPV” or “DD”), and all other terms are as were defined for equation (1).

The coefficient of interest is β6, which represents the percentage change in sale price, as expressed in 2009 dollars, when PV is added to the home, after accounting for the differences between PV and non-PV homes (β4) and the differences between the initial sale and the second sale of non-PV homes (β5). If differences in selling prices exist between PV and non-PV homes, we would expect the coefficient to be positive and statistically significant.28

To further attempt to mitigate the potential for omitted variable bias, two robustness models are estimated for the base DD model: one with the combined subdivision-block group delineations and a second with a limitation applied on the number of days between the first and second sale.29

The first robustness model is similar to the one discussed earlier. The second robustness model accounts for the fact that the home characteristics used (in all models) reflect the most recent home assessment, and therefore do not necessarily reflect the characteristics at the time of the sale. Especially worrisome are the first sales in the DD model, which can be as much as 20 years before the second sale. To test if our results are biased because of these older sales - and the

28 This is the classic model form derived from a quasi-experiment, where the installation of PV is the treatment. An alternative specification would look at the incremental effect of PV system size holding the starting differences between PV and non-PV homes as well as the time-trend in non-PV homes constant. This model form was not evaluated in the current analysis effort, but could be considered grounds for future research in this area.

29 Ideally a matched dataset could be utilized, for reasons described earlier, but because the matching procedure severely limited the size of the dataset, the resulting dataset was too small to be useful.
large periods between sales - an additional data screen is applied in which the difference between the two sale dates is limited to five years.30

3.5. Age of the PV System for Existing Homes Hedonic Models

The age of the PV system at the time of home sale could affect the sales price premium for existing homes (PV systems on new homes are, by definition, also new). This might occur because older PV systems have a shorter expected remaining life and may become somewhat less efficient with age (and therefore deliver a lower net present value of bill savings), but also because older PV systems will have generated more energy bill savings for the home seller and the seller may therefore more-willingly accept a lower price. Together, these factors suggest that premiums for older PV systems on existing homes would be expected to be lower than for newer systems. In order to test this directly the following base model is estimated:

\[
\ln(P_{ik}) = \alpha + \beta_1 (T_i) + \beta_2 (N_k) + \sum_a \beta_3 a_i + \beta_4 (PV_i \cdot SIZE_i \cdot AGE_i) + \varepsilon_{ik}
\] (4)

where

\(AGE_i\) is a categorical variable for three groups of PV system age as of the time of sale of the home: 1) less than or equal to one year old; 2) between 2 and 4 years old; and, 3) five or more years old.

Therefore, \(\beta_4\) is a vector of parameter estimates for the percentage change in sales price for each additional kW added to a PV system for each of the three PV system age groups, and all other terms are as are defined for equation (2). The assumption is that the coefficients for \(\beta_4\) will be decreasing - indicating they are valued less - as the age of the PV systems decrease. The sample used for this model is the same as for the existing home model defined previously.

Additionally, two sets of robustness models are explored, one using the coarsened exact matched dataset and the other using the combined subdivision-block group delineations, to test the robustness of the results for selection and omitted variable bias, respectively.

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30 As was discussed earlier, a screen for this eventuality (using \textit{adjaar}) is incorporated in our data cleaning. This test therefore serves as an additional check of robustness of the results.
3.6. Returns to Scale Hedonic Models

As discussed earlier, it is not unreasonable to expect that any increases in the selling prices of PV homes may be non-linear with PV system size. In equation (2), it was assumed that estimated price differences were based on a continuous linear relationship with the size of the system. To explore the possibility of a non-linear relationship among the full sample of homes in the dataset, the following model is estimated:\textsuperscript{31}

\[
\ln(P_{ik}) = \alpha + \beta_1(T_i) + \beta_2(N_k) + \sum_a \beta_3(X_i) + \beta_4(PV_i \cdot SIZE_i) + \beta_5(PV_i \cdot SIZE_i \cdot SIZE_i) + \varepsilon_{ik}
\]

\[\text{(5)}\]

where

\[\beta_5\] is a parameter estimate for the percentage change in sales price for each additional kW added to a PV system squared, and all other terms are as are defined for equation (2).

A negative statistically significant coefficient (\(\beta_5\)) would indicate decreasing returns to scale for larger PV systems, while a positive coefficient would indicate the opposite.

Somewhat analogously, as was discussed previously, premiums for PV systems may be related to the size of the home.\textsuperscript{32} To test this directly using the full dataset, the following model is estimated:

\[
\ln(P_{ik}) = \alpha + \beta_1(T_i) + \beta_2(N_k) + \sum_a \beta_3(X_i) + \beta_4(SQFT_i) + \beta_5(PV_i \cdot SIZE_i) + \\
\beta_6(PV_i \cdot SIZE_i \cdot SQFT_i) + \varepsilon_{ik}
\]

\[\text{(6)}\]

where

\[SQFT_i\] is a continuous variable for the number of square feet for the home in transaction \(i\),\textsuperscript{33} \(\beta_6\) is a parameter estimate for the percentage change in sale price for each additional 1000 square feet added to the home,

\textsuperscript{31} Neither this nor the following model is coupled with robustness models in this paper.

\textsuperscript{32} PV system size is also somewhat correlated with house size as a result of the tendency for increasing energy use and larger roof areas on larger homes. If this correlation was particularly strong then coefficient estimates could be imprecise. The correlation between PV house size and PV system size in the full sample of our data, however, is rather weak, at only 0.14. Clearly, many factors other than house size impact the sizing of PV systems.

\textsuperscript{33} In all of the previous models the number of square feet is contained in the vector of characteristics represented by \(X_i\), but in this model it is separated out for clarity.
\( \beta_5 \) is a parameter estimate for the percentage change in sale price for each additional kW added to a PV system,

\( \beta_6 \) is a parameter estimate for the percentage change in sale price for each additional 1000 square feet added to PV homes, assuming the size of the PV system does not change, and all other terms are as were defined for equation (2).

A negative statistically significant coefficient for \( \beta_6 \) would indicate decreasing returns to scale for PV systems as homes increase in size. Alternatively, a positive and statistically significant coefficient would indicate increasing returns to scale for PV systems installed on larger homes.
3.7. Model Summary

To summarize, the entire set of 21 estimated models discussed herein is shown in Table 7. The following definitions of terms, all of which were discussed earlier, are relevant for interpreting the models listed in the table, and therefore are briefly reviewed again. All “base” models are coupled with a set of “robustness” models (as noted by a capital “R” in the model number). The “Other” (returns to scale) models are presented alone. Models 1 - 4 and 6 - 8 use the hedonic pricing model, whereas Model 5 is based on the difference-in-difference (DD) model. “Fixed” (versus “continuous”) means that the PV variable is entered into the regression as a zero-one dichotomous variable (for Models 1-1Rb and 5-5Rb), whereas “continuous” (for all other models) means that the model estimates the impact of an increase in PV system size on residential selling prices. Base Models 1, 2, 7 and 8 use the full dataset, while Models 4 and 6 are restricted to existing homes, Model 3 to new homes, and Model 5 to the repeat sales dataset. The “matched” models use the smaller dataset of coarsened exact matched (PV and non-PV) homes. “Base” models estimate neighborhood fixed effects at the census block group level, whereas the “subdivision” models estimate neighborhood fixed effects at the combined subdivision-block group level.

Table 7: Summary of Models

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Model Name</th>
<th>Base Model</th>
<th>Robustness Model</th>
<th>Other Models</th>
<th>Dataset</th>
<th>Neighborhood Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixed - Base</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Block Group</td>
<td></td>
</tr>
<tr>
<td>1Ra</td>
<td>Fixed - Matched</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Matched Block Group</td>
<td></td>
</tr>
<tr>
<td>1Rb</td>
<td>Fixed - Subdivision</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Subdivision/Block Group</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Continuous - Base</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Block Group</td>
<td></td>
</tr>
<tr>
<td>2Ra</td>
<td>Continuous - Matched</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Matched Block Group</td>
<td></td>
</tr>
<tr>
<td>2Rb</td>
<td>Continuous - Subdivision</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Subdivision/Block Group</td>
<td></td>
</tr>
<tr>
<td>2Rc</td>
<td>Continuous - PV Only</td>
<td>X</td>
<td></td>
<td></td>
<td>PV Only Block Group</td>
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<tr>
<td>3</td>
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<td>X</td>
<td></td>
<td></td>
<td>New Block Group</td>
<td></td>
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<tr>
<td>3Ra</td>
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<td>X</td>
<td></td>
<td></td>
<td>New Matched Block Group</td>
<td></td>
</tr>
<tr>
<td>3Rb</td>
<td>New - Subdivision</td>
<td>X</td>
<td></td>
<td></td>
<td>New Subdivision/Block Group</td>
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</tr>
<tr>
<td>4</td>
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<td>X</td>
<td></td>
<td></td>
<td>Existing Block Group</td>
<td></td>
</tr>
<tr>
<td>4Ra</td>
<td>Existing - Matched</td>
<td>X</td>
<td></td>
<td></td>
<td>Existing - Matched Block Group</td>
<td></td>
</tr>
<tr>
<td>4Rb</td>
<td>Existing - Subdivision</td>
<td>X</td>
<td></td>
<td></td>
<td>Existing Subdivision/Block Group</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Difference-in-Difference (DD) - Base</td>
<td>X</td>
<td></td>
<td></td>
<td>Repeat Sales Block Group</td>
<td></td>
</tr>
<tr>
<td>5Ra</td>
<td>Difference-in-Difference (DD) - Subdivision</td>
<td>X</td>
<td></td>
<td></td>
<td>Repeat Sales Subdivision/Block Group</td>
<td></td>
</tr>
<tr>
<td>5Rb</td>
<td>Difference-in-Difference (DD) - Sdiff &lt; 5 Years</td>
<td>X</td>
<td></td>
<td></td>
<td>Repeat Sales w/ sdiff &lt; 5 Block Group</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Age of System - Base</td>
<td>X</td>
<td></td>
<td></td>
<td>Existing Block Group</td>
<td></td>
</tr>
<tr>
<td>6Ra</td>
<td>Age of System - Matched</td>
<td>X</td>
<td></td>
<td></td>
<td>Existing - Matched Block Group</td>
<td></td>
</tr>
<tr>
<td>6Rb</td>
<td>Age of System - Subdivision</td>
<td>X</td>
<td></td>
<td></td>
<td>Existing Subdivision/Block Group</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Returns to Scale - Size</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Block Group</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Returns to Scale - Square Feet</td>
<td>X</td>
<td></td>
<td></td>
<td>Full Block Group</td>
<td></td>
</tr>
</tbody>
</table>
4. Estimation Results

Estimation results for all 21 models (as defined in Table 7) are presented in Tables 8-11, with the salient results on the impacts of PV on homes sales prices summarized in Figures 2-4. The adjusted $R^2$ for all models is high, ranging from 0.93 to 0.95, which is notable because the dataset spanned a period of unusual volatility in the housing market. The model performance reflects, in part, the ability of the inflation index and temporal fixed effects variables to adequately control for market conditions.

Moreover, the sign and magnitude of the home and site control variables are consistent with a priori expectations, are largely stable across all models, and are statistically significant at the 1% level in most models. Each additional 1000 square feet of living area added to a home is estimated to add between 19% and 26% to its value, while the first acre adds approximately 40% to its value with each additional acre adding approximately 1.5%. For each year a home ages, it is estimated that approximately 0.2% of its value is lost, yet at 60 years, age becomes an asset with homes older than that estimated to garner premiums for each additional year in age. Finally, for each additional 100 feet above the median elevation of the other homes in the block group, a home’s value is estimated to increase by approximately 0.3%. These results can be benchmarked to other research. Specifically, Sirmans et al. (2005a; 2005b) conducted a meta-analysis of 64 hedonic pricing studies carried out in multiple locations in the U.S. during multiple time periods, and investigated similar characteristics as included in the models presented here, except for relative elevation. As a group, each of the home and site characteristic estimates in the present

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34 For simplicity, this paper does not present the results for the quarter and block group (nor combined subdivision-block group) fixed effects, which consist of more than 900 coefficients. These are available upon request from the authors.

35 All models were estimated with Stata SE Version 11.1 using the “areg” procedure with White’s correction for standard errors (White, 1980). It should also be noted that all Durbin-Watson (Durbin and Watson, 1951) test statistics were within the acceptable range (Gujarati, 2003), there was little multicollinearity associated with the variables of interest, and all results were robust to the removal of any cases with a Cook’s Distance greater than $4/n$ (Cook, 1977) and/or standardized residuals greater than four.

36 As mentioned in footnote 22, a variety of approaches were tested to control for market conditions, such as spatial temporal fixed effects (e.g., census block / year quarter) both with and without adjusted sale prices. The models presented here were the most parsimonious. As importantly, the results were robust to the various specifications, which, in turn, provides additional confidence that the effects presented are not biased by the fluctuating market conditions that have impacted the housing market for some years.

37 In some models, where there is little variation between the cases on the covariate (e.g., acres), the results are non-significant at the 10% level.
study differ from the mean Sirmans et al. estimates by no more than one half of one standard deviation.

In summary, these results suggest that the hedonic and repeat sales models estimated here are effectively capturing many of the drivers to home sales prices in California, and therefore increasing confidence that those same models can be used to accurately capture any PV effects that may exist.

4.1. Fixed and Continuous Effect Hedonic Model Results

The results from the base hedonic models (equations 1 and 2) are shown in Table 8 as Models 1 and 2, respectively. These models estimate the differences across the full dataset between PV and non-PV homes, with Model 1 estimating this difference as a fixed effect, and Model 2 estimating the difference as a continuous effect for each additional kilowatt (kW) of PV added. Also shown in the table are the results from the robustness tests using the coarsened exact matching procedure and the combined subdivision-block group delineations, as shown as Models 1Ra and 1Rb for PV fixed effect models and Models 2Ra and 2Rb for continuous effect variables. Finally, the model that derives marginal impact estimates from only PV homes is shown in the table as Model 2Rc.

Across all seven of these models (Models 1 – 2Rc), regardless of the specification, the variables of interest of PV and SIZE are positive and significant at the 10% level, with six out of seven estimates being significant at the 1% level. Where a PV fixed effect is estimated, the coefficient can be interpreted as the percentage increase in the sales price of a PV home over the mean non-PV home sales price in 2009 dollars based on an average sized PV system. By dividing the monetary value of this increase by the number of watts for the average sized system, this premium can be converted to 2009 dollars per watt ($/watt). For example, for base Model 1, multiplying the mean non-PV house value of $480,862 by 0.036 and dividing by 3120 watts, yields a premium of $5.5/watt (see bottom of Table 8). Where SIZE, a continuous PV effect, is used, the coefficients reflect the percentage increase in selling prices in 2009 dollars for each additional kW added to the PV system. Therefore, to convert the SIZE coefficient to $/watt, the mean house value for non-PV homes is multiplied by the coefficient and divided by 1000. For
example, for base Model 2, $480,862 is multiplied by 0.012 and divided by 1000, resulting in an estimate of $5.8/watt.38

As summarized in Figure 2, these base model results for the impact of PV on residential selling prices are consistent with those estimated after controlling for subdivision fixed effects ($5.4/watt and $5.6/watt for fixed and continuous effects, respectively), differing by no more than $0.2/watt. On the other hand, the estimated PV premiums derived from the coarsened exact matched dataset are noticeably smaller, decreasing by 20 to 30%, and ranging from $3.9/watt to $4.8/watt for fixed and continuous effects, respectively. Alternatively, the PV only Model 2Rc estimates a higher $/watt continuous effect of $6.4/watt, although that estimate is statistically significant at a lower 10% level. This estimate, because it is derived from PV homes only, corroborates that any changes to the home that are coincident with the installation of the PV (e.g., energy efficient upgrades) are not influencing results dramatically.

Figure 2: Fixed and Continuous Effect Base Model Results with Robustness Tests

38 To be exact, the conversion is a bit more complicated. For example, for the fixed effect model the conversion is actually \((\exp(\ln(480,862)+0.036)-480,862)/3.12/1000\), but the differences are de minimis, and therefore are not used herein.
Though results among these seven models differ to some degree, the results are consistent in finding a premium for PV homes over non-PV homes in California, which varies from $3.9 to $6.4/watt on average, depending on the model specification. These sale price premiums are very much in line with, if not slightly above, the historical mean net installed costs (i.e., the average installed cost of a system, after deducting available state and federal incentives) of residential PV systems in California of approximately $5/watt from 2001 through 2009 (Barbose et al., 2010), which, as discussed earlier, may be reasonable given that both buyers and sellers might use this cost as a partial basis to value a home.39

Additionally, the one other hedonic analysis of PV selling price premiums (which used reasonably similar models as those employed here but a different dataset, concentrating only on homes in the San Diego metropolitan area) found a similar result (Dastrop et al., 2010). In their analysis of 279 homes that sold with PV systems installed in San Diego (our model only contained 35 homes from this area40 – See Table 5), Dastrop et al. estimated an average increase in selling price of $14,069, which, when divided by their mean PV system size of 3.2 kW, implies an effect of $4.4/watt.41

39 Although not investigated here, one possible reason for sales price premiums that are above net installed costs is that buyers of PV homes may in some cases price in the opportunity cost of avoiding having to do the PV installation themselves, which might be perceived as complex. Moreover, a PV system installation that occurs after the purchase of the home would likely be financed outside the first mortgage and would therefore lose valuable finance and tax benefits, thereby making the purchase of a PV home potentially more attractive that installing a PV system later, even if at the same cost.

40 Though we identified a higher number of PV homes that sold in the San Diego metropolitan area in our dataset, the home and site characteristics provided to us from the real estate data provider did not contain information on the year of the sale and therefore were not usable for the purpose of our analysis.

41 In a different model, Dastrop et al. (2010) estimated an effect size of $2.4/watt but, for reasons not addressed here, this estimate is not believed to be as robust.
### Table 8: Fixed and Continuous Base Hedonic Model Results with Robustness Tests

<table>
<thead>
<tr>
<th></th>
<th>Fixed Base</th>
<th>Fixed Robustness Matched Subdivision</th>
<th>Fixed Robustness Matched Subdivision PV Only</th>
<th>Continuous Base</th>
<th>Continuous Robustness Matched Subdivision</th>
<th>Continuous Robustness Matched Subdivision PV Only</th>
<th>Continuous Robustness Matched Subdivision PV Only</th>
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<tr>
<td><strong>Model 1</strong></td>
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<tr>
<td>pv</td>
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<td>(0.006)</td>
<td>(0.001)</td>
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<tr>
<td></td>
<td>(0.009)</td>
<td>(0.040)</td>
<td>(0.010)</td>
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<tr>
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<td>0.013</td>
<td>0.015***</td>
<td>0.015***</td>
<td>-0.002</td>
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<td>(0.011)</td>
<td>(0.003)</td>
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<tr>
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<td>-0.004***</td>
<td>-0.004***</td>
<td>-0.006***</td>
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<tr>
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<td>(0.0012)</td>
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<td>ages2sqr</td>
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<td>0.00004***</td>
<td>0.00003***</td>
<td>0.00003***</td>
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<tr>
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<td>(0.000003)</td>
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<td>bgre_100</td>
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<td>0.003***</td>
<td>0.003***</td>
<td>0.013***</td>
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<tr>
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<td>(0.004)</td>
<td>(0.001)</td>
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<tr>
<td>intercept</td>
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<td>12.961***</td>
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<td>12.710***</td>
<td>12.842***</td>
<td></td>
<td></td>
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<tr>
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<td>(0.010)</td>
<td>(0.044)</td>
<td>(0.012)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Numbers in parenthesis are standard errors. *** p<0.01, ** p<0.05, * p<0.1

Results for subdivision, block group, and quarterly fixed effect variables are not reported here, but are available upon request from the authors.

**Total n**
- Fixed: 72,319
- Continuous: 13,329
- Total: 72,319

**Adjusted R^2**
- Fixed: 0.93
- Continuous: 0.94
- Total: 0.93

**Mean non-pv asp2**
- Fixed: $480,862
- Continuous: $480,862
- Total: $475,811

**Mean size (kW)**
- Fixed: 3.1
- Continuous: 3.0
- Total: 2.7

**Estimated $/Watt**
- Fixed: $5.5
- Continuous: $5.6
- Total: $6.4

*PV Only Model Notes: Mean non-pv asp2 amount shown is actually the mean PV asp2. Sample is limited to blockgroups with more than one PV home*

### 4.2. New and Existing Home Model Results

Turning from the full dataset to one specific to the home type, we estimate continuous effects models for new and existing homes (see equation (2)). These results are shown in Table 9, with Model 3 the base model for new homes and Model 4 the base model for existing homes. Also
shown are the results from the robustness tests using the coarsened exact matching procedure and the combined subdivision-block group delineations, as Models 3Ra and 3Rb, respectively, for new homes, and as Models 4Ra and 4Rb, respectively, for existing homes.

The coefficient of interest, SIZE, is statistically significant at or below the 10% level in all of the new home models and at the 1% level in all of the existing home models. Estimates for the average $/watt increase in selling prices as a result of PV systems (as summarized in Figure 3, which also includes the results presented earlier for all homes, Models 2, 2Ra, and 2Rb) for new homes are quite stable, ranging from $2.3 to $2.6/watt. In comparison, for PV sold with existing homes, not only are the selling price impacts found to be higher, but their range across the three models is somewhat greater, ranging from $6.4 to $7.7/watt.

**Figure 3: New and Existing Home Base Model Results with Robustness Tests**

![Figure 3: New and Existing Home Base Model Results with Robustness Tests](image)

Though the reasons for the apparent discrepancy in selling price impacts between new and existing homes are unclear, and warrant future research, they might be explained, in part, by the difference in average net installed costs, which, from 2007 to 2009, were approximately $5.2/watt for existing homes and $4.2/watt for new homes in California (derived from the dataset used for Barbose et al., 2010). The gap in net installed costs between new and existing homes is
not wide enough to fully account for these findings, however, with the model estimates for PV selling price premiums below the average net installed costs for new homes and above the average net installed costs for existing homes.42

Several alternative explanations for the disparity between new and existing home premiums exist. As discussed previously, there is evidence that builders of new homes might discount premiums for PV if, in exchange, PV systems provide other benefits for new home developers, such as greater product differentiation and increased the sales velocity, thus decreasing overall carrying costs (Dakin et al., 2008; SunPower, 2008). Further, sellers of new homes with PV might be reluctant to aggressively increase home sale prices for installed PV systems because of the burgeoning state of the market for PV homes and concern that more aggressive pricing could even slow home sales. Additionally, because many builders of new homes found that offering PV as an option, rather than a standard feature, posed a set of difficulties (Farhar et al., 2004b; Dakin et al., 2008), it has been relatively common in past years for PV to be sold as a standard feature on homes (Dakin et al., 2008). This potentially affects the valuation of PV systems for two reasons. First, because sales agents for the new PV homes have sometimes been found to either not be well versed in the specifics of PV and felt that selling a PV system was a new sales pitch (Farhar et al., 2004b) or to have combined the discussion of PV with a set of other energy features (Dakin et al., 2008), up-selling the full value of the PV system as a standard product feature might not have been possible. Secondly, the average sales price of new homes in our dataset is lower than the average sales price of existing homes: to the extent that PV is considered a luxury good, it may be somewhat less-highly valued for the buyers of these homes.

These downward influences for new homes are potentially contrasted with analogous upward influences for existing homes. Related, buyers of existing homes with PV may - to a greater degree than buyers of the less expensive new homes in our sample - be self selected towards those who place particular value on a PV home, and therefore value the addition more. Finally, in contrast to new home sellers, who might not be familiar with the intricacies and benefits of the

42 A small number of “affordable homes” (n = 7) are included in the new PV homes subset, which, as a group, appear to have a slight downward yet inconsequential effect on the overall sales premium results, and therefore were not investigated further herein. If the number of affordable homes with PV was significant in future research, those effects would best be controlled for directly.
PV system, existing home sellers are likely to be very familiar with the particulars of the system and its benefits, and therefore might be able to “up-sell” it more effectively.

These possible influences, in combination, may explain the difference in average PV premium between new and existing homes. The present analysis did not seek to disentangle or evaluate these specific drivers, however, leaving that important effort for future research.

Table 9: New and Existing Home Base Hedonic Model Results with Robustness Tests

<table>
<thead>
<tr>
<th></th>
<th>New Homes</th>
<th></th>
<th></th>
<th>Existing Homes</th>
<th></th>
<th></th>
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<td></td>
<td>Base</td>
<td>Robustness</td>
<td></td>
<td>Base</td>
<td>Robustness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>Model 3Ra</td>
<td>Model 3Rb</td>
<td>Model 4</td>
<td>Model 4Ra</td>
<td>Model 4Rb</td>
</tr>
<tr>
<td>size</td>
<td>0.006*</td>
<td>0.006**</td>
<td>0.014***</td>
<td>0.011***</td>
<td>0.012***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td></td>
</tr>
<tr>
<td>sqft_1000</td>
<td>0.247***</td>
<td>0.190***</td>
<td>0.250***</td>
<td>0.256***</td>
<td>0.238***</td>
<td>0.251***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.006)</td>
<td>(0.002)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td></td>
</tr>
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<td>l1acre</td>
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<td>0.279***</td>
<td>0.517***</td>
<td>0.373***</td>
<td>0.426***</td>
<td>0.376***</td>
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<tr>
<td></td>
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<td>(0.073)</td>
<td>(0.024)</td>
<td>(0.010)</td>
<td>(0.046)</td>
<td>(0.012)</td>
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<tr>
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<td>-0.009*</td>
<td>0.019***</td>
<td>0.011</td>
<td>0.017***</td>
</tr>
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<td>(0.027)</td>
<td>(0.005)</td>
<td>(0.002)</td>
<td>(0.011)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>ages2</td>
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<td>0.081****</td>
<td>-0.010*</td>
<td>-0.005***</td>
<td>-0.006***</td>
<td>-0.005***</td>
</tr>
<tr>
<td></td>
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<td>(0.017)</td>
<td>(0.006)</td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.000)</td>
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<tr>
<td>ages2sqr</td>
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<td>-0.02443***</td>
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<td>0.00004***</td>
<td>0.00004***</td>
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<tr>
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<td>(0.001676)</td>
<td>(0.004407)</td>
<td>(0.001604)</td>
<td>(0.00003)</td>
<td>(0.000014)</td>
<td>(0.000004)</td>
</tr>
<tr>
<td>bgre_100</td>
<td>0.008***</td>
<td>0.027***</td>
<td>0.007***</td>
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<td>-0.002</td>
<td>0.002</td>
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<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.009)</td>
<td>(0.001)</td>
</tr>
<tr>
<td></td>
<td>(0.022)</td>
<td>(0.066)</td>
<td>(0.025)</td>
<td>(0.013)</td>
<td>(0.077)</td>
<td>(0.014)</td>
</tr>
</tbody>
</table>

Numbers in parenthesis are standard errors, *** p<0.01, ** p<0.05, * p<0.1
Results for subdivision, block group, and quarterly fixed effect variables are not reported here, but are available upon request from the authors

Total n          27,873 | 8,068 | 27,873 | 44,384 | 4,887 | 44,384
Adjusted R^2    0.94  | 0.94  | 0.94  | 0.93  | 0.95  | 0.94
n (pv homes)   935  | 802  | 935  | 897  | 618  | 897
Mean non-pv asp2 $397,265 | $399,162 | $397,265 | $532,645 | $590,428 | $532,645
Mean size (kW) | 2.5  | 2.4  | 2.5  | 3.8  | 3.7  | 3.8
Estimated $/Watt $2.3 | $2.6 | $2.6 | $7.7 | $6.4 | $6.5

38
4.2.1. Difference-in-Difference Model Results

Delving deeper into PV system impacts on existing homes, Table 10 (and Figure 4) shows the results of the base Difference-in-Difference Model 5 as well as results from the two robustness tests (all of which can be compared to Models 4, 4Ra, and 4rb above, as is done in Figure 4). As a reminder, one robustness model limited the differences in sales dates between the first and second sales to five years (Model 5Rb), and the other robustness model used the combined subdivision-block group delineations as fixed effects variables (Model 5Rc). The variables of interest are PVH, SALE2 and especially PVS.

PVH estimates the difference in the first sale prices of homes that will have PV installed (as of the second sale date) relative to non-PV homes. The three models are consistent in their estimates, showing approximately a 2% premium for “future” PV homes, though only two of these estimates are statistically significant, and then only at the 10% level. Regardless, this finding suggests that PV homes tend to sell for somewhat more even before the installation of PV, presumably as a result of other amenities that are correlated with the (ultimate) installation of PV (such as, potentially, energy efficiency features). SALE2 estimates the price appreciation trend between the first and second sales for all homes. The coefficient for this variable is significant at the 1% level, and is fairly stable across the models, indicating a clear general trend of price increases, over and above inflation adjustments, of approximately 2% to 2.5% between the first and second sales.

Finally, and most importantly, homes with PV systems installed on them as of the second sale - after controlling for any inherent differences in first sale prices (PVH) and any trend between the first and second sales (SALE2) - show statistically significant sale price premiums of approximately 5 to 6%. These premiums equate to an increase in selling prices of approximately $6/watt for existing homes, closely reflecting the results presented earlier for the hedonic models in Table 9 and Figure 3. For comparison purposes, both sets of results are presented in Figure 4.

The premium for existing PV homes as estimated in the DD Models 5, 5Ra, and 5Rb and both robustness tests for the hedonic model (using the “matched” and “subdivision” datasets, Models 4Ra and 4Rb respectively) are consistently between $6 and $6.5/watt and are in line with –
though slightly higher than - the mean net installed costs of PV on existing homes in California of approximately $5.2/watt from 2007 through 2009. The base hedonic existing home model, on the other hand, estimates a higher premium of $7.7/watt. One possible explanation for this inconsistency is that the two robustness tests for the hedonic model and the various difference-in-difference models are less likely to be influenced by either selection or omitted variable bias than the base hedonic model. Regardless of the absolute magnitude, a sizable premium for existing PV homes over that garnered by new PV homes is clearly evident in these and the earlier results.

**Figure 4: Existing Home Hedonic and Difference-in-Difference Model Results with Robustness Tests**

![Diagram showing estimated average sale price premium for PV homes (in $/Watt DC) for different models and robustness tests.](image)

Note: Error bars represent the 90% confidence intervals for the underlying sale price premium (% change in sale price) and do not include variation in either the mean sale price or mean system size, both of which are used to calculate the $/watt premium.
Table 10: Difference-in-Difference Model Results

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<th>Sdiff&lt;5</th>
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<td>Model 5Ra</td>
<td>Model 5Rb</td>
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<tr>
<td>pvh</td>
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<td>0.024</td>
<td>0.022*</td>
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<tr>
<td></td>
<td>(0.013)</td>
<td>(0.021)</td>
<td>(0.012)</td>
</tr>
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<td>sale2</td>
<td>0.023***</td>
<td>0.026***</td>
<td>0.019***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>pvs</td>
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<td>0.061**</td>
<td>0.049***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.027)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>sqft_1000</td>
<td>0.255***</td>
<td>0.256***</td>
<td>0.251***</td>
</tr>
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<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
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<td>lt1acre</td>
<td>0.374***</td>
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<td>0.377***</td>
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<td>(0.013)</td>
<td>(0.012)</td>
</tr>
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<td>0.009**</td>
<td>0.011***</td>
</tr>
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<td>(0.004)</td>
<td>(0.003)</td>
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<td>-0.005***</td>
<td>-0.005***</td>
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<td>0.00004***</td>
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<td>(0.000003)</td>
<td>(0.000003)</td>
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<td>0.000</td>
<td>0.001</td>
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<td>(0.001)</td>
<td>(0.001)</td>
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<tr>
<td>intercept</td>
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<td>(0.013)</td>
<td>(0.015)</td>
<td>(0.014)</td>
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</table>

Numbers in parenthesis are standard errors. *** p<0.01, ** p<0.05, * p<0.1. Results for subdivision, block group, and quarterly fixed effect variables are not reported here, but are available upon request from the authors.

<table>
<thead>
<tr>
<th></th>
<th>Base Model 5</th>
<th>Model 5Ra</th>
<th>Model 5Rb</th>
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<tbody>
<tr>
<td>Total n</td>
<td>28,313</td>
<td>19,265</td>
<td>28,313</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.93</td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>n (pv homes)</td>
<td>394</td>
<td>159</td>
<td>394</td>
</tr>
<tr>
<td>Mean non-pv asp2</td>
<td>$488,127</td>
<td>$450,223</td>
<td>$488,127</td>
</tr>
<tr>
<td>Mean size (kW)</td>
<td>4.0</td>
<td>4.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Estimated S/Watt</td>
<td>$6.2</td>
<td>$6.3</td>
<td>$6.0</td>
</tr>
</tbody>
</table>

4.3. Age of PV System for Existing Home Hedonic Model Results

To this point, the marginal impacts to selling prices of each additional kW of PV added to existing homes have been estimated using the full dataset of existing homes, which has produced an average effect, regardless of the age of the PV system. As discussed previously, it is
conceivable that older PV systems would garner lower premiums than newer, similarly sized systems. To test this directly, a base model is constructed - see equation (4) - that estimates the marginal impacts for three age groups of PV systems: no more than one year old at the time of sale; between two and four years old; and five or more years old. Results from this model as well as two robustness tests, using the coarsened exact matching procedure and the combined subdivision-block group delineations, are shown in Table 11 as Models 6, 6Ra, and 6Rb, respectively.

Each model finds statistically significant differences between PV and non-PV homes for each age group, and more importantly, premium estimates for newer PV systems are - as expected - larger than those for older PV systems and are monotonically ordered between groups, providing some evidence that older systems are being discounted by the buyers and sellers of PV homes. Specifically, the three models estimate an average premium for PV systems that are one year or less in age of $8.3-9.3/watt, whereas those same models estimate an average premium of $4.1-6.1/W for systems that are five or more years old.

4.4. Returns to Scale Hedonic Model Results

In the previous modeling, the marginal impacts to selling prices of each additional kW of PV in the continuous models have been estimated using a linear relationship. To test whether a non-linear relationship may be a better fit, a SIZE squared term is added to the model as shown in equation (5). Similarly, decreasing or increasing returns to scale might be related to other house characteristics, such as the size of the home (i.e., square feet). This hypothesis is explored using equation (6). Both model results are shown in Table 11 as Model 7 and 8, respectively.

Both models find small and non-statistically significant relationships between their interacted variables, indicating a lack of compelling evidence of a non-linear relationship between PV system size and selling price in the dataset, and a lack of compelling evidence that the linear relationship is affected by the size of the home. As such, the impact of PV systems on residential selling prices appears to be well approximated by a simple linear relationship, while the size of the home is not found to impact the PV sales price premium. In combination, these results seem to suggest that while California’s tiered rate structures may lead to energy bill savings from PV
investments that vary non-linearly with PV system size and also vary by home size, those same rate structures have not – to this point – led to any clear impact on the PV premium garnered at the time of home sale. Similarly, though larger PV systems may be installed at a discount to smaller ones on a $/watt basis, and though any marginal green cachet that exists may diminish with system size, those possible influences are not apparent in the results presented here.
# Table 11: Age of PV System and Return to Scale Hedonic Model Results

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<tr>
<th></th>
<th>Age of PV Systems for Existing Homes</th>
<th>Returns to Scale</th>
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<td>Base</td>
<td>Robustness Matched</td>
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<td></td>
<td>Model 6</td>
<td>Model 6Ra</td>
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<tr>
<td>size*1 year old</td>
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<td>0.016***</td>
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<td>(-0.004)</td>
<td>(-0.005)</td>
</tr>
<tr>
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<tr>
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<td>(-0.002)</td>
<td>(-0.003)</td>
</tr>
<tr>
<td>size*5+ years old</td>
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<td>0.008**</td>
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<tr>
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<td>(-0.003)</td>
<td>(-0.004)</td>
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<td>size</td>
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<td>0.021***</td>
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<td>(0.006)</td>
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<td>0.001</td>
</tr>
<tr>
<td>size*sqft_1000</td>
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<td>-0.003</td>
</tr>
<tr>
<td>sqft_1000</td>
<td>0.256***</td>
<td>0.238***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.015)</td>
</tr>
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<td>lt1acre</td>
<td>0.373***</td>
<td>0.426***</td>
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<td>(0.010)</td>
<td>(0.046)</td>
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<td>0.010***</td>
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<td>(0.011)</td>
</tr>
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<td>-0.006***</td>
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Numbers in parenthesis are standard errors. *** p<0.01, ** p<0.05, * p<0.1
Results for subdivision, block group, and quarterly fixed effect variables are not reported here, but are available upon request from the authors.

Total n = 44,384
Adjusted R² = 0.93
n (pv homes) = 897
Mean non-pv asp2 = $532,645
Mean size (kW) = 3.8
Estimated S/Watt = $8.3 - $6.1

Note: $/watt estimates for Returns to Scale models include the non-statistically significant interaction coefficients and therefore should be interpreted with caution.
5. Conclusions

The market for solar PV 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. Some of those “PV homes” have sold, yet little research exists estimating if those homes sold for significantly more than similar non-PV homes. Therefore, one of the claimed incentives for solar homes - namely that a portion of the initial investment into a PV system will be recouped if the home is sold – has, to this point, been based on limited evidence. Practitioners have sometimes transferred the results from past research focused on energy efficiency and energy bills more generally and, while recent research has turned to PV that research has so far focused largely on smaller sets of PV homes concentrated in certain geographic areas. Moreover, the home sales price effect of PV on a new versus an existing home has not previously been the subject of research. Similarly unexplored has been whether the relationship of PV system size to home sales prices is linear, and/or is affected by either the size of the home or the age of the PV system.

This research has used a dataset of approximately 72,000 California homes, approximately 2,000 of which had PV systems installed at the time of sale, and has estimated a variety of different hedonic and repeat sales models to directly address the questions outlined above. Moreover, an extensive set of robustness tests were incorporated into the analysis to test and bound the possible effects and increase the confidence of the findings by mitigating potential biases. The research was not intended to disentangle the various individual underlying influences that might dictate the level of the home sales price premium caused by PV, such as, energy costs savings, the net (i.e., after applicable state and federal incentives) installed cost of the PV system, the possible presence of a green cachet, or seller attributes. Instead, the goal was to establish credible estimates for the aggregate PV residential sale price effect across a range of different circumstances (e.g., new vs. existing homes, PV system age).

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 range from approximately $3.9 to $6.4 per installed watt (DC) among a large number of different model specifications, with most models coalescing near $5.5/watt. That
value corresponds to a premium of approximately $17,000 for a relatively new 3,100 watt PV system (the average size of PV systems in the study). These results are similar to the average increase for PV homes found by Dastrop et al. (2010), which used similar methods but a different dataset, one that focused on homes in the San Diego metropolitan area. Moreover, these average sales price premiums appear to be comparable to the average net (i.e., after applicable state and federal incentives) installed cost of California residential PV systems from 2001-2009 (Barbose et al., 2010) of approximately $5/watt, and homeowners with PV also benefit from electricity cost savings after PV system installation and prior to home sale.

Although the results for the full dataset from the variety of models are quite similar, when the dataset is split among new and existing homes, PV system premiums are found to be markedly affected, with new homes demonstrating average premiums of $2.3-2.6/watt, while existing homes are found to have average premiums of $6-7.7/watt. Possible reasons for this disparity between new and existing PV homes include: differences in underlying net installation costs for PV systems; a willingness among builders of new homes to accept a lower PV premium because PV systems provide other benefits to the builders in the form of product differentiation, leading to increased sales velocity and decreased carrying costs; and, lower familiarity and/or interest in marketing PV systems separately from the other features of new homes contrasted with a likely strong familiarity with the PV systems among existing home sellers.

The research also investigated the impact of PV system age on the sales price premium for existing homes, finding - as would be expected - evidence that older PV systems are discounted in the marketplace as compared to newer PV systems. Finally, evidence of returns to scale for either larger PV systems or larger homes was investigated but not found.

In addition to benchmarking the results of this research to the limited previous literature investigating the sales price premiums associated with PV, our results can also be compared to previous literature investigating premiums associated with energy efficiency (EE) or, more generally, energy cost savings. A number of those studies have converted this relationship into a ratio representing the relative size of the home sales price premium to the annual savings expected due to energy bill reductions. These ratios have ranged from approximately 7:1
(Longstreth et al., 1984; Horowitz and Haeri, 1990), to 12:1 (Dinan and Miranowski, 1989), to approximately 20:1 (Johnson and Kaserman, 1983; Nevin et al., 1999; Eichholtz et al., 2009), and even as high as 31:1 (Nevin and Watson, 1998).

Although actual energy bill savings from PV for the sample of homes used for this research were not available, a rough estimate is possible, allowing for a comparison to the previous results for energy-related homes improvements and energy efficiency. Specifically, assuming that 1,425 kWh (AC) are produced per year per kW (DC) of installed PV on a home (Barbose et al., 2010; CPUC, 2010) and that this production offsets marginal retail electricity rates that average $0.20/kWh (AC) (Darghouth et al., 2010), each watt (DC) of installed PV can be estimated to save $0.29 in annual energy costs. Using these assumptions, the $/watt PV premium estimates reported earlier can be converted to sale price to annual energy savings ratios (see Figure 5).

A $3.9 to $6.4/watt premium in selling price for an average California home with PV installed equates to a 14:1 to 22:1 sale price to energy savings ratio, respectively. For new homes, with a $2.3-2.6/watt sale price premium, this ratio is estimated to be 8:1 or 9:1, and for existing homes, with an overall sale price premium range of $6-7.6/watt, the ratio is estimated to range from 21:1 to 26:1. Without actual energy bill savings, these estimates are somewhat speculative, but nonetheless are broadly consistent with the previous research that has focused on EE-based home energy improvements.

43 The 1,425 kWh (AC) estimate is based on a combination of a 19% capacity factor (based on AC kWh and CEC-AC kW) from CPUC (2010), and an 0.86 conversion factor between CEC-AC kW and DC kW (Barbose et al., 2010).
Although this research finds strong evidence that homes with PV systems in California have sold for a premium over comparable homes without PV systems, the extrapolation of these results to different locations or market conditions (e.g., different retail rates or net installed costs) should be done with care.

Finally, additional questions remain that warrant further study. Perhaps most importantly, although the dataset used for this analysis consists of almost 2,000 PV homes, the study period was limited to sales occurring prior to mid-2009 and the dataset was limited to California. Future research would therefore ideally include more-recent sales from a broader geographic area to better understand any regional/national differences that may exist as well as any changes to PV premiums that occur over time as the market for PV homes and/or the net installed cost of PV changes. More research is also warranted on new versus existing homes to better understand the nature and underlying drivers for the differential premium discovered in this research; in addition to further hedonic analysis, that research could include interviewing/surveying home builders and buyers and exploring the impact of demographic, socio-economic, and others factors on the PV premium.
Additionally, future research might compare sales price premiums to actual annual home energy cost savings, to not only to explore the sale price to annual energy cost savings ratio directly, but also to explore if a green cachet exists over and above any sale price premiums that would be expected from energy cost savings alone. Further, house-by-house PV system and other information not included in the present study might be included in future studies, such as the actual net installed costs of PV for individual households, rack-mounted or roof-integrated distinctions as well as other elements of PV system design, the level of energy efficiency of the home, whether the home has a solar hot water heater, whether the PV system is customer or 3rd party owned at the time of sale, and if the homeowner can sell the green attributes the system generates.44 Such research could elucidate important differences in PV premiums among households, PV system designs and state and federal programmatic designs, as well as bolster confidence in the magnitude of the PV premium estimated here. Finally, and more generally, additional research could investigate the impact of PV systems on the time homes remain on the market before sale, a factor that may be especially important for large developers and sellers of new homes.

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44 3rd party owned PV systems would not be expected to command the same sort of premium as was discovered here. Although the level of penetration of 3rd party owners in our data was not significant (below 10%), and therefore would likely have not influenced our results in a substantive way, any future research, using more recent data, must account for their inclusion specifically.
References


Folks living in Premier Homes’ all-solar Premier Gardens development in Sacramento can’t stop talking about their low energy bills. And their neighbors are getting a little miffed.

Premier Homes built 95 entry-level homes in Rancho Cordoba near Sacramento in 2004, across the street from 98 similar homes built by another builder. The homes are nearly identical in size and price but the Premier Homes are near zero energy homes with advanced energy-saving features and a 2.2-kWh photovoltaic system on every roof. And when Premier Gardens’ homeowners started moving into their homes in fall 2004, their September energy bills averaged $20 while their neighbors were paying around $70, according to ConSol, a US Department of Energy Building America Team Partner that worked on the project.

Premier Gardens is the Sacramento area’s first near zero energy home community designed to cut energy bills at least 50% and the first Premier community offering solar energy as a standard feature. Premier had offered solar as an optional upgrade on previous developments and the Roseville builder has been committed to energy-efficient construction for more than a decade.

“It is an opportunity to set ourselves apart as a small builder,” said John Ralston, vice president of sales and marketing for Roseville-based Premier Homes. “The market will be wanting more energy efficiency in California as time goes on and we want to stay ahead of it.”

Premier hopes to differentiate themselves from other builders in a very competitive market dominated by large corporate production home builders, according to Rob Hammon of ConSol. The development was open for sales in August 2004 and the

Premier Gardens is a unique opportunity for first-time homebuyers to live in an extremely energy-efficient home that will provide them with a solid value, both now and in the years to come.”

Kevin Yttrup, President of Premier Homes

**BUiLDER PROFILE**

**Builder’s Name:**
Premier Homes
www.builtbypremier.com

**Where:**
Roseville, CA

**Founded:**
mid 1980s

**Development:**
Premier Gardens - Sacramento, CA

**Size:**
95 homes

**Square footage:**
1,285 - 2,248 sq.ft. (3 to 6 bedrooms)

**Price range:**
$245,000 to $335,000

**Number of homes per year:**
70-90

**Solar status:**
First all ZEH development, have offered solar in the past
last home was sold in December 2005, faster than nearby subdivisions.

Premier branded Premier Gardens as a “Premier ProEnergy Community” and said it was the first Sacramento area all-solar development to offer entry-level buyers so many energy features as part of the standard package. “We are excited to bring the first standard “near zero energy” community to Sacramento and we are confident buyers will be amazed at the savings,” Kevin Yttrup, president of Premier Homes, told the media when Premier Gardens was announced. “Premier Gardens is a unique opportunity for first-time homebuyers to live in an extremely energy-efficient home that will provide them with a solid value, both now and in the years to come.”

While the builder next door made granite countertops standard, Premier chose to offer regular kitchen countertops but they made the photovoltaic systems standard, along with a host of other energy-efficient features including high-efficiency furnaces and air conditioners, tankless water heaters, high-performance windows, and better insulation. Homes in both developments sold for similar prices.

All of the Premier Gardens homes meet the DOE Building America goal for today’s zero energy house with their 60% reduction in power drawn from the grid and reduced natural gas consumption. SMUD certified the homes as SMUD Solar Advantage homes, which means the homes exceed the current California Title 24 energy cooling requirements by as much as 30%. In addition, the homes met state ENERGY STAR® Homes requirements.

ConSol conducted air leakage testing of the ducts and whole house through its ComfortWise program as each house was completed in Premier Gardens. The Sacramento Municipal Utility District (SMUD) is tracking the electric bills of all the homes in both developments and is collecting data every 15 minutes on electric consumption at 18 homes in Premier Gardens and 18 of the neighboring community. SMUD is also collecting PV production data every 15 minutes on the Premier Gardens homes. SMUD is sharing this data with ConSol which is evaluating it for the Building America Program, and to determine potential benefits to the utility. SMUD is also helping to subsidize the project at $7,000 per home and is providing $20,000 in marketing support in hopes that this and future PV projects can help SMUD shave its summer afternoon load peaks.

For utilities dealing with peak load issues and for consumers who may face higher peak rates, the Premier Gardens project provides some tantalizing results. In July 2005, while Building America and SMUD were doing their research, Sacramento experienced its hottest July on record. With everyone turning on their air conditioners, the utility broke their all-time-peak demand record three days in a row. But, while the sun was high, the PV systems on the near zero energy homes cranked away and

**KEY FEATURES**

- **2 kW GE Energy AC photovoltaic system**
- Tankless hot water heater and R-4 pipe insulation on all major hot water lines
- An engineered heating and air conditioning system
- Furnace AFUE .91, AC with SEER 14
- Dual-pane, vinyl frame spectrally selective glass windows, with u-factor of 33-37 and SHGC of .32-.35
- Tightly sealed air ducts buried in attic insulation, duct blaster tested
- Fluorescent lighting in all permanent fixtures
- Insulation R-38 in attic, R13 batt to R-19 in walls, 1” rigid foam house wrap, R4.2 duct insulation
- HERS score of 90 (based on pre-July 2006 HERS system)

**Annual Energy Bill Comparison**

Premier Gardens home owners paid $600 less per year on their energy bills than homeowners in standard construction homes and $400 less than those in ComfortWise homes.
the Premier Gardens homes had peak demands that were 75% lower than their neighbors. “The ability of solar to level out air conditioning-driven peak demand makes it a desirable investment for utilities and for consumers who want to help decrease the likelihood of rolling blackouts and sky-high utility prices,” said Baccei.

“Zero Energy Homes provide multiple benefits—lower energy bills for the homeowner and reduced energy demand on hot summer days when electricity is more expensive and the power grid most utilized,” said Paul Bender, SMUD manager of power production.

Solar System

The 2.2-kW photovoltaic system installed on Premier Gardens’ homes is an integrated tile PV product manufactured by GE Energy called Gecko modules. The tiles are similar in dimension to cement roof tiles and lay on the roof shingle fashion to blend with surrounding roofing. The system consists of 48 GT-55 modules and a SMA Sunny Boy 2500 inverter. SMUD supplied each home with a PV meter to record the solar electric system’s energy output; this figure appears on the homeowner’s monthly electric bill along with their electricity usage.

ConSol and SMUD reported in March 2006 that the PV systems were performing exceptionally well and consistently exceeding estimated kilowatt hour production by 10% over the course of the first year. The homes produced about 3,350 kWh per year out of a total average of 7,007 kWh consumed per household between September 2004 and September 2005.

The systems were installed by an installation company founded by Premier Homes’ owners. Premier liked the aesthetics of the roof-integrated PV panels and found home buyer acceptance was high. Some home builders are hesitant to install PV systems on the fronts of homes. Others believe that the visibility of PV systems can be desirable for home buyers who want to “show off” their photovoltaic systems.

Selling Solar

Some of Premier’s most dedicated solar fans are its sales staff. “I am their walking, living, breathing advertisement for solar out here,” said Sheri Gage, sales manager and owner of one of the first solar homes completed at Premier Meadows, a 65-unit Premier Homes development at Live Oak 50 miles north of Sacramento.

“I’ve been in since December 2005, and my electric bills have ranged from a high of $70 to a low of $1.60 per month (for a 1,990 sq ft home),” said Gage. “People have been walking into my sales office who are paying between $250 and $800 a month on their electric bills.”

PG&E has raised the rates several times in the last two years. In August 2006, they announced another rate increase in September with two more likely to follow.”

To show home buyers they have a choice, Premier Homes has run a very successful campaign advertising $30 a month bills. “We did an analysis of the Premier Gardens homes for a 9-month period in 2005. All 95 homes averaged $30 per month,” said Don Rives sales manager at Premier Homes Premier Gardens and now Premier Bay Drive Estates, another all solar Premier development.

Energy-Efficient Features and Innovations

“The first step in designing a near zero energy home is to significantly reduce the home’s overall energy use. This enables the home builder to install a smaller, less expensive PV system to meet the home’s electrical needs,” said Rob Hammon of ConSol.

Building America, through its team leader ConSol, provided an energy analysis to help Premier select energy-efficient measures for the five house plans featured in the community. Each home is equipped with a high-efficiency 0.91 AFUE furnace and a...
correctly sized SEER 14 air conditioner. Ducts are tightly sealed and buried in the attic insulation for an insulation value equivalent to R-13. Each home has a tankless on-demand hot water heater so power isn’t wasted keeping a 60-gallon tank of water hot 24 hours per day, 365 days per year, and all of the major hot water lines are insulated with R-4 pipe insulation.

The windows are high-performance, dual-pane, vinyl-frame spectrally selective glass windows. Fluorescent lights are installed in all of the recessed downlights and other installed light fixtures in the home. There is R-38 insulation in the attic and R-13 batt insulation in the wall cavities. In addition the outside walls are sheathed in a 1-inch layer of rigid foam insulation, which takes the place of house wrap and provides an additional insulation and water barrier. The Home Energy Rating Score (HERS) averages 90 (based on pre-July 2006 HERS rating system) for these homes.

Even without the solar, the homes used 22% less energy than homes in SMUD’s service territory built to California’s Title 24 standard and 13% less than the homes in the neighboring development built to SMUD Advantage home standards.

Dollars and Sense

The PV systems and the energy efficiency features together add about $10,000-15,000 to the cost of a home. SMUD contributed financially to the project, committing to provide Premier about $7,000 per home toward the cost of each PV system and $200 per home for advanced energy-efficiency features. As previously stated, Premier priced the homes so the near zero energy homes cost no more than the neighboring homes. In a RAND study, one of the Premier Gardens residents calculated that the homes in the two developments cost the same per square foot at the time he purchased his new home. Thus at Premier Gardens homeowners are getting “today’s zero energy homes” at prices that are competitive with the much less efficient homes of their neighbors. And the project has continued to generate positive press for Premier Homes.

The Bottom Line

Premier Homes took the success of its solar-powered energy-efficient homes down the road to Roseville, where the builder has offered the same features standard at another Premier ProEnergy community, Premier Oaks. The 49 homes at Premier Oaks are slightly larger than the Premier Gardens homes (1,800 to 3,300 sq ft) and expected savings are 60%-63% above a home built to Title 24.

Premier is also offering PV as a standard feature at its 35-home Premier Bay Drive Estates in Yuba City, the first all-solar community in Yuba City, with homes up to 3,000 sq. ft. selling for $200,000 and up.

Premier has become so convinced of the selling power of solar that in July 2006, half way through construction on its 65-home Premier Meadows development north of Sacramento, it switched from solar as an option to making solar a standard feature. “If we believe in this stuff we just have to do it,” said Premier sales manager Don Rives.

For more information visit:
www.buildingamerica.gov
New Homes With SunPower Solar Systems are Bright Spot in Market

New Homes with Solar Selling Twice as Fast; 92 Percent of Homeowners Would Recommend a Solar Home

SAN JOSE, Calif., June 24, 2008 /PRNewswire-FirstCall via COMTEX News Network/ -- While much of the residential real estate and building markets have faced severe challenges in recent months, there is one area that is shining brightly. SunPower Corporation (Nasdaq: SPWR), a Silicon Valley-based manufacturer of high-efficiency solar cells, solar panels and solar systems, announced today that new homes powered with SunPower solar electric power systems are selling more than twice as fast, on average, as new homes without solar. Additionally, a survey of owners of new homes with SunPower systems indicates that 92 percent would recommend a new solar home to a friend.

Solar Sells Faster

SunPower has installed, or is currently installing, its high-efficiency solar power technology in more than 75 new home communities throughout California. A recent study conducted by The Ryness Company found that new homes in 13 communities with SunPower solar systems were selling at an average of 3.46 homes per month, while sales of comparable homes without solar in adjacent or nearby communities were selling at a rate of 1.71 per month. Comparable communities were selected based upon geographic location, square footage and lot sizes, publicized sales prices and development concept. The data was gathered from sales in 2006 through March 2008 from three regions in the state.

-- In the Sacramento region, new solar homes are selling at a rate of 3.20 per month, while comparable non-solar homes are selling at a rate of 1.90 per month.

-- New solar homes in the San Francisco Bay Area are selling at a rate of 3.24 per month, while comparable non-solar homes are selling at a rate of 1.33 per month.

-- In the Central Valley region, new solar homes are selling at a rate of 4.72 per month, while comparable non-solar homes are selling at a rate of 2.37 per month.

"Homebuyers value solar systems today because they can significantly reduce their electric bills and help reduce greenhouse gas emissions," said Jon Nicholson, division president of Standard Pacific Homes in Sacramento. "Families in our energy-efficient solar communities are reducing their utility costs by up to 60 percent, and enjoy the satisfaction of generating their own clean, renewable energy."

Satisfied Solar Home Owners

In a SunPower survey of 133 people who own new homes with SunPower solar systems, 92 percent of respondents said they would recommend a home with solar to a friend. Ninety percent indicated that inclusion of a solar power system was very important or somewhat important in their decision to buy their home. Eighty-five percent responded that they would definitely or likely buy another solar home in the future.

Comments gathered as part of the anonymous survey included the following:

-- "We would not have purchased the larger home had it not been for the solar savings."

-- "We have already recommended [solar] to many of our friends."

-- "We have looked at other homes, even really liked the floor plans, but without solar it was out of the question."

"Most of the builders we work with include the installation of high-performing SunPower solar power systems with high-quality energy efficiency features," said Bill Kelly, general manager, New Homes Division, for SunPower. "This combination of solar technology and energy efficiency results in very low utility costs for the homeowner while improving home comfort. This is a great value for homeowners, and an investment by our homebuilder partners towards cleaner air and a better environment."

Most homebuilders working with SunPower install the SunPower SunTile(R) system on their homes. SunTile is a roof-integrated...
system that blends seamlessly into the roof and features the most efficient solar technology available on the market.

SunPower's survey is supported by a recently completed market research study of new construction home buyers commissioned by the California Energy Commission (http://www.gosolarcalifornia.ca.gov/builders/marketing_resources/index.html), which found that solar is generally seen "as a proven, reliable technology that can pay for itself and will help reduce global warming." In addition, nearly all respondents consider residential solar power systems to be "user-friendly" and "low maintenance."

SunPower works with homebuilders such as Centex, Standard Pacific, The Olson Company, and Woodside Homes.

About SunPower

SunPower Corporation (Nasdaq: SPWR) designs, manufactures and delivers high-performance solarelectric systems worldwide for residential, commercial and utility-scale power plant customers. SunPower high-efficiency solar cells and solar panels generate up to 50 percent more power than conventional solar technologies and have a uniquely attractive, all-black appearance. With headquarters in San Jose, Calif., SunPower has offices in North America, Europe and Asia. For more information, visit http://www.sunpowercorp.com. SunPower is a majority-owned subsidiary of Cypress Semiconductor Corp. (NYSE: CY).

Forward Looking Statements

This press release contains forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995, Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934. Forward-looking statements are statements that do not represent historical facts. The company uses words and phrases such as "would," "can," and "will," and similar expressions to identify forward-looking statements. Forward-looking statements in this press release include, but are not limited to, the company's plans and expectations regarding: (a) installing solar power systems in more than 75 new home communities throughout California; (b) reducing electric bills by up to 60 percent; (c) lowering greenhouse gas emissions; (d) recommending a home with solar to a friend or buy another home with solar; (e) systems paying for themselves; and (f) reducing global warming. These forward-looking statements are based on information available to the company as of the date of this release and management's current expectations, forecasts and assumptions, and involve a number of risks and uncertainties that could cause actual results to differ materially from those anticipated by these forward-looking statements. Such risks and uncertainties include a variety of factors, some of which are beyond the company's control. In particular, risks and uncertainties that could cause actual results to differ include: (i) construction difficulties or potential delays in the project implementation process; (ii) unanticipated delays or difficulties securing necessary permits, licenses or other governmental approvals; (iii) the risk of continuation of supply of products and components from suppliers; (iv) unanticipated problems with deploying the systems on the sites; (v) the actual energy generation; (vi) the actual energy consumption rate; (vii) unexpected changes in utility service rates; (viii) variations in carbon dioxide emissions reductions; (ix) continued customer satisfaction; and (x) other risks described in the company's Quarterly Report on Form 10-Q for the quarter ended March 30, 2008, and other filings with the Securities and Exchange Commission. These forward-looking statements should not be relied upon as representing the company's views as of any subsequent date, and the company is under no obligation to, and expressly disclaims any responsibility to, update or alter its forward-looking statements, whether as a result of new information, future events or otherwise.

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News Provided by COMTEX
Recognition Of Energy Costs and Energy Performance in Real Property Valuation

Considerations and Resources for Appraisers

Second Edition

May 2012
About the Institute for Market Transformation

The Institute for Market Transformation (IMT) is a Washington, DC-based nonprofit organization dedicated to promoting energy efficiency, green building, and environmental protection in the United States and abroad. Much of IMT’s work addresses market failures that inhibit investment in energy efficiency. For more information, visit http://www.imt.org.

About the Appraisal Institute

The Appraisal Institute (AI) is a global membership association of professional real estate appraisers, with nearly 23,000 members in nearly 60 countries throughout the world. Its mission is to advance professionalism and ethics, global standards, methodologies, and practices through the professional development of property economics worldwide. Organized in 1932, the Appraisal Institute advocates equal opportunity and nondiscrimination in the appraisal profession and conducts its activities in accordance with applicable federal, state and local laws. Members of the Appraisal Institute benefit from an array of professional education and advocacy programs, and may hold the prestigious MAI, SRPA and SRA designations.

Credits and Acknowledgements

The first edition of this document was prepared by Gretchen Parker and Mark Chao of IMT. Chao was the lead author of this second edition. Tommy McCarthy provided assistance with research for the second edition. Bill Garber of the Appraisal Institute and Jim Amorin, AI’s past President, edited the document. Rick Borges, President-elect of AI, provided additional review and comment. In addition, a panel of nine experienced appraisers convened by Garber and Paula Konikoff of AI reviewed the second edition and helped to define its early direction. Finally, we offer special thanks to Paul Jacobs and Theddi Wright Chappell for their attentive review of this new edition.

Reviewers of the first edition include appraisers Ted Baker, John Bentkowski, Justin Casson, Frank Donato, Robert Gallaher, James Murrett, James Park, Raymond Redner, David Scribner, and Linda Yancey; Michael Nevin of Con Edison; Laurie Kokkinides of the New York State Energy Research and Development Authority (NYSERDA); Bob Sauchelli and Robert Rose of the U.S. Environmental Protection Agency; and Drury Crawley of the U.S. Department of Energy.

We have drawn upon many helpful resources in composing this document. We note especially the valuable perspective of various documents written by Theddi Wright Chappell, Scott Muldavin, and James Finlay. See also the Resources section.

IMT’s work on energy efficiency and property valuation originated in the late 1990s under the support of the Pacific Gas & Electric Company (PG&E) and NYSERDA. Support from both PG&E and NYSERDA came from dedicated public-benefits funds collected from ratepayers. The creation of this second edition has been made possible by the generous support of the Tilia Fund and the Kresge Foundation.
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1. Introduction

Various factors affect the value of real property – location, the composition and condition of structures, operating history and potential future use, and many others. Each factor affects the income and investment potential of property. Each has its own influence on investor and occupant preferences, which ultimately determine how money flows for financing, purchasing, and rental in the real estate market.

Energy consumption is one of these factors. It usually has significant effects on net income from buildings – effects often higher than any other operating expense, and at times higher than property taxes. Therefore buildings that are energy efficient can create significantly greater net income for owners than otherwise similar buildings that are not so efficient.

Because energy and energy efficiency are invisible, with effects revealing themselves incrementally over time, they have long been hard to track and easy to overlook. As a result, market players have failed to fully recognize energy performance as a factor affecting property value. This situation has changed dramatically since the Institute for Market Transformation (IMT) issued the first edition of this document in 2000. Investors and the general public around the country have become increasingly aware of the importance of energy efficiency. The track record of energy-efficient technology and high-performance buildings has become longer and better documented. Assessment tools, energy rating systems, and energy-performance databases for buildings have become well established, and even required in several major jurisdictions nationwide. As a result, not only do owners more closely track their own buildings’ energy performance, they and other market stakeholders can actually find convenient and meaningful comparables (comps) for energy use in similar buildings. And wide segments of the market are recognizing and indeed hotly demanding “green buildings,” a concept that encompasses energy efficiency as well as many other approaches to environmental sustainability.

Purpose of This Guide

As the market has become more aware of energy efficiency and green buildings, the importance of providing real estate appraisers with necessary information to thoroughly analyze the effects of energy performance on property value has
increased as well. There are several areas of opportunity that can be addressed through education and awareness, including understanding how and to what extent energy efficiency affects the bottom line; enhancing the availability and credibility of supporting information; and positioning appraisers to recognize potential market reactions to energy performance.

We address all of these issues directly in this document. Our ultimate aim is to increase credibility and reliability of property valuation by helping appraisers and other interested parties to understand, find, and rigorously apply available information on energy performance in buildings.

Our resource guide is organized into six sections, including this introduction.

**Section 2 discusses why energy matters**, with a discussion of the typical magnitude and variability of energy’s effects on cash flow and net income.

**Section 3 discusses how to assess energy performance in buildings**, including identification of equipment and components, examination and normalization of energy bills, and engineering simulations.

**Section 4 presents how to compare or “benchmark” building energy performance** — that is, how to generate energy-related comps.

**Section 5 discusses technical qualifications, certification, and other assurances** of the competence and professional responsibility of preparers of energy-performance documentation.

**Section 6 discusses how the market values energy efficiency in buildings**, presenting case studies of how buyers and renters do recognize and place incremental value on energy performance and green building.

Finally, the **Appendix** provides a brief overview of common energy-efficient measures, including sections on insulation, windows, lighting, and heating, ventilation, and air-conditioning systems.

**Limitations**

We recognize that appraisers’ needs and priorities vary widely from practice to practice and from case to case. We therefore present options spanning a range of complexity, cost, and accuracy.

There exist myriad tools and approaches for tracking and modeling energy performance in commercial buildings. While it would be impractical to address all methods in detail, we have endeavored to include those which represent or
have the immediate potential to represent widely-used industry standards. The chosen methods cover a broad range. Still, in certain cases, appraisers may receive energy-related information based on methods not addressed here. In these cases, the appraiser should attempt to assess independently whether it meets criteria of credibility and technical rigor.
2. Energy, Operating Costs, Cash Flow, and Value

Energy and Net Operating Income in Buildings

In most building types, energy costs are a major component of operating costs, cash flow, and overall net operating income (NOI). Energy consumption and energy costs are also highly variable, depending on the efficiency of the building and its equipment, as well as building type, location, age, and other important factors. Thus, insofar as NOI and discounted cash flow are foundations of building value, accurate assessment of energy costs is an important element of accurate valuation.

This linkage applies especially in commercial and multifamily residential real estate, where building owners tend to be well informed and methodical about reducing costs and raising net income. Furthermore, market stakeholders are increasingly recognizing other advantages to energy performance and sustainability in buildings, including occupant comfort and health, productivity, and employee and tenant retention, as well as fulfillment of social and ethical responsibility. This market recognition may reflect itself in increased rents and sale prices of energy-efficient and green buildings, as documented in a growing body of published literature.

High energy prices amplify the importance of energy as a factor affecting NOI. The average natural gas price for residential buildings in the United States stood at $6.37 per thousand cubic feet (tcf) in Jan 2000. By January 2009, this price had nearly doubled to $12.49/tcf. Despite a significant retreat in prices since then, natural gas still had an average price of $9.79/tcf in January 2011, or an increase of almost 54 percent.1 Average U.S. electricity prices also rose significantly between January 2000 and 2011 – by 43 percent, from 8.24 cents per kilowatt-hour (¢/kWh) to 11.79¢/kWh.2

The importance of energy arises not only from the relative magnitude of energy costs as a portion of NOI, but also in the variability of energy costs in buildings. Differences of at least 20 to 30 percent in energy costs can be achieved via energy efficiency retrofits to existing buildings. And even within populations of comparable buildings, the range of energy costs between the most efficient and

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the most energy-intensive buildings covers an even greater percentage difference.

Application of the income capitalization approach to valuation, in which NOI is divided by a capitalization rate (cap rate) determined by the appraiser, translates effects on NOI into effects on value. Table 1 below shows an example, reported in an appraisal conducted by a Certified General Appraiser in California, for a medium-sized motel that underwent a rather standard energy efficiency upgrade, including improvements to windows, heating and cooling systems, and controls. In this case, an annual reduction of energy costs by 45 percent led to an increase in the calculated value by 8.5 percent, assuming no change in any other line items or in cap rate. Note, furthermore, that an appraiser might even choose to adjust cap rate downward in a case like this, because of reduction in operating risk after retrofit. In this case, the incremental value would be even higher.

Energy-cost variations from energy efficiency retrofits can influence overall NOI by up to ten percent.
**Figure 1**

Effects of an Energy Upgrade on the Value of a Motel as Calculated by the Income Capitalization Approach
*(based on an actual appraisal; all figures in $)*

<table>
<thead>
<tr>
<th></th>
<th>Pre-retrofit</th>
<th>After energy upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INCOME</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room</td>
<td>503,029.00</td>
<td>503,029.00</td>
</tr>
<tr>
<td>Other</td>
<td>3,595.00</td>
<td>3,595.00</td>
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<tr>
<td>Gross Scheduled Income</td>
<td>506,624.00</td>
<td>506,624.00</td>
</tr>
<tr>
<td>Vacancy Rate</td>
<td>35%</td>
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</tr>
<tr>
<td>Net Scheduled Income (NSI)</td>
<td>329,305.60</td>
<td>329,305.60</td>
</tr>
<tr>
<td>% of NSI</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OPERATING EXPENSES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric</td>
<td>18,766.00</td>
<td>10,450.00</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>5,447.00</td>
<td>2,850.00</td>
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<tr>
<td>Water</td>
<td>2,886.00</td>
<td>2,886.00</td>
</tr>
<tr>
<td>Janitor</td>
<td>5,475.00</td>
<td>5,475.00</td>
</tr>
<tr>
<td>Landscape</td>
<td>3,900.00</td>
<td>3,900.00</td>
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<tr>
<td>Taxes Real &amp; EMP</td>
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<td>31,059.00</td>
</tr>
<tr>
<td>Television, Cable, and Satellite</td>
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<td>Pest</td>
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<tr>
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<tr>
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<tr>
<td>Advertising</td>
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<td>2,550.00</td>
</tr>
<tr>
<td>Legal &amp; Accounting</td>
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<td>1,500.00</td>
</tr>
<tr>
<td>License</td>
<td>500.00</td>
<td>500.00</td>
</tr>
<tr>
<td>Bed Tax</td>
<td>32,930.56</td>
<td>32,930.56</td>
</tr>
<tr>
<td>Reserve</td>
<td>8,232.64</td>
<td>8,232.64</td>
</tr>
<tr>
<td><strong>Subtotal Expenses</strong></td>
<td>201,384.20</td>
<td>190,471.20</td>
</tr>
<tr>
<td><strong>Net Operating Income</strong></td>
<td><strong>127,921.40</strong></td>
<td><strong>138,834.40</strong></td>
</tr>
<tr>
<td>% of NSI</td>
<td>38.85%</td>
<td>42.16%</td>
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<tr>
<td>Cap Rate</td>
<td>8.75%</td>
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<tr>
<td>Formula Employed</td>
<td>Net Operating Income / Cap Rate</td>
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</tr>
<tr>
<td>Opinion of Value</td>
<td>1,461,958.86</td>
<td>1,586,678.88</td>
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<tr>
<td>Gross Energy Retrofit Effect</td>
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<tr>
<td>Cost of Energy Retrofit</td>
<td>27,680.00</td>
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</tr>
<tr>
<td><strong>NET ENERGY RETROFIT EFFECT</strong></td>
<td><strong>97,040.00</strong></td>
<td></td>
</tr>
</tbody>
</table>
Importance of Energy Costs by Building Type

The relative significance of energy costs is different for different building types. Obviously, a building which uses very little energy, such as an unconditioned warehouse, will have comparatively low and insignificant energy costs. Conversely, energy costs can be quite significant in a building with large energy consumption. It is therefore useful to have a general understanding of the building types and characteristics for which energy strongly influences operating costs.

Buildings which have significant equipment or process energy costs will usually top the list. For manufacturing or special process buildings with energy-intensive equipment, energy costs can be of primary importance. Examples would include refrigerated warehouses, hothouses, and other specialized structures. In more typical buildings, energy use from equipment and processes can also be significant. Grocery stores have large refrigeration loads, and commercial kitchens have large cooking and refrigeration loads, as well as large ventilation loads from exhaust hoods.

Ordinary building energy uses—lighting, heating, cooling, and ventilation—can be more significant in some building types than others. Buildings with large numbers of people, such as theaters or gymnasiums, require large quantities of ventilation air that must be provided through fans and duct systems, and which must be heated and cooled. Buildings with specialized lighting requirements, such as theaters, museums, or jewelry stores, will require unusually high lighting energy use. Buildings with unusually large window areas, such as glass-façade office buildings or automobile dealerships, will experience unusually large heating and cooling loads.

Buildings with unusually long operating hours or extreme environmental influences will have significantly higher energy usage. For example, hospitals operate 24 hours a day all year long. Some types of businesses, such as grocery stores, also have nearly full-time operating hours. Finally, buildings exposed to constant wind or extreme temperatures, such as those at seaside locations or on mountaintops, will have unusually high energy consumption. Some or all of these factors may be present in a building and can be recognized in the appraisal process.

In sum, energy performance strongly affects cash flow and net operating income from some buildings. The influence of energy performance arises from both its magnitude and its variability. Therefore, accurate reflection of energy costs is a critical part of accurate valuation via the income capitalization approach.
We present further information on how to obtain and use credible information on energy costs in Section 3.

Assessing Uncertainty in Energy-Reporting Methods

Energy-reporting methods, as with other elements of appraisal, involve a degree of uncertainty — a natural consequence of making estimates with imperfect data, and projecting future income streams and market preferences based on present information. Appraisers therefore tolerate some uncertainty in all aspects of the appraisal, while seeking to keep it to a minimum.

Sources of uncertainty fall into two general categories — the inherent spread of data points (statistical variation) and the imperfection of data collection and analysis (measurement and modeling error). True, energy cost estimates are subject to uncertainty in both of these areas. But it is also apparent that uncertainty is likely no worse a problem with energy than with other factors affecting value.

Inspection of the Experience Exchange Report of the Building Owners and Managers Association (BOMA) indicates that utility costs are typically the largest single itemized expense for office buildings, constituting about a third of total operating costs in most urban areas. Moreover, the variability of energy costs is about the same as for the other revenue and expense categories. In other words, the problem of statistical variation is probably comparable between energy costs and other elements of NOI. It follows further that the degree of care and precision that appraisers apply to estimates of non-energy components of NOI should also apply to estimates of energy costs.

Even when measurement and modeling error is unavoidable, an appraiser can seek to minimize error by using reliable, building-specific data grounded in well-substantiated technical methods. The following sections discuss in more detail various types of data sources on building energy use and costs.
3. Assessment of Building Energy Performance

Once the appraiser sets out to include energy costs in NOI and/or discounted cash-flow calculations, the objective should be to make as accurate and well-substantiated an energy-cost estimate as possible. But common methods for energy-cost assessment by appraisers often suffer from questionable credibility and poor accuracy. The following section describes problematic methods of energy assessment and reporting, then outlines alternative techniques to obtain more technically accurate, building-specific estimates of energy costs that appraisers can confidently use.

Energy Cost References

Where owners’ disclosures are suspect or absent altogether, appraisers may seek energy-cost information from standard references such as the *Experience Exchange Report* of BOMA and *Income/Expense Analysis* publications of the Institute for Real Estate Management (IREM). These sources collect survey data from owners on income and expenses, and present results as average figures for given locations and building types.

Appraisers sometimes use these averages as default energy-cost figures for NOI calculations. This approach, while certainly convenient, can pose challenges to credibility. Given the range of building types, vintages, features, and equipment, treating all buildings as average does not tell the entire story. It is more appropriate to use standard references and averages as indicators of a reasonable range of energy costs, rather than as default figures for the subject property.

Equipment Reference Guides With the Cost Approach

With new construction, in employing the cost approach to valuation, appraisers may try to obtain cost figures for the individual energy-related equipment in buildings. Many refer to Marshall & Swift statistics or various data sources from RS Means, which include figures on the prices of various lighting, heating, ventilation, and air conditioning (HVAC) equipment. Some RS Means sources offer some comparisons between the annual cost of conventional versus energy-saving equipment in terms of their annual energy consumption, cost, and expected lifetime, as well as various lighting quality indices.

For the cost approach, these references are essential — but when appraisers also want to take into account future cash flows, these sources have their limitations. Many energy efficiency measures pay their incremental costs back
In assessing billing histories, an appraiser should ask for evidence that the energy cost levels result from working features, not erratic external conditions like weather or anomalies like broken equipment.

Considerations of Methods for Energy Performance Assessment

Billing histories
One of the most direct methods of assessing building energy costs is to examine the building’s utility bills. Examination of bills themselves, particularly multiple years’ worth, is more time-consuming than reviewing summary financial statements, but also removes the potential that the owner is fudging or obscuring the numbers. Bills are also preferable to standard reference sources in the sense that billing records are specific to the building itself, and at some level will reflect the presence of efficient built features or operations.

The problem with billing histories is that they reveal little about why bills show the numbers they do. A building may have low energy use (relative to the levels that appraisers might normally encounter) because it has advanced, well-maintained energy-efficient features; on the other hand, it may have broken equipment or an owner who is willing to sacrifice occupant comfort for energy-cost savings by running the HVAC system in a miserly way. Bills may also be anomalously low or high because of abnormal weather conditions, partial vacancies, unusually long operating hours, or the presence of unusual energy-using equipment. Furthermore, in older buildings, there may be more than one utility meter; also, the metered floor area may not correspond to the floor area used in the NOI calculation.

Given the number of confounding factors, it is less than optimal to use energy bills alone—even multiple years’ worth—in estimating energy costs for a calculation of NOI. In addition to the bills, an appraiser can ask for evidence that the building’s energy costs result from the presence of desired features, not undesired anomalous factors or erratic external conditions.

rapidly — lighting measures in less than a year, commonly, and HVAC measures in three to five. Therefore, a cost-based estimate of the incremental value of energy efficiency will tend to fall below an estimate based on income capitalization or discounted cash flow. Even when the equipment reference guides do present estimated operating costs as well as initial costs, their data are based on manufacturing and engineering specifications, as opposed to tested performance of the measures in actual buildings.

Moreover, energy-efficient buildings are often designed in a highly integrated way, in which building systems and equipment are chosen for optimal performance with each other. This integration can lead not only to reduced operating costs, but also lower initial costs than would be reflected in piecemeal selection and pricing of building elements.
There are two ways to show that low energy bills result from efficiency rather than other conditions. The first way is to verify the presence of efficient features, either visually or through a record of installation and performance verification, or ideally, both. The second way is to normalize the bills by correcting for the effects of building space use, weather, occupancy, and other factors.

**Energy bills plus verification of efficient features**

The simplest approach to using energy bills for appraisal purposes is to supplement the bills with a procedure to verify the presence of working energy-efficient measures. The purpose of this verification is to document the energy efficiency measures which help to determine the magnitude of the utility bills. Under this approach, an appraiser could verify the presence of efficient building features through a visual inspection, using a checklist. (See Appendix for a discussion of energy-efficient technologies and materials commonly found in commercial buildings.) Any appraiser could complete a checklist of simpler building features; for more complex measures, special training or qualifications would be needed to identify measures and to assess their working condition. To supplement the identification of measures, the appraiser could ask the owner for a written record of installation and performance histories for special efficiency measures.

Measure-by-measure performance verification is a common element of energy performance contracts, in which an outside contractor provides an energy-efficient upgrade for which the building owner pays over time as savings are gradually achieved. Since savings levels are the basis for repayment terms, protocols for measurement and verification of savings under these contracts tend to be rigorously specified.

The International Performance Measurement and Verification Protocol (IPMVP) is the standard for verification of energy efficiency measures in the performance-contracting field. While the Protocol provides for varying degrees of precision (and level of effort) in verifying energy efficiency savings, all are based on best practices in energy analysis and assessment.

**Energy bills normalized for weather, occupancy, operating hours, and other factors**

While appealing in its simplicity, verification of features does not always provide complete answers to explain high or low energy bills. For example, if a building had consistently average energy bills, they could be the result of reliable energy efficiency measures which were offset by a history of unusually long hours of
operation, or by a stretch of extreme weather patterns. This building, then, under normal operation and weather, would be expected to have lower than average utility bills because of its efficiency features.

Energy bills may be corrected for various confounding variables through a process called normalization, which essentially breaks down a series of energy bills into their component parts so that the extraneous variables can be controlled for, isolating the efficiency performance variables to predict future energy savings. In this process, bills over an extended period are analyzed and correlated to the variables in question, which may typically include outdoor air temperature, occupant density, and operating hours. The billing patterns are then expressed as a multivariate linear function of the variables. This equation can then be used to predict the building’s energy performance based on specified “normal” conditions.

The big advantage of normalization is that it provides a much more rigorous treatment of the energy bills than the simple verification method. In some ways normalization is simpler, because it does not require a detailed survey of all the building energy features (although listing them would be an informative complement to the analysis). Normalization does, however, require reliable historical data on a number of independent variables, such as heating and cooling degree day data, hours of occupancy, numbers of occupants, internal and equipment loads, etc. It may also require data on physical parameters that have a direct relationship to energy usage, such as floor area, glazing area, or ventilation rates. The more complicated the building, the more independent variables will need to be analyzed. Moreover, while normalization techniques are well understood, their application to a particular building can require a certain amount of trial and error to develop the most descriptive regression equation that makes the best use of the available information about the building.

Use of normalized billing is relatively common among building managers and building energy consultants, covering a range of applications. Owners and managers may use normalized billing to simply track energy use and trends, to forecast operational cash flow, and to help identify opportunities for energy cost savings via retrofits, maintenance, or improved operations. Normalized billing is also used as a basis for energy-efficiency performance contracts. In this case, normalized bills can be used to project a baseline level of energy consumption against which the post-retrofit actual energy use can be compared.

Normalization of energy bills is sometimes carried out by a contracted specialist, but can also be done by non-experts, especially via the use of desktop utility-
tracking software such as Metrix and EnergyCAP. A normalized billing analysis and projection from such tools should generally be a reliable source of energy-cost information for use in appraisal.

**The ENERGY STAR building label** Normalized billing now has another important application through the ENERGY STAR building label program of the U.S. Environmental Protection Agency (EPA). Under this program, the ENERGY STAR label, which is best known as a mark of energy-efficient performance in appliances, copiers, computers, and homes, may be assigned to energy-efficient buildings in a wide range of categories, including office buildings, hotels, retail stores, medical office buildings, hospitals, senior care facilities, schools, and others.

The EPA system for assessing buildings and assigning the label is based on normalized billing. An applicant collects 12 consecutive months of utility billing information, along with information on a number of normalization factors — occupant density, space use, floor area, numbers of personal computers per person, hours of operation, and outdoor temperature. The collected data is entered into a program called Portfolio Manager, in which a calculation engine then normalizes the bills for the given factors. Building owners and managers can then use Portfolio Manager data to monitor performance, track changes over time, and identify opportunities for upgrading energy efficiency.

Notably, Portfolio Manager also generates an ENERGY STAR rating, a score on a 0-100 scale that indicates how a building stacks up against other buildings with similar physical and operating characteristics. A closely related program called Target Finder allows an owner to start with a desired ENERGY STAR rating score and identify the energy consumption levels needed to qualify, thus defining goals for design and/or retrofit. A rating score of 75 or higher qualifies a building for the ENERGY STAR label. Please see Section 4 for a discussion of the use of ENERGY STAR ratings as a basis for energy-performance comps against other buildings.

Normalization does have its limitations. With the EPA normalization and benchmarking tool, as with other normalization software, it should be understood that results may vary depending on the normalization factors chosen. In certain cases, normalization may not recognize important anomalous factors that strongly affect energy use. For example, a building may have stuck dampers or incorrect setpoints in the HVAC system, leading to high energy use that weather, occupancy, and other normalization corrections will not catch. Normalization will also be unlikely to reveal cases where low energy use results
from underheating and undercooling of occupied areas, though EPA does require that any buildings qualifying for an ENERGY STAR label must have an engineer’s certification that minimal comfort conditions are met.

**Design simulation**

For some buildings (including, most obviously, new buildings) energy billing data may be absent. For other buildings, the magnitude of energy costs may warrant a more detailed assessment of the energy performance and how it is influenced by the equipment and operation of the facility. In these cases, an owner may be able to provide the appraiser with the results of a computer simulation of the building’s energy performance, based on the building’s built features, its location, and other factors. Simulations are most commonly conducted in conjunction with design of new buildings or comprehensive retrofits. In other cases, it may be worth the time and expense to develop such a simulation model of an existing facility specifically for the appraisal.

A computer simulation model is essentially a sophisticated engineering calculation of the energy flows in a building and their cost. Much as NASA scientists use simulations to study the effects of space flight, building engineers use simulations to study the energy performance of buildings and their equipment. As with any simulation model, the results can only be as good as the input data, so there must be a reasonable amount of effort expended to adequately describe the building and its operation. The energy analyst must necessarily make simplifying assumptions about the building, so it is also necessary that the simulation be performed by a person with the training and experience to make these simplifications in a way that does not compromise the accuracy of the simulation. Done properly, however, energy simulations provide the ultimate tool for predicting energy costs for a building in a way that recognizes the performance of the specific energy features of the building.

**DOE-2**

The longtime standard for building energy performance simulation is a computer program called **DOE-2**, which was developed by the U.S. Department of Energy (DOE) more than 25 years ago and has been undergoing periodic improvements and revisions ever since. DOE-2 requires voluminous input data on the geometry, materials, equipment, and controls of the building. It also considers internal heat gains within the building, the effects of solar radiation incident on the building, the relevant utility rate schedule, the daily and weekly variations in operating and occupancy schedules, and other factors. DOE-2 calculates hourly expected energy consumption for the building, taking into account historical hourly weather files for the building location. Summed over
the entire year, hourly consumption estimates can yield an estimate of whole-
building consumption.

The DOE-2 simulation procedures are available in a range of software packages
(user interfaces), ranging from simple text-based programs to interactive
graphics-intensive tools, for use by architects, engineers, building scientists, and
building operators. Most users currently use the programs on standard desktop
personal computers. A list of commercially-available versions of DOE-2 may be
found at http://gundog.lbl.gov/dirsoft/d2vendors.html.

DOE-2 is a rather specialized computer program, and one must possess a college
engineering level of understanding of building energy and analysis principles to
use it with confidence. In particular, it is necessary to ensure that input
information on building parameters is accurate and reasonable; some DOE-2
versions automatically reject unreasonable input data, but in many cases,
verification of inputs can only be conducted through third-party review.

Yet despite these caveats, DOE-2 is among the most widely used energy analysis
tools, and is accepted as rigorous and accurate for building simulation purposes;
results generally fall in the range of plus or minus five-percent accuracy.

DOE-2 may be especially accurate in predicting energy use when the simulation
model is “calibrated” to past energy bills. In the calibration process, the user
actually adjusts the calculational engine of the simulation model so that it
accurately “backcasts” (as opposed to “forecasts”) past bills. The modified
simulation model is then used to forecast future energy consumption and costs.
Figure 2 depicts actual energy costs for an average large commercial customer
in Con Edison’s service territory in New York (10,800 kWh and 31 kilowatts per
month), compared to a fictitious simulation of energy costs, before and after
simulated calibration.

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3 The accuracy of a calibration (that is, the closeness of fit between the simulation and the past
bills) is commonly quantified by means of two statistical indices: mean bias error, or MBE, and
coefficient of variation of the root mean square error, or CV(RMSE). The lower these indices are,
the closer the fit. Generally, a simulation model is considered calibrated if its MBE falls within
±10%, and if CV(RMSE) is within ±30%. (Stein, J., 1997.)
The advantage of calibrated simulation is that by tuning the model to past bills, one should, in theory, generate a model that is more accurately representative of the energy-use behavior of the specific subject building. The problem, however, is that tuning the model is a highly sensitive and ultimately subjective endeavor; the model may inevitably be tuned in any of a number of ways, which will likely yield different patterns of forecasted energy use. Therefore it is imperative that the specialist performing the calibration be a real expert not only with the software, but also with technical aspects of building science, in order to assure that calibration adjustments represent reasonable engineering assumptions, not random guesswork.

**Other simulation and analysis tools**

Other energy-simulation tools, which target various building types and cover a range of cost and complexity, may also yield information for use in appraisal.

**EnergyPlus**, like DOE-2, is a whole-building energy simulation program. Based on user inputs about building features and HVAC systems, EnergyPlus calculates heating and cooling loads and energy consumption. It is regarded as more of a full-featured tool than DOE-2, in its capacity to deal with more complex HVAC systems. Also like DOE-2, EnergyPlus was developed by the U.S. Department of Energy for free release into the public domain; it now has several commercially-developed interfaces.
The HVAC giants *Trane* and *Carrier* both offer proprietary building-simulation services, which are generally used to determine heating and cooling loads to help ensure selection of correctly-sized equipment. Simulations from both companies can also be used by building owners to demonstrate compliance with federal tax-deduction provisions based on energy efficiency in buildings.

A more comprehensive and regularly updated list of commercial and residential energy-simulation tools, with useful discussion of the features, uses, strengths, and weaknesses of each, is available at [http://apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm](http://apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm).

**Billing histories and design simulation: which to prefer?**

In gathering comments from appraisers and energy-analysis specialists on these proposed tools, IMT has observed a rather distinct disparity in each professional sector’s preferences. Appraisers widely consider billing histories to be acceptable for use in the valuation process, and simulation tools somewhat less so. Energy specialists tend to hold the opposite position; they are skeptical about billing-based assessment, and more confident in simulation methods, particularly those that involve calibration to measured performance.

There are various possible reasons for this divergence. Appraisers’ preference for billing histories may be based on a sense that bills represent information that is more tangible than the results of an engineering calculation. Appraisers may be able to apply their own judgment more constructively to billing histories, which require relatively little technical background, than to simulation, which is a “black box” to all but the most highly trained programmers and engineers. Enhanced billing methods may also be more popular among appraisers in that they resemble currently-applied methods more closely than simulations do; changing practice by enhancing billing assessment would be a manageable incremental step, whereas assessing and trusting a simulation would be more of a leap in practice.

Energy specialists, on the other hand, prefer simulation methods because they are able to take into account the detailed dynamics of building performance, including the effects of various specific technologies in the building. They are familiar with these tools, work with them regularly, and not surprisingly, generally view the more advanced tools such as DOE-2 and EnergyPlus as the leading edge in their work. To them billing methods are, technically speaking, much blunter instruments, subject to confounding factors and gaming as described above.
4. Benchmarking and Energy Performance Comps

Appraisers often seek information on buildings with comparable characteristics when estimating property value as a whole, and for confirming or arriving at ranges for particular expenses, such as energy costs. The purpose of this section is to highlight tools that can be used to evaluate currently-available data sources on comparable properties (“comps”) for use against subject buildings, including government building survey results and data from private agencies and companies.

We emphasize that comp data should be used only as checkpoints for estimates of energy costs, but not as default figures for the energy costs of the subject building. For estimating energy costs for the subject building itself, the appraiser should refer to Section 3.

Ideally, energy-related comps should fulfill the following criteria:

- The comp building set should represent the same specific building type as the subject building.
- The same energy cost calculation method should be employed for both the subject building and the comp data set.
- A sufficiently representative or large data set should be sampled.

The appraiser may conclude that, after applying these criteria, none of the available databases can offer a rigorous enough energy cost for comparison to the subject building. In this case, the appraiser will have to make a subjective judgment as to what level of credibility to assign given energy cost figures, or may request corroborating information from other analytic methods applied to the subject building.

Existing Baseline Databases

The building databases enumerated below are widely accessible and convenient, but have relatively small sample sizes and informal collection methodologies. These databases examine costs only; they lack information on the specific built features of buildings. Therefore, these sources only weakly satisfy the above criteria.
Building Owners and Managers Association (BOMA)
The BOMA Experience Exchange Report, available through online subscription only, has data from more than 6,500 buildings and 250 markets. The dataset covers office buildings only. Energy consumption is broken down by utility and presented as dollars per square foot per year. Data are presented for downtown and suburban sectors of metropolitan areas, in aggregate and broken down by floor-area ranges. Sample sizes vary widely according to location and floor-area category.

CBECS (Commercial Building Energy Consumption Survey)
The CBECS database is the only national-level survey of commercial buildings and their energy suppliers, put together by the Energy Information Administration of the U.S. Department of Energy. The main advantage of the survey is that it collects information on the physical characteristics of buildings, building use and occupancy patterns, equipment use, conservation features and practices, and types and uses of energy in buildings. Monthly utility bills are also reviewed to corroborate energy consumption and expenditure claims. Its disadvantages are that it is only conducted quadrennially and that it does not allow searches by geographic location to levels of resolution finer than the nine US census regions. CBECS data come from multiple sources for each building: interviews with building owners, tenants or managers; documentation from energy suppliers; energy simulation model runs; and weather data.

The most recent CBECS was completed in 2003, and consisted of interviews covering more than 5,200 commercial buildings. There are more than 4.8 million commercial buildings in the nation, and the buildings in the sample were selected to represent them as closely as possible. As has been detailed more extensively elsewhere, CBECS is mostly limited by the difficulty inherent in representing such a large number of buildings with such a small sample size. There are also concerns that some portion of the collected data may be inaccurate and that some important factors impacting energy use are left out entirely. To add to these challenges, CBECS is now two updates behind schedule, which means the data is a snapshot of the nation’s building stock as it stood nearly a decade ago.

Other Methods

Simulated reference buildings
In many states, developers have the option of demonstrating energy-code compliance by conducting an energy simulation for a building and comparing the results to those of a similar simulation for a hypothetical minimally code-compliant reference building made with stipulated features and materials. Comparison with the reference building thus can tell the code official (and the appraiser) how the energy performance of the subject building compares to minimum code requirements.

Since codes set forth the same basic energy-efficiency requirements that apply to all new buildings within a given type, this method also provides a possible means for comparing buildings against each other. For example, one new building may be shown to have energy consumption 30 percent lower than its code-defined reference building, while another may show levels only five percent lower than its respective reference building.

Comparison to a simulated reference building is preferable to using database comparison methods because it employs the same tool to estimate energy performance between buildings, inherently represents the same building type, and avoids the issue of needing a large comparison data set.

Rating systems
Energy performance documentation in the form of a rating delivers energy cost information to the appraiser with a built-in baseline, in that it represents where the subject building stands in relation to other buildings.

As introduced in Section 3, the ENERGY STAR benchmarking tool and its underlying programs, Portfolio Manager and Target Finder, provide a rating of the normalized energy consumption of the given building.

Portfolio Manager compares the results of the normalization analysis with statistical information from the 2003 version of CBECs. This comparison yields a rating for the subject building, on a percentile scale of one to 100. Buildings with a rating of 75 or higher (that is, those that outperform 75 percent of similar buildings in CBECs) qualify for the ENERGY STAR building label.
The **HERS Index** (Home Energy Rating System), developed and overseen by RESNET (the Residential Energy Services Network), provides a rating of a building’s energy efficiency on a scale of 0 to 100 and beyond. This rating is based on an assessment by a certified professional home energy rater, including a comparison with a simulated reference building minimally compliant with the 2004 edition of the International Energy Conservation Code (IECC), which is the basis for many required residential energy codes throughout the United States.

Notably, in the HERS system, the lower the rating, the better in terms of energy efficiency. A score of 0 means that the building consumes no net energy, while a score of 100 means that the home is minimally compliant with the IECC. Scores below or above 100 reflect the deviation in energy consumption from the IECC reference level. Therefore, a building with a score of 80 consumes 20 percent less energy than the IECC level, while a home with a score of 150 consumes 50 percent more.

HERS ratings are already recognized by the real estate finance sector as a robust tool for energy assessment. They are the basis for “energy-efficient mortgages,” which offer owners or buyers of rated energy-efficient homes increased financing for purchase or energy efficiency improvements. Fannie Mae, Freddie Mac, the U.S. Department of Veterans Affairs, and the Federal Housing Administration all have special underwriting guidelines for energy-efficient mortgages, using HERS ratings.

The U.S. Green Building Council oversees another certification and rating system for buildings, called **LEED**, which stands for Leadership in Energy and Environmental Design. LEED includes various specific systems for rating different types of buildings, including new construction, existing buildings, retail, homes, schools, and others. For all the various types, LEED rating systems are applied on a 100-point scale, with a hierarchy of designations from Certified (40+ points) to Platinum (80+ points). In the decade since its creation, LEED has grown to become the preeminent green building label, widely accepted as the market standard. Today, more than 1 billion square feet of space are LEED certified.

Appraisers should note that LEED ratings are not quantitative indices of energy cost or energy consumption alone. Points are awarded for criteria ranging from site selection to the use of recycled construction materials. The LEED rating, while the authoritative measure in its chosen area, is ultimately a subjective measure of environmental quality, rather than an objective index of energy cost or consumption.

Still, energy is a significant part of a LEED rating, accounting for up to 35-38 points out of the possible 100. Moreover, the methods for assigning LEED points
for energy employ the same best-practice approaches described above – for new commercial construction, a comparison against minimal code compliance; for existing buildings, a comparison with similar buildings via ENERGY STAR and Portfolio Manager; and for homes, a comparison with the HERS index. Therefore if a LEED rating is available for a building, a rigorous underlying energy comp should be too.

**Benchmarking mandates: a growing trend**

Across the country, cities and states looking to cut their energy consumption and raise their green profiles are adopting “rating and disclosure” laws. While the specifics vary, the theme is consistent: building owners are required to track energy use and submit the data to a central database, which is either partially or wholly public.

With these mandates, policymakers are betting that readily available information on building performance will fuel market demand for energy-efficient buildings, motivating owners to retrofit existing stock and think green when planning new construction. As this report went to press, rating and disclosure policies were in place in New York City, San Francisco, Washington DC, Austin, Seattle, California, and Washington State, and under consideration in several other cities and states. IMT’s 2011 report, *Building Energy Transparency*, provides a more detailed summary of specific policies and emerging best practices.

All of the benchmarking and disclosure mandates now in force in the United States require the use of Portfolio Manager and the Energy Star rating scale, where applicable. As a result, these jurisdictions will soon have databases of building performance data of unprecedented scope and quality.

Exact details are still being worked out, but in New York City, Washington DC, and San Francisco, the data from the buildings required to benchmark will be made available on a public website in some form. At a minimum, each building’s ENERGY STAR rating and energy use intensity (consumption per square foot) should be available. Additionally, as the data flow in, these jurisdictions will be performing city-wide analyses and releasing useful summary statistics and performance metrics, creating an unprecedented opportunity in terms of energy use comparison. Most notably, *buildings in these databases will be available as comps with each other, not just comps with CBECs samples of similar buildings.*
Other jurisdictions are employing various transactional triggers, designed to ensure that prospective tenants have access to performance data before a contract is signed. This disclosure format does not present as clear an opportunity for appraisers as a public website. However, if the jurisdictions aggregate and analyze the data, and make the results public, these policies should create very significant new sources for appraisers and others to use in generating energy comps.
5. Technical and Legal Assurances From Preparers of Energy Documentation

Real estate appraisers are subject to intense scrutiny and liability. Appraisers’ work is shaped by multiple laws and interests, including the Uniform Standards of Professional Appraisal Practice (USPAP), the scope and expectations for the assignment as stipulated by lenders, as well as the risk of potential litigation from disgruntled parties. In this context, it is imperative that appraisers ensure the credibility of the data that they use, and of any third parties providing such information.

The reliability of energy assessment and comparisons, no matter how well-tested and technically robust the given methods, depends heavily on the competence of the person performing the analysis. Therefore, not only should an appraiser verify the technical basis of energy performance documentation as discussed in Section 3; he or she should also seek assurances about the technical credibility and responsibility of the preparer. This section describes three types of such assurances:

- **Assurance of technical competence** in the form of a professional license or other related training or experience;
- **Assurance of legal responsibility** for the document contents in the form of a signed statement;
- **Assurance of coverage by professional liability insurance.**

**Technical Assurances**

To some extent, the level of technical complexity of the energy assessment tool used defines the required level of expertise of the energy performance document provider. Therefore, someone preparing a building’s utility bills and list of efficient features will not require the same level of qualification as someone who conducts a sophisticated whole building simulation such as DOE-2. In some cases, the tool itself may be designed for either a technical or non-technical user. In this instance, the documentation provider would not require special certification at all.

Appraisers agree that appropriate licensure of documentation providers is very important as protection against future liability. For this reason, appraisers may not want to change an appraisal to reflect unusually low energy costs if the statement comes from an unlicensed expert rather than a Professional Engineer (PE). This section discusses a number of both licensed and degree course training—from professional engineer certification to utility or industry-
sponsored course work in efficient building operation. Evidence of relevant training in any of the forms below should elicit confidence from the appraiser in the competence of the document preparer and its contents.

**Professional Engineer/Licensed Architect certification**

Energy-performance documentation may be certified by a PE or a licensed architect. PEs render services such as consultation, investigation, evaluation, planning, or design of public or private utilities, structures, machines, processes, circuits, buildings, equipment, or projects. This includes evaluation and certification of buildings’ energy performance. Architects, of course, are the professionals responsible for building design, and in some cases may also conduct analyses of energy performance as part of the design process.

Like other professions that are tested and licensed, upon filling legal requirements engineers and architects obtain licenses via state offices or boards, which in most states not only qualify and license individuals, but also establish and enforce laws and regulations. Accountability to state licensing board oversight is in itself one of the most powerful aspects of the assurances embodied in the two types of licenses. Low energy-cost information verified by an architect or PE would likely give appraisers the greatest confidence that the figures are attributed to energy-efficient measures in a building.

To become a PE, an individual must pass rigorous experience and exam requirements, including graduating from an engineering program accredited by ABET (formerly known as the Accreditation Board for Engineering and Technology, Inc., and with the initials now constituting the official name), fulfilling 12 years of education/experience acceptable to ABET, and passing the Fundamentals of Engineering and Principles and Practice of Engineering exams. Many PEs belong to the National Society of Professional Engineers.

For architects, licensing requirements generally include providing verification of a bachelor’s or higher accredited degree in architecture, a minimum of three years of architectural work experience, and successful completion of a series of written examinations.

The ENERGY STAR building label requires that applications be certified by a PE. (Architects are not recognized under this program.) In this way, the credibility of the preparer is essentially “built in” to the tool, and does not require additional verification by the appraiser. Other billing normalization methods, as well as DOE-2 and other simulation tools, do not contain the intrinsic assurances that ENERGY STAR does.
Although DOE-2 is more technically sophisticated than the ENERGY STAR benchmarking method, neither DOE-2’s users, nor the tool’s output documentation, are required to be certified in any way. In some states, code compliance based on DOE-2 simulation must be certified by a PE stamp.

It should be noted that both the PE and licensed architect designations only provide a limited degree of technical assurance insofar as they do not guarantee specific expertise in energy performance assessment. Ideally, the appraiser should seek additional evidence regarding the preparer’s technical competence, such as their area of specialty, training, or experience.

Equivalent training or background
In the absence of any of the above certifications, appraisers might consider alternative qualifications from the energy performance documentation provider of a building, such as equivalent course work or project experience. The following is an overview of certification programs, courses, and training that specifically cover energy performance in commercial buildings, and should be recognized when evaluating energy-cost documentation in an appraisal.

Building Operator Certification
Developed by the Northwest Energy Efficiency Council (NEEC) more than a decade ago and now active nationwide, the Building Operator Certification (BOC) is a program for training and certification of building operators and facility managers. The program offers voluntary courses for individuals who are responsible for the energy- and resource-efficient operation of building systems. Certification is granted at two levels. Level 1, which covers building systems and equipment, requires 56 hours of classroom study and five long project assignments; Level 2 emphasizes troubleshooting and maintenance, and requires 49 hours of classes and three projects. BOC graduates are required to take continuing-education credits to maintain their certification. Typical registrants include individuals from both the public and private sector: engineers, utility company employees, energy service company representatives, electricians, general foremen, and facility operators.

Utility-offered training
Verification of energy bills by the utility provider can provide additional assurance that low cost figures are valid and therefore worth reporting in an appraisal, as opposed to relying on rule-of-thumb references from standard sources. Preparers of such energy-performance documentation may

http://www.theboc.info/
demonstrate technical qualifications via a certificate of completion of a utility-sponsored training course in whole-building energy analysis tools.

**Degree courses**
A growing number of degree courses are now available to those in the energy sciences or engineering field, and if presented by the documentation provider, should offer some assurance to appraisers in their technical competence in energy. Many courses are offered by both state and private schools.

**Certifications from ASHRAE**
ASHRAE is an international organization of 50,000 members, organized to advance the sciences of HVAC for the public’s benefit through research, standards writing, continuing education, and publishing. Energy efficiency in buildings is a major focus of the organization.

ASHRAE offers several certifications for trained experts in building energy performance assessment. These include the following designations:

- Building Energy Assessment Professional
- Building Energy Modeling Professional
- Commissioning Process Management Professional
- High-Performance Building Design Professional

All these certifications require submittal of an application, review of guidance materials, and taking a proctored examination in person. The presence of any of these certifications is a credible indication of substantial training and/or experience in the given field.

**HERS rater certification and quality assurance**
HERS raters are certified after receiving a full week of required training from RESNET-accredited providers, passing a comprehensive written examination, and performing two ratings in the presence of a certified trainer. Aspiring raters may also take the test without formal classroom training, instead relying on experience and self-study.

Furthermore, even after accreditation, HERS raters are subject to oversight of their work by accredited “rating providers.” Such oversight includes desk audits of a minimum of ten percent of ratings and field inspection for a minimum of one percent.

Taken together, training and quality assurance of HERS ratings and raters are among the most comprehensive of any energy efficiency programs in the country. Note, however, that HERS ratings apply to residential homes only, not
commercial buildings. But RESNET, IMT, and other groups are now working on COMNET, a system applicable to commercial buildings, which is ultimately intended to generate ratings with similar rigor and quality assurance as with HERS.

Assurance of Professional Responsibility

While the various certifications and assurances of technical competence described above will provide the appraiser with some degree of protection against liability, additional assurance should be sought in the form of a signed statement from the documentation provider. With the understanding that, as with all areas of appraisal, the energy cost estimates of NOI may be contested at some future time, IMT recommends that the third-party energy performance documentation provider (the preparer, reviewer, building owner, or contractor) should certify in writing that the information being provided is true and correct to the best of their knowledge.

Appraiser disclaimers and limiting conditions

In addition to requesting assurance of professional responsibility from the documentation provider, appraisers should also be certain to protect themselves in the appraisal by including disclaimer and limiting conditions language. Language already used by appraisers, such as: 1) a clearly and conspicuously presented Extraordinary Assumption per the Uniform Standards of Professional Appraisal Practice (USPAP) in which uncertain information is presumed to be true, or 2) that suggested by the International Valuation Standards Committee should suffice for purposes of estimations of energy cost as well. Eventual integration of energy documentation requirements into state or national appraisal standards would also protect appraisers against liability.

Other typical general assumptions and limiting conditions are listed below as they may appear in an appraisal report:

- The information furnished by others is believed to be reliable. However, no warranty is given for its accuracy.

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6 "The statements of fact contained in the report are believed to be true and correct. The Valuer should identify the sources of data relied upon, indicate whether there was reliance on data supplied by others, and if data from others is relied upon, state whether there was further verification of that data by the Valuer." Section 7.2.2. Assumptions and Limiting Conditions.

7 The Appraisal of Real Estate, p. 582 (AIREA, 9th Ed., 1987)
• The forecasts, projections, or operating estimates contained herein are based upon current market conditions, local energy prices, anticipated short-term supply and demand factors, and a continued stable economy. These forecasts are, therefore, subject to changes in future conditions.  

Information contained herein is obtained from sources deemed reliable but not guaranteed by the appraiser, who is not an expert in these matters.

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8 The Appraisal of Real Estate, p. 582 (AIREA, 9th Ed., 1987)
9 Suggested language from a CA Certified General commercial real estate appraiser, 12/1/98.
6. Market Demand for Energy Efficiency and Green Buildings

Beyond energy efficiency – green buildings and sustainability

The concept of “green buildings” takes energy efficiency strongly into account, but goes further in also considering water use, sustainability of source materials, waste reduction, air quality, land use, and other factors. Value of green buildings arises from many of the same factors cited above for energy-efficient buildings, including direct cost reductions from lower utility bills, increased attractiveness of buildings, and occupant comfort and health.

Social responsibility has become a key motivator for many businesses, especially larger corporations, as well as universities, government agencies, and other major economic entities in the United States. The concept of social responsibility includes various elements, including treatment of employees, service to the community, and limitation of environmental impact. In the latter regard, many of these institutions now recognize that the selection of which buildings to own and/or lease is a significant way to exercise social responsibility. Choosing energy-efficient and green buildings, to many, is simply good citizenship worth some extra effort and expense.

Going green with buildings goes beyond fulfillment of ethical missions and doing good for its own sake. For many businesses, owning and occupying green buildings can be good marketing too. Energy-efficient and green buildings can help project a desired image, not only of community connections and social responsibility, but also of technical savvy and readiness to innovate. Earning a positive LEED designation or an ENERGY STAR label is not just something to feel good about within a company – it is something to project to the public.

The increasing prevalence of energy-performance disclosure mandates will likely greatly magnify both the internal and external motivations for building owners to pursue energy efficiency and sustainability. Under the mandates, not only will owners know about their buildings – they will know about everyone else’s, and everyone will know that each other knows! This transparency can be expected to lead to unprecedented competition among building owners. Such competition will apply not only to a few super-progressive companies trying to out-green each other at the top of the efficiency and sustainability ratings. It will also create powerful motivation among owners of underperforming buildings to
improve energy performance and shed embarrassingly low ratings and the reputational drag associated with them.

Evidence of energy-related value
All these factors collectively have spurred a significant shift of the real estate market in the United States toward greater recognition of value associated with energy-efficient and green buildings. Market recognition of the value of energy efficiency and sustainability applies especially to larger commercial properties, but has been well documented in other sectors too. Evidence of this transformation is still scattered, but it is accumulating steadily.

Statistical studies
Recent published research has repeatedly concluded that buildings rated as energy-efficient and sustainable have higher occupancy rates, fetch higher rents, and sell for more than comparable but unrated and less efficient buildings.

- University of Arizona and Indiana University study of office-building investment data from National Council of Real Estate Investment Fiduciaries. In a 2010 study published in The Journal of Real Estate Research, Gary Pivo, professor at the University of Arizona, and Jeffrey Fisher, director of the Benecki Center for Real Estate at Indiana University, examined data from the National Council of Real Estate Investment Fiduciaries on investment performance for nearly 1,200 office properties. Using controls to isolate effects, they found that buildings with the ENERGY STAR label had significantly stronger financial performance than unlabeled similar buildings. ENERGY STAR buildings had 10 percent lower utility costs, 4.8 percent higher rents, 1 percent higher occupancy rates, and ultimately, 5.9 percent higher net income per square foot and 13.5 percent higher market values. ENERGY STAR buildings also showed lower cap rates than non-labeled properties, indicating expectation of stable cash flows over time.

- University of California and Maastricht University study of effective rents and sale prices of rated office buildings. This study examined a data sample from October 2009 of nearly 21,000 office buildings, comparing


rents and sale prices per square foot of those with ENERGY STAR and LEED ratings versus those without such ratings, while correcting for variation in other factors. These samples, taken from CoStar databases, included almost 21,000 rental buildings and 5,000 buildings sold since 2004, of which 2,687 had ratings under ENERGY STAR or LEED.

Effective rents, which are a function of rent amount and occupancy rate considered together, were 8 percent higher on average for rated buildings than for non-rated ones. Similar comparison of sale prices showed a premium of about 13 percent.

Growing demand and market share for energy efficiency and green buildings

- **Market share of green buildings.** The market share of green commercial and institutional buildings in the U.S. rose from 2 percent of total sectoral value in 2005 ($3 billion) to about 10 to 12 percent ($24-29 billion) in 2008. This share is expected to grow to 20 to 25 percent ($56-70 billion) by 2013.¹²

- **Willingness to invest in energy efficiency.** A November 2009 report by Jones Lang LaSalle found that 74 percent of corporate real estate executives are willing to invest in retrofitting spaces they own to save energy and improve sustainability. This figure represented a rise from 53 percent in a similar survey the previous year. The report stated that 89 percent consider energy use and other sustainability criteria when looking to buy or lease office space. This study also found that 37 percent of respondent companies would pay a lease premium of 1 to 10 percent for sustainable building space.¹³

Case studies

There are many case studies that document how energy efficiency and green building design have led to lower energy costs, improved financial performance, and other benefits for owners.¹⁴ Much less common are studies that show actual quantitative effects of documented energy performance on the appraised


value or market-defined sale price of the building. The lack of such evidence is presumably largely a matter of research effort and access, not necessarily lack of relevant cases. But in 2005, IMT did carry out two studies that definitively demonstrated such effects.

**Morrison Manor (Troy, N.Y.).** This 83-unit multifamily residential building was purchased for $750,000 in 2000. The new owner then installed a variety of energy efficiency measures, including replacement windows, added insulation, and new gas-fired heating and domestic hot water systems replacing electric baseboards and water heaters. The owner then decided to capture the savings by paying utility bills himself, passing along those costs to tenants as increased rent. These rents increased by 11 to 36 percent, with no accompanying rise in vacancy rate. The owner attributed “at least $85,000 and possibly much more” in increased rent per year to the retrofits. He sold the property for $1.79 million in 2005, just five years after initial purchase and less than two years after completion of the retrofits.

**Pine Harbor (Buffalo, N.Y.).** In this complex of 208 subsidized rental units, the owner pays utility bills. A switch from electric to gas heat in most units and some common areas yielded an increase in appraised value of 33 percent, or $4.68 per square foot. This appraised increase does not take account of greatly improved indoor comfort and tenant-landlord relations, with probable effects on tenant retention and reduction in vacancy rates; if such effects could be quantified, it would be reasonable to expect even higher incremental value effects.

**Conclusion**

The value of energy efficiency and sustainability in buildings goes beyond merely theoretical or calculated energy savings and financial performance. Now more than ever, this value is the reflection of real market demand and willingness of tenants and investors to pay more for efficient and green buildings. Increasing statistical evidence and case studies support this value trend. As the market share of green and energy-efficient buildings continues to grow, market awareness and preferences for efficiency and sustainability will likely become more and more evident via sales comps to appraisers everywhere, with effects pushing in both directions – toward increased value for efficient and green buildings, and toward diminished value for

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underperforming buildings with greater expenses and larger negative environmental impacts.

Market value of energy efficiency and sustainability is rising and becoming more definitive for many reasons, including evolving social and cultural priorities, increased public awareness about energy and sustainability in buildings, more accessible information tools and comps, and an expanding track record of technical know-how and implementation success in practically all subsectors of the real estate market. No longer invisible and oft-overlooked, energy performance and sustainability have become standard, even central criteria for defining and distinguishing value in buildings.

This appendix has three goals:

1. To assist the appraiser in understanding the basic categories of energy efficiency measures in buildings, and the specific sectors in which certain measure types are most important;

2. To advise the appraiser about how to identify and compare energy-performance levels of specific building materials and components;

3. Where available, to identify specific information sources with more information on how measure types affect energy consumption and energy costs.

With some measure types, especially lighting, energy savings and effects on cash flow are relatively easy to quantify. With other measures, however, it is usually quite difficult to assess how individual energy-efficiency measures will perform in terms of savings and payback. In an appraisal, therefore, use of this appendix to identify energy-efficient measures would have to be carried out in conjunction with examination of billing histories, operating expense statements, or engineering analyses of whole-building performance. See Section 3.

Insulation

The amount of heating and cooling that a building requires usually depends very heavily on transmission of heat through the “building envelope” — its outer shell of walls, windows, doors, roof, and bottom floor. Insulation of the building envelope, especially top-floor ceilings, is therefore a very important way to reduce a building’s energy bills.

Insulation can be made of various materials, including synthetic foam, cellulose fiber, mineral fiber, and fiberglass. The performance of insulation is expressed in terms of its “R-value,” or thermal resistance — the higher the R-value, the better the protection against heat transmission.\(^{17}\) R-values are usually visibly

\(^{17}\) Specifically, R-value is the inverse of the amount of heat that passes through a square foot of surface area, per degree of temperature difference on either side of the surface.
marked on insulation products, but note that R-value will depend on the
thickness of the insulation (as, for example, with double layers of fiberglass in an
attic) and most importantly, on installation quality. Absence of gaps and
avoidance of moisture and compression are essential for the durability and
proper function of insulation.

Insulation is especially important in small buildings (for example, single-family
residences), which have a larger ratio of surface area to volume than larger
buildings. Though we usually think of insulation as a protection against heat
losses during cold weather, insulation also helps buildings to stay cool in the
summer. In both hot and cold weather, insulation offers benefits in occupant
comfort as well.

**Windows**

Windows strongly affect a building’s energy consumption because of their
contribution to the building’s heat losses in cold weather and heat gains in
warm weather. Windows transmit heat, either from indoors to outdoors or vice
versa, by several means: 1) transmitting heat through the window panes; 2)
transmitting heat through the window frame; 3) leaking cold or warm air
through small seams between pane and frame or between frame and wall; and
4) allowing sunlight to enter the building and warm the indoors.

There are various types of window frames and window glass. Frame types
include aluminum (which is light and durable but transmits heat readily);
aluminum with thermal breaks (in which outer and inner layers of aluminum are
separated by an insulating layer); wood; insulated and regular vinyl; fiberglass;
and hybrid/composite. Windows may have one, two, or three panes of glass,
with or without special coatings or films to encourage or inhibit transmittance
of light or heat. Some windows are made of sealed multilayer glass units filled
with argon, a gas with especially good insulating properties.

In colder and temperate parts of the country, the most important energy-
related aspect of windows is their thermal performance — that is, their ability
to retain heat in the building during the colder times of year, and to keep heat
out during hot weather. The figure of comparison for window thermal
performance is called *U-factor*. Note that U-factor, somewhat confusingly, has
units that are the *inverse* of R-value for insulation; therefore the lower the U-
factor, the better. Another potentially relevant factor is the solar heat gain
coefficient (SHGC), which is an index of how well a window blocks out heat
caused by sunlight; the lower the SHGC, the less heat gain through the window.
(SHGC is most important in warmer climates, where cooling needs predominate.)

In both residential and nonresidential sectors, the National Fenestration Rating Council (NFRC)\(^{18}\) rates and labels windows for their U-factor and SHGC, as well as visible light transmittance coefficient. NFRC certification is recognized in the building-code compliance process in many states.

Aside from their direct impact on a building’s energy bill, the thermal properties of windows also have a major effect on the comfort of building occupants. When the indoor surfaces of an inefficient window become cold in the winter, people may sense the chill from the cold surfaces even at some distance away. Further, cold indoor surfaces can prompt the condensation of moisture or even the formation of frost, which can lead to an array of problems — including mildew and water stains, peeling of paint, and rotting and deformation of frames and sills.

**Lighting**

Lighting upgrades are among the most popular energy efficiency measures in major commercial building sectors, including office buildings, retail, health care, and educational facilities. Energy-efficient lighting measures have a long and successful track record, are relatively simple to install, and provide reliable, easily quantified energy savings.

Lighting typically accounts for more than 30 percent of electricity consumption in commercial buildings, and as much as 50 percent in some office buildings. Lighting upgrades can significantly reduce electricity consumption by as much as 65 percent while maintaining or even enhancing lighting quality. In addition, efficient lighting systems also generate less heat than inefficient systems, and therefore can help to reduce cooling costs.

Several elements of lighting systems present opportunities for energy savings: lamps (including bulbs and fluorescent tubes), ballasts, fixtures, controls, and daylighting.\(^{19}\)

*Fluorescent lamps* are the most commonly used commercial light source in North America. They come in various shapes and sizes. T12 lamps, which are

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\(^{18}\) For more information, see [www.nfrc.org](http://www.nfrc.org).

\(^{19}\) The remainder of this section is drawn largely from *Lighting Fundamentals* in the Lighting Upgrade Manual issued by the Green Lights Program of the U.S. Environmental Protection Agency, February 1997. See [www.epa.gov/buildings/ebhome/lightingfund.pdf](http://www.epa.gov/buildings/ebhome/lightingfund.pdf) for more details.
four-foot tubes 1½ inches in diameter, are the most common. Narrower, more efficient T10 and T8 lamps often replace T12s in routine lighting upgrades.

**Compact fluorescent lamps** (CFLs) replace conventional incandescent bulbs in various fixtures, especially overhead lighting. They cost several times more than conventional bulbs, but consume about 65 to 75 percent less energy, and last up to ten times longer. CFLs are not usually compatible with dimmable switches and fixtures.

**Ballasts** are the devices that deliver and stabilize electric current in fluorescent lighting tubes of various types. **Magnetic ballasts** (which are also called electromagnetic ballasts), in turn, encompass several types. Standard core-coil magnetic ballasts are the least efficient ballasts. So-called “high-efficiency” core-coil ballasts are about ten percent more efficient than standard ones, but despite the terminology, are still much less efficient than electronic or hybrid ballasts.

**Electronic ballasts** can replace magnetic ballasts in most fluorescent lighting applications, and consume about 12 to 25 percent less electricity for equivalent amounts of light. They also offer reduced noise and flicker, and are compatible with dimming in some cases. **Hybrid ballasts** (also known as cathode cut-out ballasts) are core-coil magnetic ballasts with some electronic components. They are approximately as efficient as electronic ballasts.

Ballasts are also used for high-intensity discharge lamps (HID lamps), a broad category that includes mercury vapor, metal halide, and sodium lamps. Such lamps are most common in industrial and outdoor lighting applications, though some HID lamps, especially metal halide, are also used indoors in office or retail settings. Selection of ballasts for HID lamps can have very important effects on lamp efficiency, lamp life, and maintenance costs.²⁰

**Light fixtures** (also called luminaires) direct and distribute light by means of their orientation, reflectors, and shielding. The primary purpose of fixtures is to enhance visual comfort; in certain cases the use of reflectors may distribute enough light to targeted areas to allow for removal of some superfluous lamps, resulting in energy savings.

**Lighting controls** include timers that shut off lights according to scheduled hours of occupancy; motion sensors which switch lights on and off as people come and go; and manual and automatic dimmers. Such controls are especially

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²⁰ More information on HID ballast selection is available in *Lighting Fundamentals* (see footnote 4).
important in office buildings, in which people leave rooms and workstations unoccupied periodically during the day and for long stretches every night.

Smart building design for maximum natural light (also known as “daylighting”) can therefore be an important source of added value. Natural light reduces the need for artificial light and accompanying electricity costs. Also, perhaps even more importantly, daylighting can make indoor spaces more pleasant for occupants. Daylighting has been shown to increase productivity in offices and even to increase sales in retail settings.

Of course the arrangement of windows and skylights are key aspects of daylighting design. Light shelves and clerestories near windows can help to reflect natural light deep into interior spaces. In some newer office settings, you might encounter automated systems that measure ambient natural light and respond by delivering only needed quantities of artificial light.

**Heating, Ventilation, and Air Conditioning (HVAC) Systems**

HVAC systems vary widely in size and complexity, and cover a broad range of equipment, pipes and ducts, and controls. It is beyond the scope of this brief appendix to address the entire gamut of HVAC equipment and their efficiency ranges. Here we present a brief overview of major system types and key components, and discuss some general principles for equipment selection and management that make for efficient systems.

*Packaged HVAC systems* are relatively small, complete units that offer heating and cooling, and are ready for installation when purchased off the shelf. Packaged systems include units intended to serve entire buildings, as well as window or wall units that serve one room. *Central HVAC systems* are typically used in larger buildings. Central HVAC systems are custom designed and built, and collectively encompass a broad range of equipment types. Central systems can be quite complex.

High-efficiency HVAC systems can use 35 to 40 percent less energy than conventional new systems. Savings can be even greater when new systems are custom-engineered or replace old systems. A number of factors can contribute to greater efficiency in packaged or central systems:

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**Efficient equipment.** The overall efficiency of an HVAC system depends largely on the efficiency of the primary heating and refrigeration equipment in the system. All packaged systems have certified efficiency ratings, which may serve as a basis for comparison one against another.\(^{22}\) The key components of central HVAC systems, including chillers and boilers, also bear certified efficiency ratings. Installation of a high-efficiency chiller in a central HVAC system for a multi-story office building can reduce electrical consumption by 35 percent.

Heat pumps use a refrigeration cycle to provide either heating or cooling. For cooling, they operate like conventional air conditioners; for heating, they essentially run the refrigeration cycle in reverse, removing heat from the outdoor air or the ground and sending it indoors. Heat pumps can be efficient when it is not very cold outside, since they use “free” heat instead of fuel for a portion of the building’s heating needs. (When it is cold outside, heat pumps must provide supplementary heat, usually with electric resistance heating, which is relatively expensive and inefficient.)

**Economizers.** An economizer allows outside air to be used for cooling when its temperature is lower than the temperature inside the building. Rooftop units are particularly well suited for using this “free” cooling, and economizers are available as an option for many off-the-shelf units. Economizers can also be retrofitted to existing packaged and central systems, especially ones that are not too old.

**Variable air volume systems.** Larger, more complex buildings usually have multiple zones with simultaneously different space-conditioning needs. One highly inefficient way to meet differing heating or cooling loads in each zone involves reheating the cool supply air as desired just before it enters the room. This system is called “terminal reheat.” Also highly inefficient and costly are dual-duct systems, which maintain separate supplies of heated and cooled air, and mix them via thermostatic controls before delivering the air to rooms — essentially, heating and cooling the room at the same time!

A much more efficient alternative, variable air volume (VAV) systems control the amount of hot or cold air flowing into each area, as needed. The systems control the flow of conditioned air by any of various means. Most efficient is the use of an adjustable speed drive (ASD) to match the speed of the supply fan to the amount of air needed. ASDs are not currently available for off-the-shelf rooftop

\(^{22}\) Numerous types of efficiency ratings are used, reflecting subtle differences in the types of operating performance being measured. A detailed glossary of efficiency rating terminology for HVAC equipment may be found at [http://www.pnl.gov/fta/2_appc.htm](http://www.pnl.gov/fta/2_appc.htm).
units. Manufacturers can outfit custom and semi-custom units with ASD fan controls.

**Evaporative cooling.** Some packaged and central systems employ evaporative cooling, in which air is cooled by evaporating water. Evaporative cooling cuts the work that the system’s refrigeration equipment must do, raising the capacity of the system.

**Controls.** The most basic energy-saving HVAC controls are programmable which turn heating or cooling systems down or off when facilities are unoccupied. Even more savings may be achieved by means of energy management systems (EMS), which coordinate HVAC operations among multiple units and multiple zones, helping to prevent problems such as adjacent units working against each other (one unit heating a space, another cooling the adjacent space). Upgraded energy management systems can often reduce overall energy use by 15 percent or more. In addition, these devices maintain system start-up and set-back schedules to optimize building occupant comfort.

**Thermal storage.** Thermal storage systems operate at night when electric rates are lower, storing cold or heat for use during daylight peak hours. Though thermal storage systems do not save energy, they do reduce energy costs, as well as offering the societal benefits of reducing the need for new power plants.

**Monitoring and maintenance.** Regular monitoring and maintenance of HVAC systems is absolutely critical for efficient performance, especially with advanced and complex systems. Control failures in particular — including malfunctioning thermostats, misprogrammed EMS, and stuck dampers in VAV systems — can negate any advantages that an efficient system is supposed to provide. In addition, seemingly simple problems such as slipped fan belts, clogged filters, and fouled surfaces can also have major deleterious effects on system efficiency.

*Commissioning* is the systematic examination of building systems and operations for opportunities to fix problems, assure proper function, and optimize energy performance. Commissioning of HVAC systems by an experienced practitioner, either upon initial construction or during the building’s operating life, can be an important way to assure that efficient systems are operating as they should, and that expected energy savings will be reliably achieved.

**HVAC equipment sizing.** Appropriate sizing of HVAC equipment is critical. Building owners and managers often choose redundant or oversized cooling equipment for reliability against failure or for assurance of sufficient cooling
during the hottest weather. In these cases, the frequent result is that the cooling system operates only at a fraction of its capacity — and at suboptimal efficiency — the rest of the time. Oversized HVAC systems can therefore lead to lower overall efficiencies and higher operating costs.

This disconnection between system size and efficient system performance demands that an appraiser be especially careful in accounting for HVAC systems, which are the most expensive sets of equipment in many buildings. A cost-based valuation approach will favor larger, more expensive systems, but if oversized, these same systems will have less value in terms of the income approach than a smaller, less expensive, correctly sized system.
8. Other Resources

The following documents offer some illuminating discussion of energy performance, green building, and property value. Note that the latter three tend to emphasize investment and underwriting perspectives, rather than appraisal itself.


ABSTRACT
Solar electric systems increase the value of homes in several ways. They can reduce or eliminate the energy operating cost of the home. They hedge against or eliminate the effect of electric rate inflation. As a component of the home, in many cases they can provide an attractive vehicle for financial investment.

These monetary benefits are financially quantifiable. A solar electric system increases home value by $20,000 for each $1,000 in annual reduced operating costs, according to the Appraisal Institute. A solar electric system compares very favorably with other home improvements in percentage of cost recovered. Often, a solar system can recover much more than 100% of its cost, and this percentage actually increases over time as electric rates rise.

A solar electric system can also supply numerous intangible benefits that may be valued by some buyers.

1. INTRODUCTION
For solar to be accepted by the broadest spectrum of society, it must compete on the financial terms society expects, regardless of the intangible health or social benefits it provides. These intangible benefits are highly valued by some, but seem not to be something for which the broader cross section of society will pay more. To compete on a financial basis, it must provide a “good” financial rate of return. However “good” is relative to its comparative risk. In financial circles, this is termed “Risk vs. Reward.”

For solar to be evaluated as an investment, the risk must be quantifiable and understandable. The solar industry is getting beyond the feared risk that the systems won’t work. There is now much proof that they work very well. Another risk is liquidity. If the owner must sell the property before the system has achieved payback, can they get some money back out of the system? How much and at what rate does it depreciate?

This paper will show that solar electric systems in California will increase a home’s value. The increase in value is often as much or more than the systems initial net cost. Hence the payback risk may be eliminated from the beginning. This paper will also show that the solar system’s value as a component of the home’s value will appreciate, not depreciate over much of its 30-year design lifetime.

2. DIRECT SAVINGS INCREASE VALUE
2.1 Solar Reduces Home Cost Of Operation
A properly designed and installed solar electric system can reduce the net electrical consumption and electric bill of a home. Electric bills can often be reduced to nearly $0.00 per month. In some cases there are minimum fees. Factors affecting the reduction in the electric bill include:
- How much energy was generated by the solar system.
- When the energy was generated.
- When energy was consumed in the home.
- Net-Metering of energy exported to the utility.
- Time-of-Use rate tariffs on the imported and exported energy.
- Reduction in penalty surcharges due to offsetting high usage amounts (see Fig. 1).

![Fig 1: PG&E Rate Tiers with penalty surcharges for high levels of usage.](image)

Average users use 130% of baseline (the first two tiers). High users are penalized for excess energy consumption. Usage above average (130% of baseline) is charged at $0.194, $0.238, or $0.258 per kWh.

2.2 Reduced Cost Increases Value
According to articles by Nevin in the Appraisal Journal, the increase in appraisal value for a home with an energy efficiency measure (in this case, a solar electric system) is about twenty (20) times the annual reduction in operating costs due to that energy efficiency measure.

That is to say, if a solar system can reduce the electric bill by $1,000 per year, the home is worth about $20,000 more in increased appraisable value. The rational is that if the $1,000 is not spent on electricity, it is available to be spent on a larger mortgage payment at no net
change in the cost of living. The amount of mortgage that can be supported by $1,000 depends on mortgage rates and the tax rate of the borrower.

Nevin states that after-tax mortgage rates have averaged about 5% over the longer term. At 5%, a $20,000 mortgage costs $1,000 per year, hence the 20:1 ratio. Mortgage rates vary, so depending on market conditions, the ratio has ranged from less than 10:1 to over 25:1. As of March 2004, long term mortgage rates at historic lows of 5.5% before tax, or 3.3% after-tax. At these very low rates, the ratio is about 30:1.

The assurance to a consumer of good resale value for the solar system may be important over the near-term, mid-term and long-term futures. It would be inappropriate to assume rates will stay at low levels over the mid-term and long-term, so it is more reasonable to continue with Nevin’s estimate of 5% after-tax, giving the 20:1 ratio. This will be referred to as the “20:1 ratio product.”

Table 1 illustrates the relative increases in appraisal value compared to system net cost for several examples in California’s PG&E service area. In California the penalty surcharges increase as the electrical usage increases. Therefore, the larger systems in the example are paying relatively higher electric rates and see substantially larger savings in proportion.

2.3 Comparison To Other Home Improvements
A solar electric system compares very favorably with other home improvements in percentage of cost recovered. Often, a solar system can recover much more than 100% of its cost. The last column in Table 1 shows the percentage of cost recovery for the three solar cases.

Remodeling Online3 reported in its “2003 Cost vs. Value Report” on the relative cost recovery of common types of home improvements based on data from national home remodeling and home resale surveys. Some of these projects are highlighted in Table 2. The best cost recovery of all common remodeling projects was the addition of a deck. On average it returned 4% more in resale value than it cost.

It should be noted that all these resale values are in addition to the benefit enjoyed by having and living with each project after completion. The same can be said of solar. The solar owner gets to enjoy the utility bill savings and any desired non-financial benefits.

2.4 Probable Limits to Immediate Appreciation
Will a homebuyer pay more for a used solar system on an existing home than the net cost of a new system that they could retrofit to the home after purchase? That is, why should a buyer pay 153% (see Table 1) for a used solar system, when they can get a new one at 100%? This is an open question.

However, buyers apparently do pay about 4% more for homes with decks than if purchased a home without a deck and contracted for its installation. Even more striking, Remodeling Online3 reports that in Boston, San Francisco and St. Louis, homebuyers paid over 215% of the cost of the retrofit. This same phenomenon occurred with other types of improvements in certain cities, even though the national average was less than 100%.

2.5 Appreciation, then Depreciation
As the systems age, they should appreciate if electric rates rise. The more rates rise, the larger the 20:1 ratio product on savings. This will continue until near the end of life when depreciation can be assumed to occur (Note: “depreciation” here refers to the real loss in financial value, and is unrelated to the “depreciation schedules” used in taxation).

Depreciation will begin to occur a few years before the 25 year warranties on the solar modules expire, as the inverters begin to need replacement, and as the system requires more maintenance due to age. During this period, it is anticipated that the system’s 20:1 ratio product based on the much larger future savings will be discounted by the depreciation into end of practical life.

2.6 Price Support
In the future, homebuyers may not be willing to pay more than 100% of contemporary costs for a new system. The 20:1 ratio product shows there may be price support for paying at least

### Table 1: Example Appraisal Increases in Value for California Homes

<table>
<thead>
<tr>
<th>Pre-Solar Bill</th>
<th>Pre-Solar Usage (kWh per Month)</th>
<th>System AC Size</th>
<th>Monthly Savings</th>
<th>Final Net Cost</th>
<th>Appraisal Equity Increase @ 20:1</th>
<th>% Cost Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>$80</td>
<td>600</td>
<td>2.6 kW</td>
<td>$73</td>
<td>$17.5K</td>
<td>$17.6K</td>
<td>100%</td>
</tr>
<tr>
<td>$190</td>
<td>1100</td>
<td>5.2 kW</td>
<td>$184</td>
<td>$31.4K</td>
<td>$44.2K</td>
<td>141%</td>
</tr>
<tr>
<td>$310</td>
<td>1575</td>
<td>7.8 kW</td>
<td>$303</td>
<td>$46.3K</td>
<td>$72.6K</td>
<td>157%</td>
</tr>
</tbody>
</table>

Variables: $3.00/W Rebate, 7.5% State Tax Credit, 31% Federal Tax Bracket
Net cost includes a Permit Fee of $600 & Time-of-Use meter fee of $277
Simple roof installation by a full service provider with no complications. Utility Territory PG&E XB.

### Table 2: 2003 National Averages of Cost Recovery for Remodeling Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Project Cost</th>
<th>Resale Value</th>
<th>Percentage of Cost Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Addition</td>
<td>$6.3K</td>
<td>$6.7K</td>
<td>104%</td>
</tr>
<tr>
<td>Bathroom Remodel</td>
<td>$10.1K</td>
<td>$9.1K</td>
<td>89%</td>
</tr>
<tr>
<td>Window Upgrade</td>
<td>$9.6K</td>
<td>$8.2K</td>
<td>85%</td>
</tr>
<tr>
<td>Kitchen Remodel</td>
<td>$44K</td>
<td>$33K</td>
<td>75%</td>
</tr>
</tbody>
</table>
100%. This will provide a current owner the assurance that they can get their money back out of the system if they need to sell. In the mean time, they can enjoy its benefits. The “100% of contemporary costs for a new system” level will vary over time. In much of the world, this is a declining amount. In California, where the rebate on solar systems is declining more quickly than gross system installed costs, the net price to consumers is increasing. In California this should lead to increasing levels of price support compared to costs paid.

3. HEDGE AGAINST INFLATION
3.1 Electric Rates Have Generally Increased
Throughout history, electric rates have generally trended higher. Fig 2. illustrates the average 6.7% annual compounded increases from 1970 to 2001. This is an effective doubling of rates every 12 years.

Fig 2: California Public Utilities Commission 30 Year California Electric Rate History

3.2 Hedging
Hedging is a financial term meaning “to counterbalance with another transaction to limit risk.” A solar system offers a “hedge” or protection against continued rate increases.

A home that substantially cuts its net electric usage is less subject to inflation and price spikes. The present value of these future savings can be quantified using discount rates and estimates for inflation rates. Larger California residential customers were also subjected to changes in the rate structure established by the tiered pricing (see Fig 1).

3.3 Kilowatt-Hours Not Purchased
There are many small charges bundled with the electric generation charge for each kWh. Charges for Nuclear Decommissioning, Trust Transfer, Transmission, Distribution, Bonds, and taxes are all eliminated for each kWh that is not purchased. Future charges added to the electric rate will be avoided as well.

4. ADDITIONAL INVESTMENT IN THE HOME
A solar system offers an additional avenue for investment in the home. Like adding another room, the solar system allows the owner to put more money to work in the real property investment. There are several ways to view and test this investment.

4.1 Financial Investment Viewpoints and Tests
A financial life cycle analysis can test the feasibility of a solar project. The simplest test looks at all the costs and all the savings, including inflation, over the 30-year life of the project. If the net savings are larger than net costs, then the project pays for itself in these simple terms. Generally solar systems pay back 2 to 4 times as much as they cost. This test does not account for the “Time Value of Money” which is akin to not accounting for the lost interest you could have earned elsewhere if you didn’t have to pay for the solar system up front.

This test can also be expanded into the Payback test, which asks when a system has “Paid For Itself.” This is considered a crude test, because it does not account for the future value of all the assured savings that will be accrued due to the long warranties on solar electric modules. Usually paybacks occur in 7 to 15 years, leaving 13 to 20 years of system life remaining to be enjoyed.

A more detailed test looks at the Rate of Return over the same 30-year project life. All the costs and all savings are accounted for in their relative timeframe. Using an “Internal Rate or Return” analysis, the effective interest rate paid by the project can be found. This interest rate can be compared with other investments. Residential solar projects in California often have Internal Rates of Return in the 10% to 20% range, which compares favorably with the long term stock market at 10.5% over the last 80 years.

Fig 3: Cash flow effect of 5kW solar on a $175/month bill.

Cash flow is another type of test. It compares the savings on the utility bill with the cost of financing the system. In many cases starting the first month, it costs less to borrow the money to put a system in, than it does to keep paying the utility. Borrowing at a fixed interest rate gets more advantageous as the electric rates go up and the effective savings grow, but the loan payment stays the same. These projects often achieve positive cash flow right away, and improve as inflation increases the electric bill savings. See Fig. 3 for an example of a 5kW PV system offsetting a $175/month bill.

Generally, homes that spend $65 or more a month on electricity tend to be good candidates. Cases that show solar to be a good investment will naturally attract homebuyers who will want to get that good investment.
5. INTANGIBLE BENEFITS
There are numerous intangible benefits that will attract buyers as well; environmentally sound energy use & self-production, the feeling of independence from the utility and its high or rising rates, and incorporation of high technology that some will enjoy having built into their home.

6. EXAMPLES IN THE MARKETPLACE
6.1 Few Comparables To Date
There are few if any documented cases where a solar electric home clearly sold for a quantifiable higher amount vs. its comparables.
In California, as of March 2004, there are about 9,000 grid tied solar homes, 94% of which were installed in the last three years, since the power crisis. There are about 4,000 more in the queue to be installed in the next year.

Since the normal occupancy time of a home is about 7 years, many of these new solar homes have not sold. It is likely that most homeowners who install solar are planning on staying in their homes longer than average, or they would likely not have made the investment. Therefore, relatively few solar homes have sold throughout the state.

Once these homes begin going on the market in large numbers, and the market can evaluate the claims of reduced operating costs and assign them a value, studies can be conducted to determine the validity of the claims in this paper. It will then be possible to compare a solar home side by side with a similar non-solar home.

6.2 Reasons For Confidence
Approximately 13,000 homeowners in the last three years have seen enough value in solar systems to make a major financial commitment. As long as their systems perform, they are likely to have that value realized. This will support the market in two ways. They have a higher likelihood of purchasing solar on their new homes when they move. The author has already seen this happen in three individual cases. They will provide examples and word-of-mouth in their communities that the systems have and create value.

While the 13,000 may have purchased primarily for their own use, it is reasonable to conclude there are others who would be interested in purchasing, thus creating a market support for some extra, but as yet unquantified value.
A survey conducted for the California Energy Commission’s Renewable Energy Program showed that 50% of Californians would be willing to pay more for a home already equipped with solar technology, and more than 60% would be more interested in a home that has a renewable energy system than in one that doesn’t.

6.3 Counter Examples and Caution
Many homeowners and purchasers have opinions about the attractiveness of various solar technologies on residential roofs. Some like it, some do not, some don’t know what they are looking at and don’t object. If the home looks weird it can hurt value.
Toronto real estate appraiser Alan Wood finds that while homeowners are willing to invest solar, most are unwilling to purchase a more expensive home custom-built for this purpose. Wood further states that market appeal and resale value are lowered when the energy-conserving home looks noticeably different from most others.

7. CONCLUSION
Several ways of demonstrating that solar electric systems increase the value of homes have been shown, reducing the financial risk to purchasers. Solar electric systems can reduce or eliminate the current and future energy operating cost of the home. They hedge against or eliminate the effect of electric rate inflation. As a component of the home, in many cases they can provide an attractive vehicle for financial investment. These tangible benefits are financially quantifiable. A solar electric system increases home value by $20,000 for each $1,000 in annual reduced operating costs due to the system. In California, a solar electric system compares very favorably with other home improvements in percentage of cost recovered, often recovering more than 100% of its cost.

8. RECOMMENDATIONS
8.1 Future Areas of Study
A survey is needed of actual retail sales of solar homes. The study might test resale value against comparable homes and contemporary local net installed system costs. Another study might evaluate the change in resale value when both buyer and seller are informed of the ways of valuing a solar system on a home.

8.2 Suggestions for Implementation in Other Areas
In the author’s opinion the most important factors that could improve solar financial viability in other areas are:
- Implementation of Time-of-Use Net Metering
- Establishing a tiered electric rates penalizing high users
- Small and declining subsidies as needed
Small subsidies may be needed in certain regions with low electric rates until electric rates rise and solar costs fall as has happened in California. There are several states that have sufficiently high electric rates. If those states adopted Time-of-Use Net Metering and a tiered rate structure, solar for large users to be very close to financially viable without any subsidy, as is the case in California.

9. REFERENCES
Appraisers are breaking new ground in the area of valuing green or high performance houses. Green construction has been around for a long time. However, today more emphasis is placed on the term energy efficient as part of the green concept and Energy Star program. These terms need defining before the related valuation issues can be discussed.

Defining and Rating Green

A high performance house is one that takes advantage of energy efficiency, and sustainable and environmentally friendly products. A search of many articles and Web sites does not result in one standard definition of high performance house, but all seem to emphasize energy efficiency, sustainability, and environmentally friendly products.

The fifth edition of The Dictionary of Real Estate Appraisal defines sustainability, in green design and construction, as “the practice of developing new structures and renovating existing structures using equipment, materials, and techniques that help achieve long-term balance between extraction and renewal and between environmental inputs and outputs, causing no overall net environmental burden or deficit.”

According to the National Home Builders Association (NAHB), green construction pays attention to energy efficiency, water and resource conservation, the use of sustainable or recyclable products, and measures to protect indoor air quality.

The green trend does not appear to be a fad, but will be the market for tomorrow. The government is strongly encouraging the use of environmentally friendly construction, and there may be green-construction mandates in the future. Efforts and techniques to document and analyze green construction will come to be expected by the users of appraisal reports.

There are numerous green rating programs available in communities for appraisers to research and to learn about each program’s incentives. Three examples of these programs include Energy Star certification, LEED certification, and NAHB green certification.

Energy Star is a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy. It was created to help save money and protect the environment through energy-efficient products and practices. To earn the Energy Star label, a home must meet energy-efficiency guidelines set by the EPA. An independent home energy rater conducts onsite testing and inspection to verify that a home’s performance meets Energy Star requirements. A HERS Index is used to rate the energy efficiency of a home.

Another green certification that building owners can pursue is the Leadership in Energy and Environmental Design (LEED) certification. LEED is a voluntary green building certification program developed by the U.S. Green Building Council, which provides third-party verification of green building and performance measures. LEED-rated homes are...
considered to have the premier green rating, but LEED ratings are the most expensive ratings to obtain.

The NAHB Green Building Coalition also has a green certification program and rating for houses. A NAHB green-certified house has higher energy savings than an Energy Star house. Green certification is based on the NAHB Model Green Home Building Guidelines and the National Green Building Standard.7

Because there is not one definition for green and more than a hundred green programs, learning about the relevant green products can be a challenge for the appraiser. It requires research by the appraiser and documentation from the client. But despite the difficulty, it is important for the appraiser to be thorough and to document his or her file. Green building products, techniques, and ratings are constantly changing, so appraisers will need to stay abreast by seeking out educational opportunities. It is helpful to spend time with a builder of green houses to learn more about the products used in green construction. Also, the Appraisal Institute offers two seminars on green construction, An Introduction to Valuing Green Commercial Buildings and Valuation of Residential Green Residential Properties. More educational offerings on the subject are expected soon.

The NAHB has a local green council in most areas that offer short seminars or roundtables on the topic and would welcome appraisers. State and local green organizations also provide information. For example, for appraisers in Florida, the Web site of the Florida Green Building Coalition is helpful, http://www.floridagreenbuilding.org/db/. Other useful Web sites where appraisers can research a product, material, or term include the following:

http://www.energystar.gov/index.cfm?c=new_homes.hm_index
http://www.energystar.gov/index.cfm?c=blhrs_lenders_raters.nh_HERS
http://www.natresnet.org/
http://www.nahbgreen.org/
http://www.appraisalinstitute.org
http://www.earthadvantage.com

The incentives available to the owner or buyer are good talking points to include in the analysis. However, as mentioned before, sometimes it is very difficult to obtain the related documents. Appraisers should be patient but persistent in getting the documentation necessary to support the facts in their reports.

A third-party rating provides monthly utility savings that can be converted into a contributory value. This figure is printed on a form called the Fannie Mae Energy Report and signed by the third-party rater.

The contributory value estimate found on the Fannie Mae Energy Report form from the third-party rater can be calculated by the Calcs Plus Software using the present value of the annual energy savings, the prevailing mortgage interest rate, and the anticipated life of the measure or savings. For example, using an HP 12C to calculate the contributory value of a monthly energy savings of $59.58, or annually $714.96 ($59.58 × 12 = $714.96), with an annual interest rate of 6% for a 15-year period, results in the

---

7. The NAHB green rating is like a bowling game, the higher the green score the better. The NAHB Research Center accredits third-party verifiers and acts as the certifying body for the National Green Building Program. For more information, see http://www.nahbgreen.org.

8. Energy efficient mortgages (EEMs) are sponsored by FHA, VA, Fannie Mae, and Freddie Mac as well as conventional lenders. An EEM credits a home’s energy efficiency in the mortgage itself, and gives borrowers the opportunity to finance cost-effective, energy-saving measures as part of a mortgage and stretch debt-to-income qualifying ratios on loans, thereby allowing borrowers to qualify for a larger loan amount on an energy-efficient home. For more information, see http://www.energystar.gov/index.cfm?c=blhrs_lenders_raters.energy_efficient_mortgage.
following key strokes: \( N = 15, I = 6, \text{PMT} = $714.96, \) and the PV should result in $6,943.87.

The appraiser's question is how reliable is the estimate of monthly savings and the estimated life of the savings? Is this estimated contributory value reasonable and worthy of belief? Does this contributory value represent a number that mirrors market reaction? Each appraiser must answer these questions in relationship to the particular market and the product he or she is appraising. This approach to valuing the energy savings is only one way to approach value and should be supported with another piece of secondary support.

Having some basis for value or lack of contributory value is the main point addressed by Uniform Standards of Professional Appraisal Practice (USPAP) and by Fannie Mae in its mortgages. For example, comparing the HERS Index ratings of the comparables is a measurement of comparability. It would be ideal to have the HERS Index on all comparables; however, that is typically not available in the real world unless the subject is in a development of green construction with ample sales data.

**Describing Improvements**

Describing an Energy Star or green home should begin with page one of Fannie Mae Form 1004, the Uniform Residential Appraisal Report (URAR), even if the conclusion is no contributory value is appropriate. An accurate description of the subject property is a requirement set forth in the USPAP Standard 2.

The description of a green property begins with the site description. Green properties take advantage of trees for shading in specific locations and minimize yard watering by using deciduous plants. The improvement description should properly describe the energy and green features, which may include solar panels, low-volatile organic compound (VOC) paint, an NAHB green score or HERS Index rating, recycled glass counter tops, structural insulated panel (SIP) exterior walls, energy-efficient central air, linoleum, wool carpet, etc. Figure 1 shows an example of a description of green improvements on page one of a URAR form.

**Figure 1 Improvements Section of the URAR**

![Improvements Section of the URAR](image)
Selecting Comparables
The selection of comparables is difficult in areas where there are few green or Energy Star homes. Obtaining comparables with similar-quality features, including the energy-efficient or green features, is the goal, but these comparables are not always available. If the local multiple listing service (MLS) does not have a search field for green and Energy Star homes with a rating, ask them to insert one. This will make comparable selection easier.

Remember, don’t be fooled. Just because a house is called green or energy efficient does not mean it is certified, truly green, or energy efficient. Upon questioning agents on these statements, it is common to find the only energy-efficient features are the appliances. That is a far stretch from a certified Energy Star or certified green home.

Also, keep in mind that building codes have changed in the last five years. The typical green or Energy Star house is built above the standard building code. This makes it extremely important to use new construction as comparables when appraising new green or Energy Star houses. The use of ten-year-old houses compared to a new green-rated house without consideration of quality is inappropriate.

Finally, great care must be placed in using new construction as an arm’s-length sale. Some builders offer package deals on speculative houses and lots. The properties are marketed by the builders’ sales staff or through the MLS. This type sale would be similar to a typical arm’s-length transfer. But, where the property owner hired a builder to build a green house on a lot, it would not result in an arm’s-length transfer. The appraiser must use good judgment in qualifying the comparable sales.

Elements of Comparison
On the second page of the URAR, the sales comparison approach section has three line items that may require adjustments in the valuation of the high-performance home: Quality of Construction, Heating/Cooling, and Energy-Efficient Items (Figure 2). If adjustments are not applied, a comment should be made as to why an adjustment has not been made.

Figure 2 Sales Comparison Approach Section of the URAR

<table>
<thead>
<tr>
<th>Sale Price</th>
<th>$255,000</th>
<th>$232,000</th>
<th>$135,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Source(s)</td>
<td>MLS Tax Record</td>
<td>MLS Tax Record</td>
<td>MLS Tax Record</td>
</tr>
<tr>
<td>Verification Source(s)</td>
<td>Agent</td>
<td>Agent</td>
<td>Agent</td>
</tr>
<tr>
<td>VALUE ADJUSTMENTS</td>
<td>DESCRIPTION</td>
<td>+$0.00</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>Sale or Financing Concessions</td>
<td>Conventional</td>
<td>None</td>
<td>Conventional</td>
</tr>
<tr>
<td>Date of Sale/Time</td>
<td>4/01/XX</td>
<td>6/12/XX</td>
<td>4/01/XX</td>
</tr>
<tr>
<td>Location</td>
<td>Urban</td>
<td>Urban</td>
<td>Urban</td>
</tr>
<tr>
<td>Leasehold/Live Simple</td>
<td>Fee Simple</td>
<td>Fee Simple</td>
<td>Fee Simple</td>
</tr>
<tr>
<td>Site</td>
<td>10,000 sq. ft.</td>
<td>11,000 sq. ft.</td>
<td>10,000 sq. ft.</td>
</tr>
<tr>
<td>View</td>
<td>Residential</td>
<td>Residential</td>
<td>Residential</td>
</tr>
<tr>
<td>Design (Style)</td>
<td>Key West</td>
<td>Key West</td>
<td>Key West</td>
</tr>
<tr>
<td>Quality of Construction</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Actual Age</td>
<td>New</td>
<td>New</td>
<td>New</td>
</tr>
<tr>
<td>Condition</td>
<td>New</td>
<td>New</td>
<td>New</td>
</tr>
<tr>
<td>Above Grade</td>
<td>Total</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Room Count</td>
<td>5</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Gross Living Area</td>
<td>1,616 sq. ft.</td>
<td>1,723 sq. ft.</td>
<td>1,616 sq. ft.</td>
</tr>
<tr>
<td>Basement &amp; Finished</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooms Below Grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional Utility</td>
<td>Average</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>Heating/Cooling</td>
<td>FWA Central/Eff</td>
<td>FWA Central</td>
<td>FWA Central</td>
</tr>
<tr>
<td>Energy Efficient Items</td>
<td>83.4 HIES Score</td>
<td>Average</td>
<td>83.4 HIES Score</td>
</tr>
<tr>
<td>Garage/Carport</td>
<td>Two-Carage</td>
<td>Two-Carage</td>
<td>Two-Carage</td>
</tr>
<tr>
<td>Porch/Patio/Deck</td>
<td>Covered Entry Lanai</td>
<td>Covered Entry Lanai</td>
<td>Covered Entry Lanai</td>
</tr>
<tr>
<td>Net Adjustment (Total)</td>
<td>+ $0.00</td>
<td>+ $0.00</td>
<td>+ $0.00</td>
</tr>
<tr>
<td>Adjusted Sale Price</td>
<td>$234,330</td>
<td>$234,330</td>
<td>$234,330</td>
</tr>
</tbody>
</table>

Provided courtesy of the Alliance for Environmental Sustainability
www.alliancees.org
The appraiser should carefully consider the quality and energy features of each comparable home. Do the comparable sales have the same incentives as green or Energy Star homes? Do the incentives have value and offset some of the additional costs for the features? Items that are not quantifiable may be addressed qualitatively. A discussion of the incentives, monthly energy savings, and lower maintenance items are good talking points in the analysis.

Again, appraisers should not be afraid to ask questions and require additional documentation. Not all green or energy-efficient houses have third-party certifications. That does not mean they are not green or not energy efficient. It is important for the appraiser conducting the analysis to know how to analyze a green product’s value, as USPAP requires the appraiser to be competent in appraising the property type.

**Measuring Contributory Value**

There are a number of techniques to measure contributory value of green features, including the following:

- HERS Index rating converted into value
- Monthly energy savings × gross rent multiplier (GRM)
- Cost new or depreciated cost new
- Paired sales analysis

Notice the emphasis is on energy efficiency and not on quality. The quality issue is beyond the scope of this article. Quality issues must be carefully measured in the same manner appraisers currently measure quality differences. Qualitative analysis should include a discussion of incentives, energy savings and sustainability of green features, and compare the local building code to the green house.

Underwriters may indicate that Fannie Mae does not allow adjustments for energy-efficient features, but that is not the case. It is important, however, to have support for the energy adjustment. This is commonly done by capitalizing the energy savings (energy savings × GRM). Fannie Mae has acknowledged the role of energy-efficient items for years in its underwriting guidelines. For example, the Fannie Mae Selling Guide includes the following section:

**Insulation and Energy Efficiency of the Improvements**

An energy-efficient property is one that uses cost-effective design, materials, equipment, and site orientation to conserve nonrenewable fuels.

Special energy-saving items must be recognized in the appraisal process. The nature of these items and their contribution to value will vary throughout the country because of climatic conditions and differences in utility costs.

Appraisers must compare energy-efficient features of the subject property to those of comparable properties in the “sales comparison analysis” grid to ensure that the overall contribution of these items is reflected in the market value of the subject property.

**Cost Approach**

When the cost approach is used, it should address the green features with support from a national cost service or local builder costs. Marshall & Swift’s *Residential Cost Handbook* has an energy-efficient package adjustment that can be applied to the energy features. Marshall & Swift also has a new publication for green construction, the *Green Building Costs* supplement.

Green construction does not always mean higher cost to construct. Some builders report no additional cost as buyers often forego some quality features and replace them with green materials. Experienced builders often find the method used for green features result in less building time and less construction debris.

**Case Study: Converting Green Built to Green Contributory Value**

The following short case study uses procedures taught in the Basic Appraisal Principles and Basic Appraisal Procedures classes to support adjustments for green or energy-efficient items.

For this case study, assume Jane Cross, a builder, built an Energy Star home with a HERS Index of 64. The home also has a Green Score of 294; the Green Score is from the Florida Green Building Council (FGBC) third-party rater. The anticipated monthly energy savings is $59.58 with an energy savings contributory value estimated at $8,653.60.

The house was built for the builder’s own residence and a mortgage was obtained. Within three months of making mortgage payments, the owner/builder realized she was paying private mortgage insurance (PMI). Jane phoned the mortgage company to question the

10. The FGBC rating is based on a standard checklist of building features and components. The checklist includes the following categories: envelope, mechanicals, energy, water, lot choice, site, health, materials, disaster mitigation, and general items. At the time the case study house was built, the FGBC green ratings were 200 to 400, with the higher number indicating a house with more green features.
PMI payments. The mortgage company revealed the appraised value was not high enough to justify an 80% loan-to-value ratio. Jane was puzzled since she did not include a builder’s profit and did much of the labor herself. Her estimate of market value was much higher than the appraised value.

Upon review of the appraisal, she found the energy-efficient and green features were not noted. The comparables were not similar in quality, had no energy-efficient or green features, and one was a fifteen-year-old structure. The appraiser was questioned. The response was the energy-efficient adjustment could not be supported and would not be accepted by underwriters or Fannie Mae. Therefore, these features were ignored.

Can the energy-efficient features be supported and if so, how? Yes, the energy-efficient features can be supported in the appraisal report. Several methods can be used, including gross rent multiplier analysis, paired sales analysis, and surveys.

**Gross Rent Multiplier Analysis**
The monthly energy savings of $59.58 can be converted into a contributory value or adjustment by using the gross rent multiplier analysis. The GRM is a relationship between monthly rent and market value. Isn’t it reasonable to consider a monthly savings income attributed to the construction of the home? The property owner is anticipating a monthly savings or additional income in her pocket. Since the GRM is a good measure of income to value, why not use this method to value the energy savings? Again, this method is one tool from the appraiser toolbox and should be carefully measured with market reactions and other methods discussed in this article.

The following sales are in the same neighborhood as the subject and are similar in quality, but do not have energy-efficient or green features. The houses are one to two years old and similar in size to the subject property.

<table>
<thead>
<tr>
<th></th>
<th>604 Brown St.</th>
<th>1294 Killen St</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neighborhood</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Price</td>
<td>$244,000</td>
<td>$253,000</td>
</tr>
<tr>
<td>Monthly rent</td>
<td>$1,600</td>
<td>$1,500</td>
</tr>
<tr>
<td>GRM</td>
<td>152.5</td>
<td>155.5</td>
</tr>
</tbody>
</table>

These two sales support a close range of GRMs, indicating a GRM of 154, which is the mid-range of the two. So, the value indication by GRM analysis is $59.58 monthly savings × 154 GRM, or $9,175. This indication is similar to the value contribution estimate of $8,633.60 provided on the Fannie Mae Energy Report.

Appraisers often argue the GRM is not applicable unless the properties are also green or Energy Star houses. If that is true, does it mean you cannot use a comparable unless it is green or Energy Star rated?

One of the generally accepted appraisal techniques to support adjustments is the use of the GRM. If a GRM is not available in the immediate area, search the competing neighborhood to obtain a GRM of similar quality. The use of the proxy method is also available. The proxy method uses a sale that was not rented at the time of sale and applies a rent appropriate for the sale. If you have a green property sale, estimate a rent based on rents in the market area to arrive at a GRM of a green property.

**Paired Sales Analysis**
Using a paired sales analysis approach, pairs of sales that are similar except for the energy-efficient or green features can be analyzed as follows.

<table>
<thead>
<tr>
<th>Description</th>
<th>1274 Killen St</th>
<th>908 Silver St</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sale date</td>
<td>07/XX</td>
<td>06/XX</td>
</tr>
<tr>
<td>Sale price</td>
<td>$274,000</td>
<td>$265,000</td>
</tr>
<tr>
<td>Living area</td>
<td>2,200</td>
<td>2,122</td>
</tr>
<tr>
<td>Garage</td>
<td>2-car attached</td>
<td>2-car attached</td>
</tr>
<tr>
<td>Energy-efficient or green features</td>
<td>HERS Index 64</td>
<td>None-code built only</td>
</tr>
<tr>
<td>Difference attributed to energy features ($274,000 – $265,000)</td>
<td>$9,000</td>
<td></td>
</tr>
</tbody>
</table>

In some markets, this may not be possible if the product is new and sales are not readily available.

**Survey of Builders**
Five local builders are surveyed to obtain the amount they received from actual sales of new construction for energy-efficient features with third-party rater verification. The results are as follows.

<table>
<thead>
<tr>
<th>Builder Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Build, Inc.</td>
</tr>
<tr>
<td>Quality Builders of Old</td>
</tr>
<tr>
<td>Southern Builders</td>
</tr>
<tr>
<td>Bob and Sons, Inc.</td>
</tr>
<tr>
<td>ABC Builders</td>
</tr>
</tbody>
</table>
Leadership in Energy and Environmental Design (LEED)
CERTIFICATION FOR HOMES

WHAT IS LEED FOR HOMES?
LEED for Homes is a voluntary third-party certification system that promotes the design and construction of high-performance green homes.

LEED certification is something that consumers can look for to identify homes that have been third-party inspected, performance-tested and certified as green homes that will perform better than conventional homes.

CONSUMER BENEFITS:
Green homes save money compared to a conventional home by:
• Using less energy – between 30% and 60% less in homes case studies
• Using less water – in case studies, as high as 50% less
• Using non-toxic building materials that lower exposure to mold and mildew, reducing healthcare costs
• Making owners eligible for advantageous home financing
• Lowering home insurance premiums by 5%
• Increasing home values up to 9.1% (see website for details)

HOW MUCH DOES IT COST?
When using AES as the LEED for Homes Provider, there are four required fees for a typical single-family home:
1. AES single-family home fee: $650
2. USGBC Registration fee: $150 / $225 (depending on USGBC membership)
3. Green Rater fee: Varies based on scope of work, typically $1600, +/- $300
4. USGBC Certification fee upon completion: $225 / $300 (depending on USGBC membership)

Total typical fees for LEED certification are around $2,700. For an exact proposal, call AES at 888-533-3274 or request a free quote at our web site.

WHAT PROJECTS ARE ELIGIBLE?
LEED for Homes includes affordable housing, mass-production homes, custom designs, stand-alone single-family homes, duplexes and townhouses, suburban low-rise apartments, urban high-rise apartments and condos, and lofts in historic areas. LEED for Homes is also applicable to major home renovations (gut rehabs).

For more information, contact AES at (888-533-3274) www.AllianceES.org
The survey results show a close range of value indications, with greatest weight at $8,200. However, if the market does not recognize the energy-efficient items, the cost of the items in the contracts to build may not be indications of the value. This is another tool from the appraiser toolbox, but must be measured against the market reactions and other tools mentioned in this article.

Case Study Conclusions
New construction customers may be willing to pay for the cost of the energy-efficient items and green construction, but the resale value may not reflect contributory value for these features. The appraiser must take the necessary steps to research the market and use all the tools available to arrive at a conclusion worthy of belief and that is well supported. In the case study example, the report would include the appraiser's findings from the analyses.

<table>
<thead>
<tr>
<th>Study Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary of Value Indications for Energy Features</td>
</tr>
<tr>
<td>Fannie Mae Energy Report</td>
</tr>
<tr>
<td>GRM analysis</td>
</tr>
<tr>
<td>Paired sales analysis</td>
</tr>
<tr>
<td>Survey of builders</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incentives for Green and Energy-Efficient Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS tax credit</td>
</tr>
<tr>
<td>Utility rebate</td>
</tr>
<tr>
<td>Insurance discount (3%)</td>
</tr>
<tr>
<td>EEM closing cost reimbursement</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

The data provides four value indications for the energy-efficient items. The paired sales analysis is the most reliable approach with secondary support from the GRM and the Fannie Mae Energy Report. Strong support at $9,000 is 3.8% of the overall value of the subject property ($9,000 value for energy features/$235,000 overall value). This figure includes the high-efficiency central air, insulation, low-emittance (low-E) windows, and tankless water heater.

The incentives for the green and energy-efficient features results in $3,300 credited to the owner, not including the monthly energy savings of $59.58. The house will provide a healthier environment, a longer physical life, and lower maintenance costs due to the green construction. These incentives and monthly savings offset the additional costs of the energy features. It is logical to assume a knowledgeable buyer would consider the incentives in his or her decision making when buying a house. (However, some incentives are only for new construction or first year of ownership.)

For the subject house, the adjustment applied to the comparable sales is 5.8% on the energy-efficient features line of the URAR.

Conclusion
Appraisers are encouraged to take the time to learn the products and techniques in green construction, ensuring a new niche for their appraisal services. Taking classes on the topic and networking with green construction professionals will help increase knowledge and professionalism in these assignments and is well worth the effort.

Sandra K. Adomatis, SRA, is a real estate appraiser and owner of Adomatis Appraisal Service in Punta Gorda, Florida. She has been appraising since 1981 and specializes in the more difficult residential properties, small commercial valuations, and quality control. She was the 2009 president of the West Coast Florida Chapter. Adomatis is an Appraisal Institute instructor and the vice chair of the Appraisal Institute Education Committee.

She has been involved in Appraisal Institute development teams for residential appraising courses, and she has served on the Residential Demonstration Report Writing Committee for eighteen years, including three years as chair of the committee. Contact: adomatis@hotmail.com

Provided courtesy of the Alliance for Environmental Sustainability
www.alliancees.org
LEED Homes: Case Study Shows Increased Value

Residential Pre-Occupancy Case Study

40% LEED homes average savings in energy use and cost compared to conventional homes.

Acknowledgements
Special thanks to the Wege Foundation for their financial support in bringing the LEED for Homes program to West Michigan through the Alliance for Environmental Sustainability.

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Brett Little, BS, Sustainable Business
Calvin Delano
Sefik Arapovic, Research Intern

Design by Lissa Marques GVSU Graphic Design lissa.marques@yahoo.com

Research Methodology
AES collected pre-occupancy building energy performance data on its LEED certified residential buildings. Each home was modeled as if built to IECC 2006 energy code (with a modeled HERS score of 100), and compared to the home’s actual tested performance after construction (based on final HERS rating). The results were then aggregated and are summarized here. For a detailed analysis and results, please contact AES.

144 Homes Total
LEED-certified dwelling units used to draw data from.

Location of homes in case study

Apartment End 36
Apartment 19
Townhouse End 19
Townhouse Inside 13
Duplex 5
Single Family Home 52

Unit Breakdown
KWH kilo watt hour 1000 watts for 1 hour

LEED Bill Reduction
Electricity 28% Less Kwh Used

Average Annual Cost
$1,290 $1,489

LEED Home Non LEED LEED Non LEED LEED

CCF 100 cubic feet 100 ft³ of nat’l gas

Natural Gas 48% Less CCF Used

Annual LEED Savings
Energy Use: 38%

Utility Costs:
Carbon Dioxide 7
Sulfur Dioxide 38
Nitrous Oxide 28

Total Lin. Reduced

AES is the Midwest’s premier LEED for Homes provider.
Contact: Info@AllianceES.org Web: www.AllianceES.org
Based on this analysis and factoring in home size, aiming for a LEED Gold rating achieves the highest energy efficiency savings.

Additionally, LEED Homes at each level reduce total cost of ownership, saving tens of thousands of dollars through utility savings, during a typical 30-year mortgage period. Given the average $2,500 certification cost for a single-family LEED home through AES, owners will typically have a payback period under 2.5 years.

www.AllianceES.org
### ENERGY EFFICIENT ITEMS

The following items are considered within the appraised value of the subject property:

#### Insulation
- [ ] Fiberglass Blown-In
- [ ] Foam Insulation
- [ ] Cellulose
- [ ] Fiberglass Batt Insulation
- [ ] Other (Describe): 
- [ ] Basement Insulation (Describe):
- [ ] Floor Insulation (Describe):

#### R-Value:
- [ ] Walls
- [ ] Ceiling
- [ ] Floor

#### Water Efficiency
- [ ] Reclaimed Water System (Explain):
- [ ] Cistern - Size: Gallons
- [ ] Rain Barrels - #:
- [ ] Rain Barrels Provide Irrigation

#### Windows
- [ ] ENERGY STAR®
- [ ] Low E
- [ ] High Impact
- [ ] Storm
- [ ] Double Pane
- [ ] Triple Pane
- [ ] Tinted
- [ ] Solar Shades

#### Day Lighting
- [ ] Skylights – #:
- [ ] Solar Tubes - #:
- [ ] ENERGY STAR Light Fixtures
- [ ] Other (Explain):

#### Appliances
- [ ] ENERGY STAR Appliances:
  - [ ] Range/Top
  - [ ] Dishwasher
  - [ ] Refrigerator
  - [ ] Other:

- [ ] Water Heater:
  - [ ] Solar
  - [ ] Tankless (On Demand)

- [ ] Size: Gal.

- [ ] Appliance Energy Source:
  - [ ] Propane
  - [ ] Electric
  - [ ] Natural Gas
  - [ ] Other (Describe):

#### HVAC (Describe in Comments Area)
- [ ] High Efficiency HVAC – SEER:
- [ ] Programmable Thermostat
- [ ] Heat Pump
- [ ] Radiator Floor Heat
- [ ] Wind
- [ ] Thermostat/Controllers
- [ ] Passive Solar
- [ ] Geothermal

#### Energy Rating
- [ ] ENERGY STAR Home
- [ ] HPwES (Home Performance with ENERGY STAR)
- [ ] Other (Describe):

- [ ] Indoor Air PLUS Package
- [ ] Energy Recovery Ventilator Unit
- [ ] Certification Attached

#### HERS Information
- [ ] Rating:
- [ ] Date Rated:
- [ ] Monthly Energy Savings on Rating: $

#### Utility Costs
- [ ] Average Utility Cost: $
  per month based on:
- [ ] Dashboards - #:

#### Energy Audit
- [ ] Has an energy audit/rating been performed on the subject property?
- [ ] Yes
- [ ] No
- [ ] Unknown

If yes, comment on work completed as result of audit.

### Comments

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### Solar Panels

The following items are considered within the appraised value of the subject property:

<table>
<thead>
<tr>
<th>Description</th>
<th>Array #1</th>
<th>Array #2</th>
<th>Array #3</th>
<th>Array #4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Array #1**
  - □ Leased
  - □ Owned

- **Array #2**
  - □ Leased
  - □ Owned

- **Array #3**
  - □ Leased
  - □ Owned

- **Array #4**
  - □ Leased
  - □ Owned

#### KW

**Age of Panels**

**Energy Production Kwh per Array**

**Source for Production**

**Location (Roof, Ground, Etc.)**

**If Roof/Slope for Array**

**Azimuth per Array**

**Age of Inverter(s)**

<table>
<thead>
<tr>
<th>Name of Utility Company:</th>
<th>Cost per Kwh charged by Company:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ /Kwh</td>
</tr>
</tbody>
</table>

#### Green Features

The following items are considered within the appraised value of the subject property:

<table>
<thead>
<tr>
<th>Certification</th>
<th>Year Certified:</th>
<th>Certifying Organization:</th>
<th>□ Reviewed on site</th>
<th>□ Certification attached to this report</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Certification**
  - □ LEED® Certified:
  - □ Silver
  - □ Gold
  - □ Platinum
  - □ Other:

- **Rating**
  - □ ICC-700 National Green Building Standard Certified:
  - □ Bronze
  - □ Silver
  - □ Gold
  - □ Emerald

- **Certifying Organizations Green Score Range - High Score:**
  - Low Score:

#### Additions

**Explain any additions or changes made to the structure since it was certified:**

**Do changes require recertification to verify rating is still applicable?**

- □ Yes
  - □ No

#### Comments

- **Discuss incentives available for new panels, condition of current panels, and any maintenance issues**

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