Describing the Green House Made Easy

by Sandra K. Adomatis, SRA

Have you ever tried to describe a green home on the current residential forms? It presents a challenge and extends the writing time when using Fannie Mae Form 1004 or AI Reports Form 100. The Appraisal Institute decided there had to be a better way, and it moved forward to lead the industry with the *Residential Green and Energy-Efficient Addendum*.[1] The Addendum was created as part of the Appraisal Institute's AI Reports Form 100 series, but it can be used with the Fannie Mae Form 1004 as well. The objectives in creating the Addendum were to

- provide one central place in a report to describe green and energy-efficient features;
- standardize the reporting process;
- organize the description and expand the description sections of the residential forms;
- provide a basis for comparable sale selection; and
- proactively anticipate enactment of the proposed legislation known as the SAVE Act.

Keeping the six elements of green building in mind—site, energy, water, indoor air quality, materials, and operations and maintenance—the Addendum moves through the description of property features and addresses areas that are not covered on the residential forms. The main categories, represented in block format on the Addendum, are energy-efficient items, solar panels, green features, location-site factors, and government incentives.

Improved Information

Before the creation of the *Residential Green and Energy-Efficient Addendum*, the description of green or energy features were placed in the residential forms' text addendum or not fully described. It usually meant adding a narrative description that would take time that most residential appraisers could not afford in this time-driven environment. Underwriters often overlooked the description because the narrative format was time consuming to read.

Today, the *Residential Green and Energy-Efficient Addendum* is the go-to point in the appraisal report for green and energy-efficient details. The Addendum organizes and expands the description sections of the residential forms we currently use. Having one central place in the report for green and energy-efficient items listed in a systematic manner creates standardization of the description. Fannie Mae and Freddie Mac created the Uniform Appraisal Dataset (UAD) to standardize reporting; however, they omitted energy or green features. How will we track data on this growing industry if the data is not standardized?

The Addendum's format provides a more accurate description of the subject property, and consequently, a basis for selecting comparable green sales. If we are not familiar with green or energy-efficient buildings, it will be extremely difficult to choose comparable sales. The Addendum allows a more thought-provoking analysis of the market data.

Finally, the Addendum is a proactive movement in regards to the Sensible Accounting to Value Energy Act, or SAVE Act, which may become law in the near future.[2] The SAVE Act, if enacted, would instruct federal loan agencies to assess a borrower's expected energy costs when financing a house. The first step in the SAVE Act would require an "E"—energy costs—to be added to the principal, interest, taxes, and insurance (PITI) currently used in qualifying a buyer for a loan; going forward the PITIE would be

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[1] http://www.appraisalinstitute.org/education/downloads/AI_82003_ResIGreenEnergyEffAddendum.pdf.

[2] S. 1737. To see the bill's text and status, go to http://www.govtrack.us/congress/bill.xpd?bill=s112-1737.

taken into account. An average monthly utility cost would need to be developed and included in the debt ratio. The second phase of the SAVE Act would add a "W"—water costs—to the debt ratio for the average monthly water costs (PITIEW). The third phase of the act would add location-based transportation costs. The Addendum addresses these key points of the SAVE Act, putting the Appraisal Institute in the forefront of green valuation.

The first step to competency in green valuation is education. We can be duped into believing a property is green or energy efficient if we do not have the basic understanding of the six elements of green building. The Addendum is not a systematic guide on how to appraise or identify a green or energy-efficient house; however it does reference documents and information necessary to understand the shade of green and degree of energy efficiency. In addition, many tools are available to assist in completion of the Addendum. This article will address some of these tools; more information on appraisal of green buildings is available through the Appraisal Institute's education offerings and its *Valuation of Sustainable Buildings Professional Development Program.*[3]

Addendum Energy–Efficient Items Section

Insulation

Often, third-party certifiers of green and energy-efficient houses refer to a building's thermal or sealed envelope, and use door blowers, duct blasters, and/or infrared cameras to measure the envelope's tightness. The appraiser is not equipped or trained to measure the tightness of the envelope; therefore, the first item addressed in the Addendum is the subject property's insulation. Appraisers can only partially view the insulation in the attic in most cases. If you have plans and specifications, you can more accurately describe the type, rating, and the data source. A house that has a Home Energy Rating System (HERS) rating will have a paper trail that supports the rating and provides a wealth of information on the construction and rating system.[4] Appraisers should ask owners or realtors to have these items available for inspection. Most parties involved in the transaction are not aware of how important these documents can be to the property's valuing and marketing.

Water Efficiency

Water efficiency is an important consideration in many parts of the country where water is scarce and expensive. As previously mentioned, the SAVE Act would require the monthly water costs to be figured into the debt ratios when qualifying a borrower for a loan. Also, new homes are moving toward reclaiming of greywater that can be used in other areas such as landscaping.[5] Homes that are being retrofit for energy and water efficiency will implement water reclaiming systems. A water reclaiming system is something that appraisers could easily miss if they do not have documentation or an idea of how to identify such a system.

Rain barrels and cisterns are becoming more prevalent in an effort to conserve water. (In areas that do not allow rain barrels or cisterns these items would not be a consideration.) Cisterns can be easily overlooked if the appraiser is not aware of the signs that may identify them, and owners often forget to mention they have a cistern. The last property I appraised with a cistern is a good example of this situation. This house had a concrete deck that was connected to a second story porch, with what appeared to be a room under the deck. I could not find a door to this "room," however. The owners saw my dilemma and asked if they could help with something. When I asked what was inside the four walls, they said a 10,500-gallon cistern for yard watering. Wow, in a neighborhood where irrigation is required and water is expensive, this is a real asset. This feature will become even more important and valuable if the SAVE Act becomes a reality.

Windows, Lighting, Appliances, and Mechanicals

Windows, appliances, daylighting, and mechanicals play an important part in the energy efficiency of the house. These features alone do not make a house energy efficient or green. The green or energy-efficient house will have mechanicals, fixtures, and design to ensure the different parts of a building work

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[3] For course and program information, go to http://www.appraisalinstitute.org/education/green_offerings.aspx and http://www.appraisalinstitute.org/education/prof_dev_programs.aspx.

[4] The HERS Index scoring system was established by the Residential Energy Services Network (RESNET); see http://www.resnet.us.home-energy-ratings.

[5] *Greywater* is domestic wastewater from kitchen, bathroom, and laundry sinks, tubs, and washers. Appraisal Institute, *The Dictionary of Real Estate Appraisal*, 5th ed. (Chicago: Appraisal Institute, 2010), 327.

together rather than against one another. This whole-building approach will result in lower operating costs.

Energy Rating, HERS, Utility Costs, and Energy Audit

A house that has been rated by a third-party certifier will have a home energy rating system (HERS) rating, which should be less than 100 if the house is energy efficient. A HERS rating is like a golf score, the lower the number, the more energy efficient the house. The net zero energy house indicates the house produces as much energy as it uses, and the energy production will be through some alternative source such as wind, geothermal, or solar. An Energy Star[6] or green-certified house will have a HERS rating. You should verify the rating by reviewing the paper trail and, ideally, including a copy of the paperwork in the report.

It is important to know the HERS rating for a typical code-built house in your area. Five years ago, the HERS rating on a code-built house in my area was 100; in 2011, it was 85. As the code continues to implement more green and energy-efficient features, the certified ratings will become more stringent to stay above the typical code-built house.

The HERS rating will provide an estimated energy savings per month for the structure. This estimate can be used in analyzing the energy adjustment that might be necessary if comparable sales do not have the same features.[7]

Why would the Addendum call for the average monthly utility cost? The utility cost can be a measurement of the energy efficiency of the house and/or lifestyle of the occupants. If you do not have access to the last twelve months' utility bills, visit a free online tool to estimate the energy costs at http://www.hespro.lbl.gov. This website is user friendly and accurate if the inputs are accurate. Try the site using your own house to measure the accuracy of the tool and to obtain a sense of reliability. I used it on my house and found it to be accurate and easy to use. Home Energy Saver Professional (HESPro) will provide the energy costs from your local energy company and energy upgrades that could lower the costs. Do you see some uses for this site beyond supplying information for the form? Try using this site in consulting with clients on upgrades to houses or assisting buyers in understanding the costs of a particular house.

Energy audits will be a growing business and one that will bring appraisers business. Incentives are often offered for energy retrofits to promote this movement, and retrofits are considered a source for new jobs. An appraisal order will be one of the jobs created by retrofits, so be proactive in learning more about energy audits and energy efficiency.

The Addendum asks if the energy upgrades suggested in an energy audit were implemented. If they have been implemented, the form provides room for a description of the improvements. Contractors should provide the homeowner with a complete list of the upgrades homeowners can use to facilitate a listing, sale, or appraisal. Or better yet, have the contractor complete an Addendum form for the homeowner. The Addendum can become their brag sheet and should be included with the agreement for listing. Figure 1 shows an example of how this information can be entered in the Energy-Efficient Items section of the Addendum.

If you have additional energy-efficient items that are not listed in the Addendum's check boxes, list them in the comments section. The large comment section provides space for an explanation of these features and additional items. A sample of comments that might be found in this section is shown in Figure 2.

Addendum Solar Panels Section

Following the Energy-Efficient Items section is the Solar Panels section. This section provides room for the description of four arrays. The section looks rather intimidating and time consuming. It will take some planning and research to gather the information, but knowing the facts is important to valuing the array(s). As solar panels decline in price, we will see more panels per house, making this an important feature to understand for proper valuation. The following gives a quick review of the terms and abbreviations used in the Solar Panel section.

- **Photovoltaic (PV) System**—An electrical system consisting of an array of one or more PV modules, conductors, electrical components, and one or more loads.[8]

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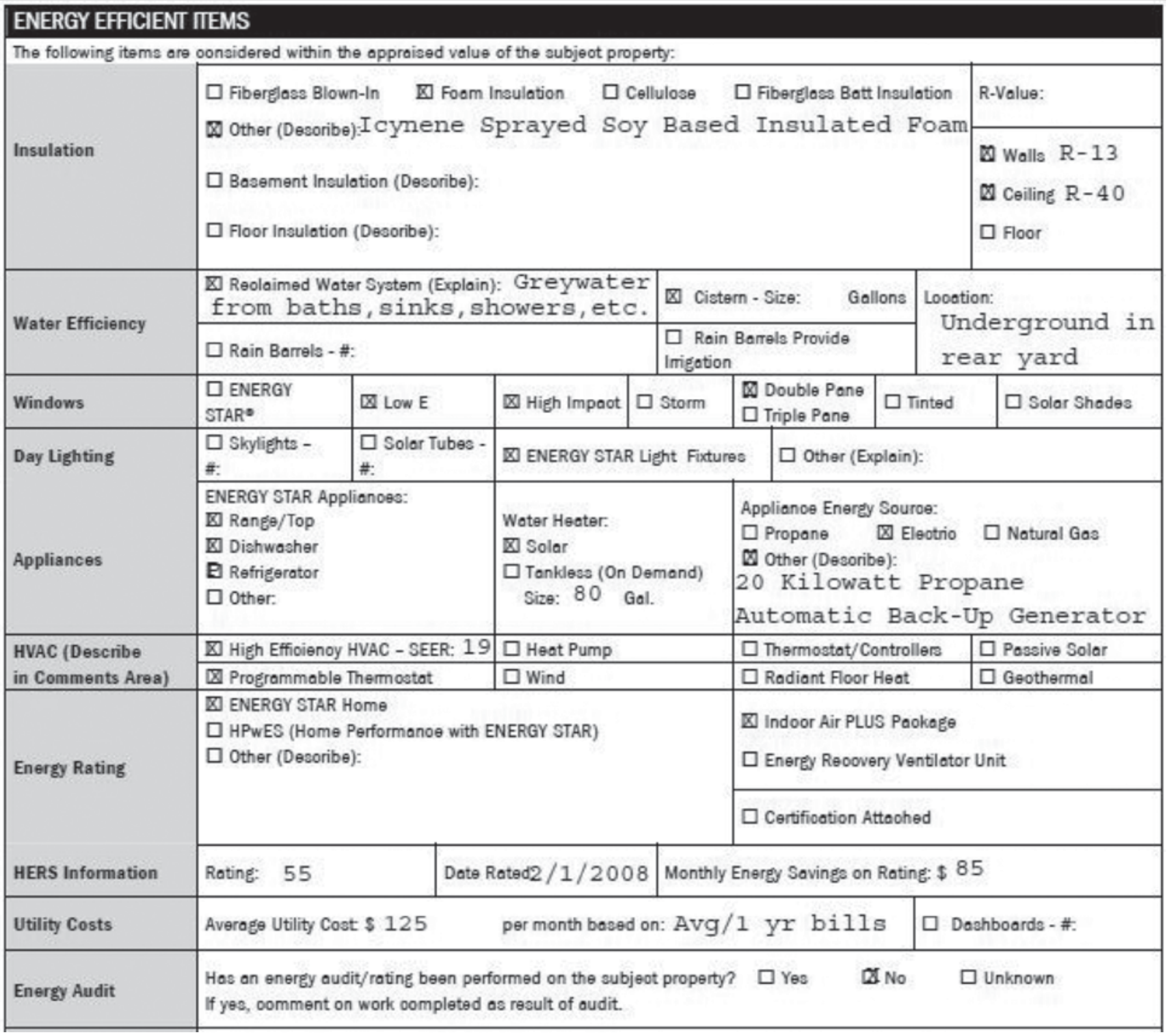
[6] For information on Energy Star, see http://www.energystar.gov.

[7] Sandra K. Adomatis, "Valuing High Performance Houses," *The Appraisal Journal* (Spring 2010): 195—201.

[8] James P. Dunlop, in partnership with the National Joint Apprenticeship and Training Committee for the Electrical Industry, *Photovoltaic Systems* (Homewood, IL: American Technical Publishers, 2007).

Figure 1 Example of Completed Energy-Efficient Items Section in *Residential Green and Energy-Efficient Addendum*



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): Icynene Sprayed Soy Based Insulated Foam ☐ Basement Insulation (Describe): ☐ Floor Insulation (Describe):			R-Value: ☒ Walls R-13 ☒ Ceiling R-40 ☐ Floor
Water Efficiency	☒ Reclaimed Water System (Explain): Greywater from baths, sinks, showers, etc. ☐ Rain Barrels - #:	☒ Cistern - Size: Gallons ☐ Rain Barrels Provide Irrigation		Location: Underground in rear yard
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: 80 Gal.	Appliance Energy Source: ☐ Propane ☒ Electric ☐ Natural Gas ☒ Other (Describe): 20 Kilowatt Propane Automatic Back-Up Generator	
HVAC (Describe in Comments Area)	☒ High Efficiency HVAC – SEER: 19 ☒ Programmable Thermostat	☐ Heat Pump ☐ Wind	☐ Thermostat/Controllers ☐ Radiant Floor Heat	☐ 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: 55	Date Rated 2/1/2008	Monthly Energy Savings on Rating: $ 85	
Utility Costs	Average Utility Cost $ 125	per month based on: Avg/1 yr bills	☐ 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.			

- **kW**—Kilowatt; a unit of power defined as voltage x current that equals 1000 watts. The size of a PV system is usually listed in kW terms; for example a 5040-watt system would be listed as 5.04kW.[9]
- **kWh**—Kilowatt hour; a unit of energy that is the equivalent to 1000 watts for one hour.[10]
- **Module**—A PV device consisting of a number of individual cells connected electrically, laminated, encapsulated, and packaged into a frame.[11]
- **Source for Production**—Most solar systems will have a customer-owned meter or converter with a digital display showing the energy produced since the panel was installed (if the inverter or meter is the original one) and the energy produced that day. The inverter or meter is usually found near the electrical box. Some electrical boxes will have a sticker that identifies an alternative energy source is in use.

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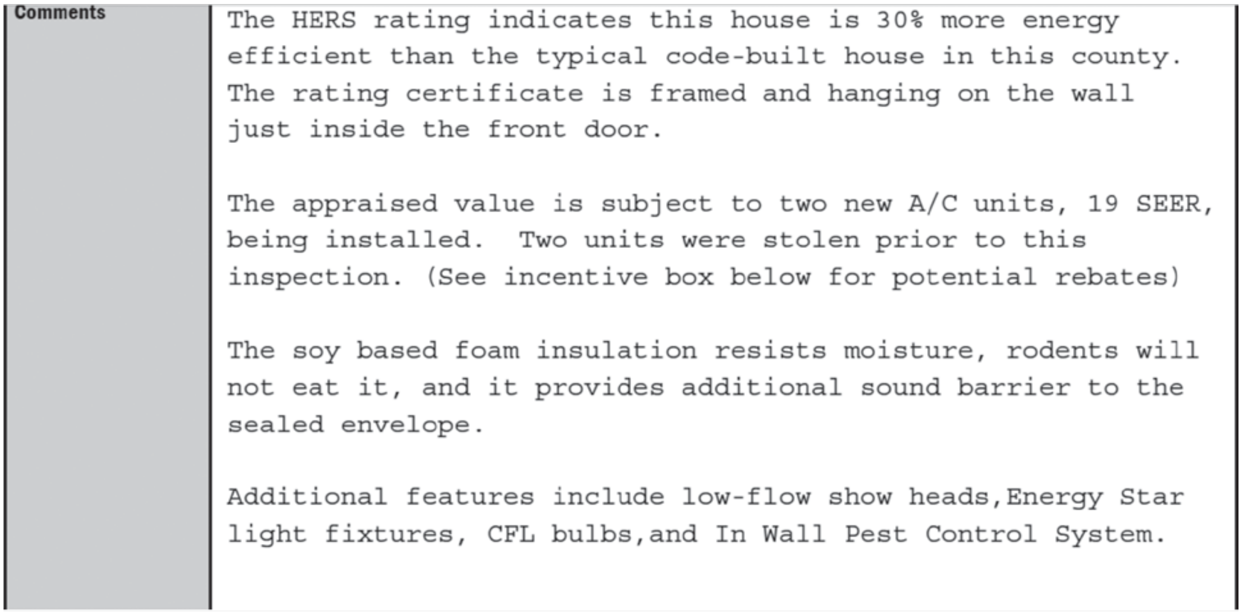
[9] Jamie L. Johnson and Geoffrey T. Klise, *Solar Electric System (PV) Valuation Model* (white paper, forthcoming).

[10] Ibid.

[11] Dunlop, *Photovoltaic Systems*.

Figure 2 Example of Comments in Energy-Efficient Items Section



The HERS rating indicates this house is 30% more energy efficient than the typical code-built house in this county. The rating certificate is framed and hanging on the wall just inside the front door.

The appraised value is subject to two new A/C units, 19 SEER, being installed. Two units were stolen prior to this inspection. (See incentive box below for potential rebates)

The soy based foam insulation resists moisture, rodents will not eat it, and it provides additional sound barrier to the sealed envelope.

Additional features include low-flow show heads,Energy Star light fixtures, CFL bulbs,and In Wall Pest Control System.

- **Roof Slope**—The rise of the slope over 12 inches results in a roof slope such as 5/12 pitch or for every 12 inches of roof the rise is 5 inches. The slope may be found on the local property appraiser's card. Plans and specifications provide the slope or if you have a compass or ruler, you can do your own measurement. The documentation or solar label inside the electrical box should provide the slope.
- **Azimuth**—The degree from true north that the surface of the solar panel diverges from, or simply stated, the roof's compass heading. Your IPhone has a compass and it can be used to determine the roof's compass heading at the location of the solar panel or at your office use the online tool available at http://tools.solmetric.com/Tools/roofazimuthtool. This website requires an address and instantly you will receive a map and the azimuth. If the solar installer has properly completed the installation labeling, a label should be inside the electrical box that will provide you with most of the items listed in the Solar Panels section.
- **Inverter**—A device that converts DC power to AC power.[12] The inverter typically only lasts around 10 years; therefore, it is important to know the age of the inverter to develop a net present value of the energy produced. Most solar panels have 20- to 25-year warranties and estimated life of the panel. However, the warranties do not usually involve replacement of the inverter.

If the panels are leased, a copy of the lease should be reviewed to understand the terms, expenses, and responsibility of the homeowner. Do not assume the array is owned. In most areas, permits are required to install a solar system. In my area, I can obtain solar permit information from the county's website.

Ask the owners if they have a regular system of cleaning the panels to obtain the maximum energy production, because dust or mold layers can block the sun's rays and reduce production. The solar panels will have a slight degradation in energy production each year that must also be considered in the net present value equation. Ask owners how much the system has saved them since installation. Using their estimated monthly savings, develop the time it will take the owners to recoup their investment. These are all talking points for a good analysis of the solar panels' value.

The Appraisal Institute recently released its endorsement of a spreadsheet that will assist in valuing the net present value of a solar power system. Sandia National Laboratories in partnership with Solar Power Electric of Port Charlotte, Florida, developed the spreadsheet. It will soon be available

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[12] Dunlop, *Photovoltaic Systems.*

online for use by the public. The Solar Panel section of the Addendum addresses all the items needed to use this great new tool.

Figure 3 shows an example of how information can be entered in the Addendum's Solar Panels section.

Addendum Green Features Section

The Green Features section of the Addendum provides a place for noting any energy rating and the certifying organization. Only two national certifying organizations have check boxes in this section, but space is provided to list the organization's name if it is not one of the two listed. There are more than 60 certifying organizations in the United States, the Addendum could not possibly list them all.[13]

The green score given by a third-party certifier will provide a rating indicating the shade of green. The certifier uses a worksheet to assign points in various categories. The certification and the worksheet are important documents to copy and include in the appraisal report. (Or, at least reference them and keep a copy in your work file.) The certifier's worksheet will assist in understanding where the green emphasis is placed in the property by the points awarded and will provide a basis for selecting comparable sales. Some certifying organizations have property databases on their websites to allow anyone to search the database by address, city, or county to obtain green certification information.[14]

The only way to ensure a building is green is through a third-party certification. However, appraisers should have an understanding of the six elements of green building to identify the green features. Some owners choose not to have a property certified to spare the additional costs. Just because a building is not certified does not mean it is not green and does not deserve proper description and valuation related to green features. The appraisal is of the property and not the certification; therefore, becoming competent in identifying the green or energy-efficient house is a necessity. In some areas, a certified home may find lower marketing time and/or a premium. That is an analysis each appraiser must undertake in his or her market area.

Figure 4 shows an example of how information can be entered in the Addendum's Green Features section.

Addendum Location-Site Section

The next section of the Addendum is the location and site description.

The first item in this section is the Walk Score. A Walk Score measures the ability to walk to amenities such as parks, schools, and shopping. Some green certifications rate walkability, and the third phase of the SAVE Act would call for consideration of location-based transportation costs in loan decisions. A higher Walk Score means the occupants at a location are not auto dependent to reach most services. A property with a high Walk Score will receive maximum points in that scoring area. The Walk Score can quickly be obtained from http://www.walkscore.com. This website provides a great deal of information about a location, including proximity to restaurants, shopping, houses of worship, and schools. This website also might be helpful in completing the neighborhood section of the appraisal report.

The description of a green property includes a description of its site. The orientation of the site has an effect on the energy efficiency of the house; therefore, the orientation of the house on the site is defined in the Location-Site section. Landscaping is also included in this description because it can affect the energy efficiency of the structure. A green score will give points for these categories when they work together to enhance energy and water efficiency

Figure 5 shows an example of how information can be entered in the Location-Site section of the Addendum.

Addendum Incentives Section

The last section of the Addendum provides space for a description of government incentives for the property to incorporate energy or green features. Completion of the Incentives section is easily accomplished by going to the Database of State Incentives for Renewables and Efficiency at http://dsireusa.org, which lists the federal, state, and local incentives available. Why are the incentives important? They offset the cost to build or cost to repair or retrofit. Incentives are usually short-lived; as a result, appraisers need to research the website each time they encounter a green property.

For example, an incentive could affect an adjustment for a solar panel. Suppose you are

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[13] http://www.pathnet.org/search/catSearch.asp.

[14] http://www.floridagreenbuilding.org.

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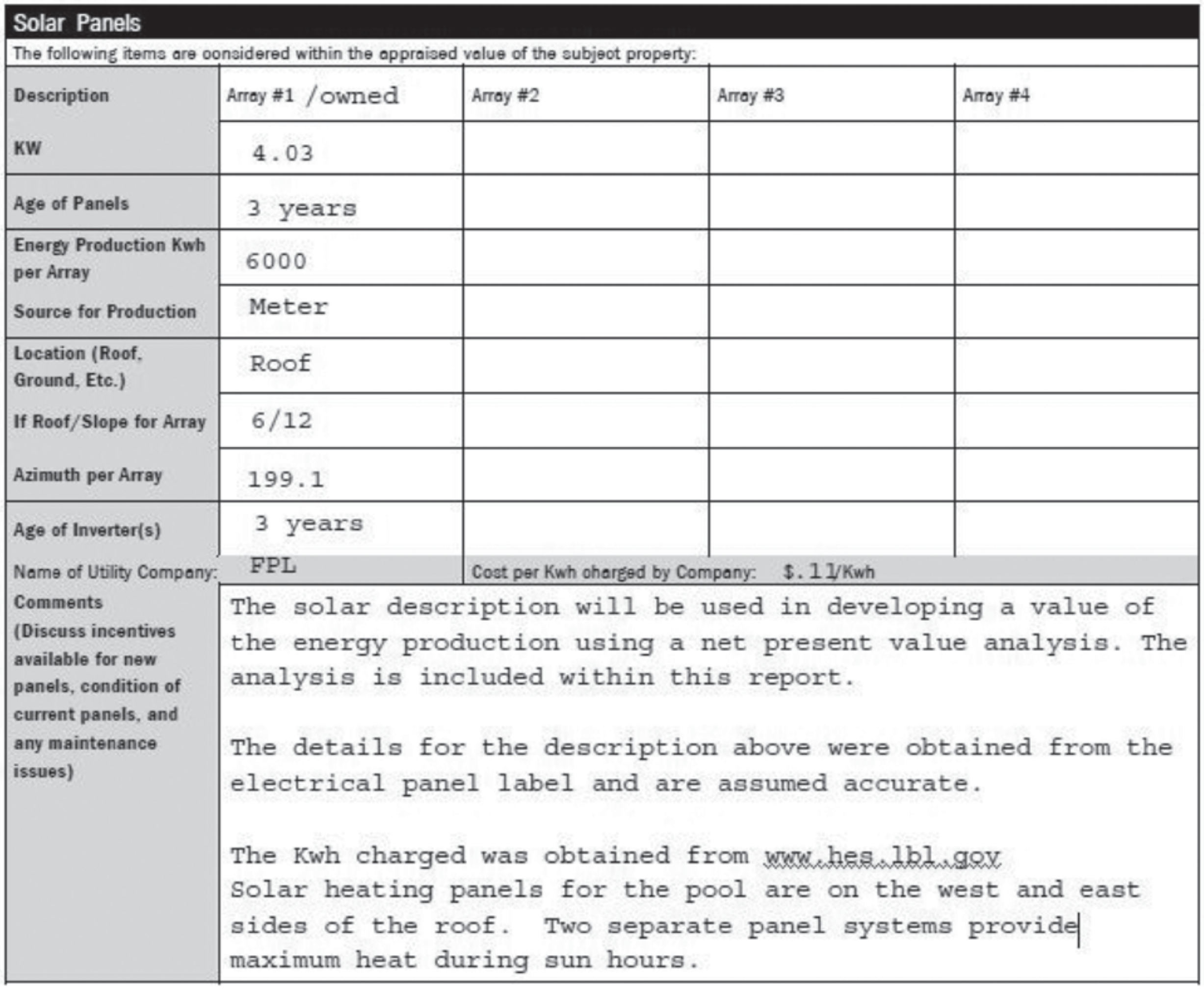
Figure 3 Example of Completed Solar Panels Section



Solar Panels

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

Description	Array #1 /owned	Array #2	Array #3	Array #4
KW	4.03			
Age of Panels	3 years			
Energy Production Kwh per Array	6000			
Source for Production	Meter			
Location (Roof, Ground, Etc.)	Roof			
If Roof/Slope for Array	6/12			
Azimuth per Array	199.1			
Age of Inverter(s)	3 years			

Name of Utility Company: FPL Cost per Kwh charged by Company: $.11/Kwh

Comments (Discuss incentives available for new panels, condition of current panels, and any maintenance issues)

The solar description will be used in developing a value of the energy production using a net present value analysis. The analysis is included within this report.

The details for the description above were obtained from the electrical panel label and are assumed accurate.

The Kwh charged was obtained from www.hes.lbl.gov
Solar heating panels for the pool are on the west and east sides of the roof. Two separate panel systems provide maximum heat during sun hours.

appraising a five-year-old solar system, and you discover $20,000 in incentives are currently offered for a new system that costs $30,000. The net present value of the old system is $15,000, and a new system can be purchased for $10,000 after rebate. What contributory value might you give the five-year-old system? Keep in mind you are appraising the property as of a specific date.

Comparable Sales Search

After you have completed the Addendum, you have a good basis for a comparable sales search. The Addendum should inspire you to be more critical of the sales chosen and diligent in the verification process. If the local certifying organization offers a database of certified homes, obtain a count of the number of certified homes in the area. This will provide the report reader with an understanding of the difficulties of comparable sales. For instance, if the search results in only ten houses certified in the past five years, one can assume comparable green sales might not exist. Start the summary to the sales comparison approach with this information to alert the underwriter that comparable sales of other certified homes may not be available.

Green MLS Tool Kit

The National Association of Realtors (NAR) has developed a "Green MLS Tool Kit."[15] Not all multiple-listing service (MLS) systems have implemented the Green

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[15] http://www.greenthemls.org/.

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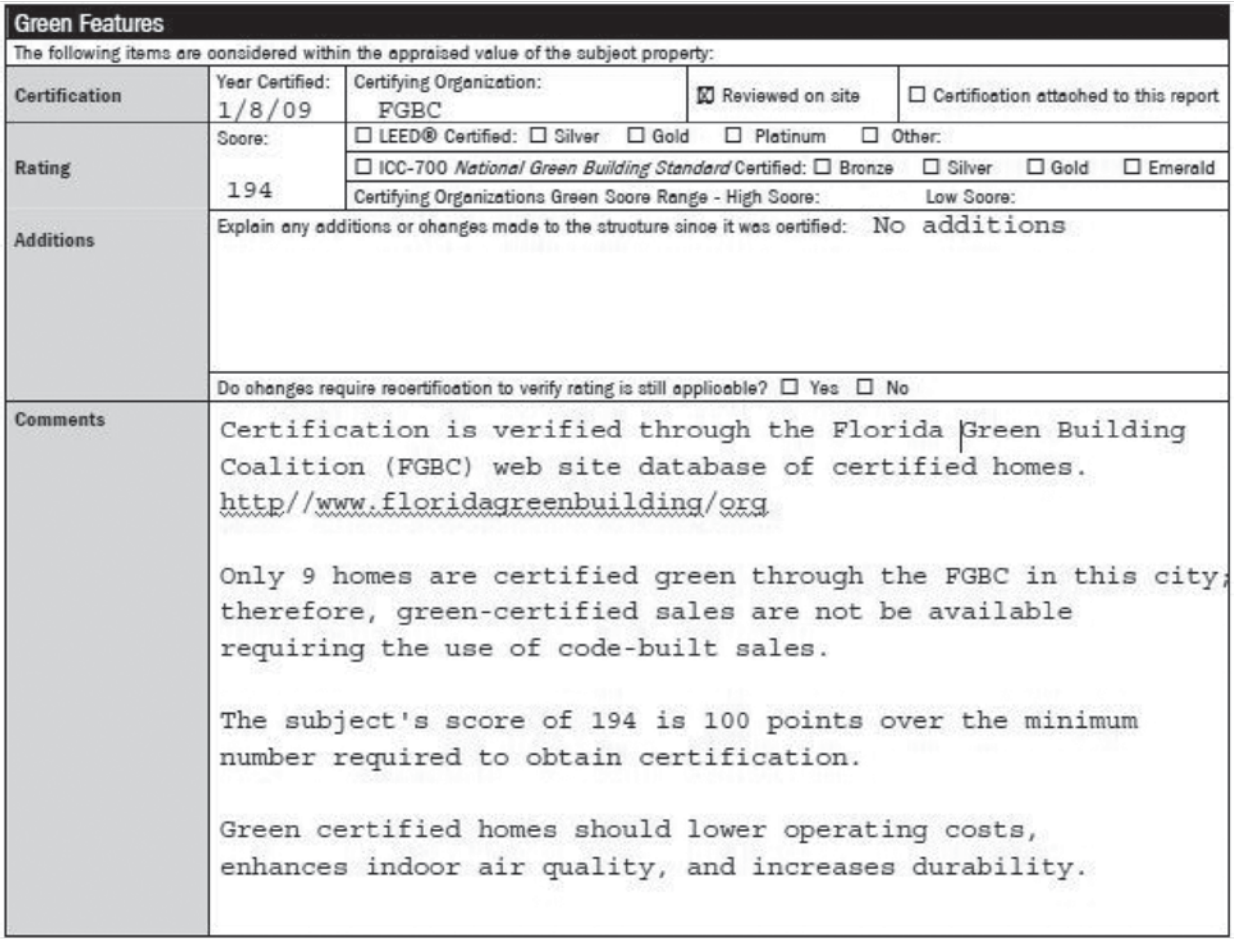
Figure 4 Example of Completed Green Features Section

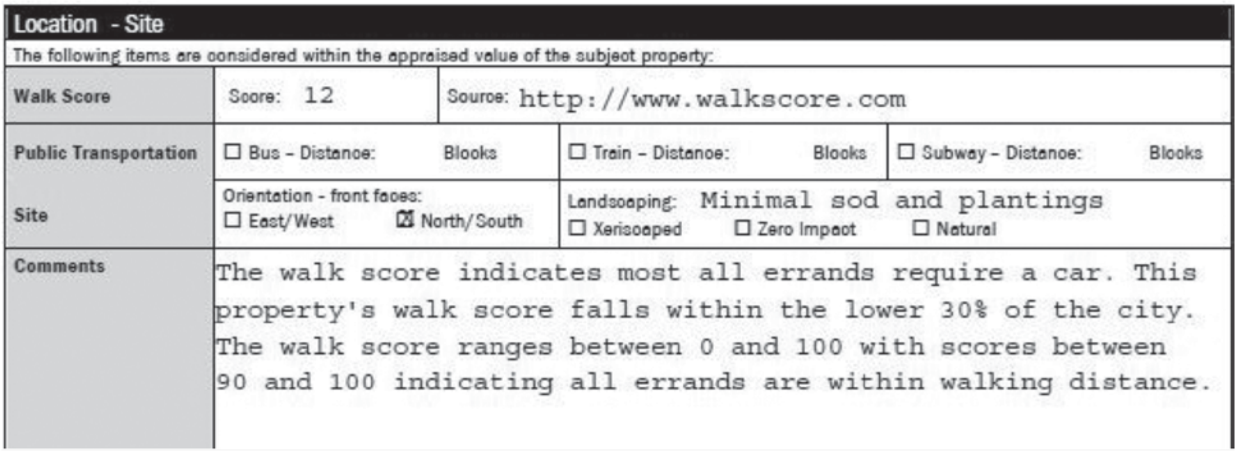


Green Features

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

Certification	Year Certified: 1/8/09	Certifying Organization: FGBC	☒ Reviewed on site	☐ Certification attached to this report
Rating	Score: 194	☐ LEED® Certified: ☐ Silver ☐ Gold ☐ Platinum ☐ Other: ☐ 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: No additions Do changes require recertification to verify rating is still applicable? ☐ Yes ☐ No			
Comments	Certification is verified through the Florida Green Building Coalition (FGBC) web site database of certified homes. http//www.floridagreenbuilding/org Only 9 homes are certified green through the FGBC in this city; therefore, green-certified sales are not be available requiring the use of code-built sales. The subject's score of 194 is 100 points over the minimum number required to obtain certification. Green certified homes should lower operating costs, enhances indoor air quality, and increases durability.			

Figure 5 Example of Completed Location-Site Section



Location - Site

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

Walk Score	Score: 12	Source: http://www.walkscore.com	
Public Transportation	☐ Bus – Distance: Blocks	☐ Train – Distance: Blocks	☐ Subway – Distance: Blocks
Site	Orientation - front faces: ☐ East/West ☒ North/South	Landscaping: Minimal sod and plantings ☐ Xeriscaped ☐ Zero Impact ☐ Natural	
Comments	The walk score indicates most all errands require a car. This property's walk score falls within the lower 30% of the city. The walk score ranges between 0 and 100 with scores between 90 and 100 indicating all errands are within walking distance.		

MLS Tool Kit, but, with time, it is inevitable. This tool kit promotes green and energy-efficient features and creates searchable data fields that allow appraisers and realtors to identify these properties. If the local MLS has not adopted the green features fields, ask them to consider adding the new data fields.

Review the features section of the MLS active and sold data sheets to track patterns that the market is beginning to seek green and energy-efficient features. Five years ago, a local MLS never mentioned these features, but today green features are usually among the first items mentioned. As the market changes, so must our valuations. Subjectively stating the market supports no discernible difference is not a choice. Even a zero adjustment requires support for the conclusion.

Verify the listed sales with a party involved to be sure the terms *green* or *energy efficient* as used are equal to your understanding of green and energy efficient. Upon verifying five sales listed in the MLS as green, I found not one was green. Three had energy-efficient appliances only, and two were code-built houses that the builder considered energy efficient. If these sales were used without verification, an error in the value may have resulted. To avoid this type of problem, the MLS boards will need to implement accountability steps to ensure these data fields are not being misused. Some MLS boards do require the agent to download the certification as an attachment to the MLS if they want the green or energy fields checked.

Cost Approach

The Addendum has provided an excellent description of the property for proper cost figures. Even if your market does not show a discernible difference for green features, the cost approach should reflect the true cost to construct. Most green houses can be built for 0% to 5% over the cost to build a code-built house. These percentages will increase if the owner has installed alternative energy sources such as solar, wind, or geothermal. Be diligent in your cost approach and explanation of the cost figures.

Conclusion

The Residential Green and Energy-Efficient Addendum is designed to extend the description of the property that currently exists on the residential forms. Even if your lender does not require the form, I am sure it will not prohibit the use of the Addendum for this complex appraisal problem. Using the form will provide a more accurate description of the property to meet the Uniform Standards of Professional Appraisal Practice (USPAP) Standards Rule 1-1(e). If you do not describe the green features properly, the client assumes you did not understand the property type, and therefore, valued it incorrectly.

Only 2.9% of all appraisers in the United States have taken the Appraisal Institute's green classes and only 1.8% of all NAR members have taken NAR's green classes. Builders, contractors, and property owners are concerned over the lack of competency in the area of green, but the Appraisal Institute is the leader in the movement toward green competency. It has put a great deal of effort into developing education and tools to assist appraisers in valuing green and energy-efficient properties.

Since the Appraisal Institute's September 29, 2011 news release announcing its green addendum, AI has received substantial national and local print and online media coverage. Through November 5, 2011 traditional media coverage potentially has been read, heard, or seen nearly 133 million times. This should tell us something about the importance of this topic.

Is your name listed in the Appraisal Institute's database of appraisers that have completed the *Valuation of Sustainable Buildings Professional Development Program*?[16] If you have not taken the development course series, consider signing up for the classes soon. This will make valuing the shades of green a less daunting task and will fulfill the first step in competency—education.

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[16] http://www.appraisalinstitute.org/findappraiser/green_sustainability_residential.aspx.

Valuing High Performance Houses

by Sandra K. Adomatis, SRA

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."[1]

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.[2]

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.[3]

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.[4] 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.[5]

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.[6] LEED-rated homes are

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1. *The Dictionary of Real Estate Appraisal*, 5th ed. (Chicago: Appraisal Institute, 2010), 192.
2. NAHB National Green Building Program, http://www.nahbgreen.org/.
3. The brochure and the NAHB Model Green Home Building Guidelines are available at http://www.nahbgreen.org/Guidelines/nahbguidelines.aspx.
4. Requirements include effective insulation systems; high-performance windows; tight construction and ducts; efficient heating and cooling equipment; and high-efficiency lighting and appliances.
5. The HERS Index is like a golf game, the lower the score the more energy efficient the house. A HERS Index of 100 is representative of the standard code-built house; an Energy Star house must be at least 15% more energy efficient than the standard home, meaning the maximum score for a qualifying home is 85. According to the EPA, there are over one million Energy Star houses. For more information, see http://www.energystar.gov.
6. LEED-certified buildings are designed to lower operating costs, reduce landfill waste, conserve energy and water, and have improved indoor environmental quality. For more information, see http://www.usgbc.org.

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=bldrs_lenders_raters.nh_HERS
http://www.natresnet.org/
http://www.usgbc.org/Default.aspx
http://www.nahbgreen.org/
http://www.appraisalinstitute.org
http://www.earthadvantage.com

The Valuation Process

Documentation

It is important to convey to the appraisal management company, lender, realtor, homeowner, or builder the necessary documentation used to complete an accurate report of a high performance house. This may take some tenacity on the part of the appraiser.

If a green or energy-efficient property has a third-party rating, there will be a paper trail. This paper trail is the documentation needed to support the analysis of the high performance home. The appraiser should ask the client for the following:

1. Any documentation of a third-party rating, score sheets, Home Energy Rating System (HERS) rating, and Fannie Mae Energy Report
2. Documentation of any incentives available to the buyer or owner, such as a
   a. lower interest rate mortgage/higher loan-to-value ratio[8]
   b. utility rebate
   c. IRS tax credit
   d. real estate tax discount
   e. expedited building permit

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 a15-year period, results in the

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[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=bldrs_lenders_raters.energy_efficient_mortgage.

following key strokes: N = 15, I = 6, 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.

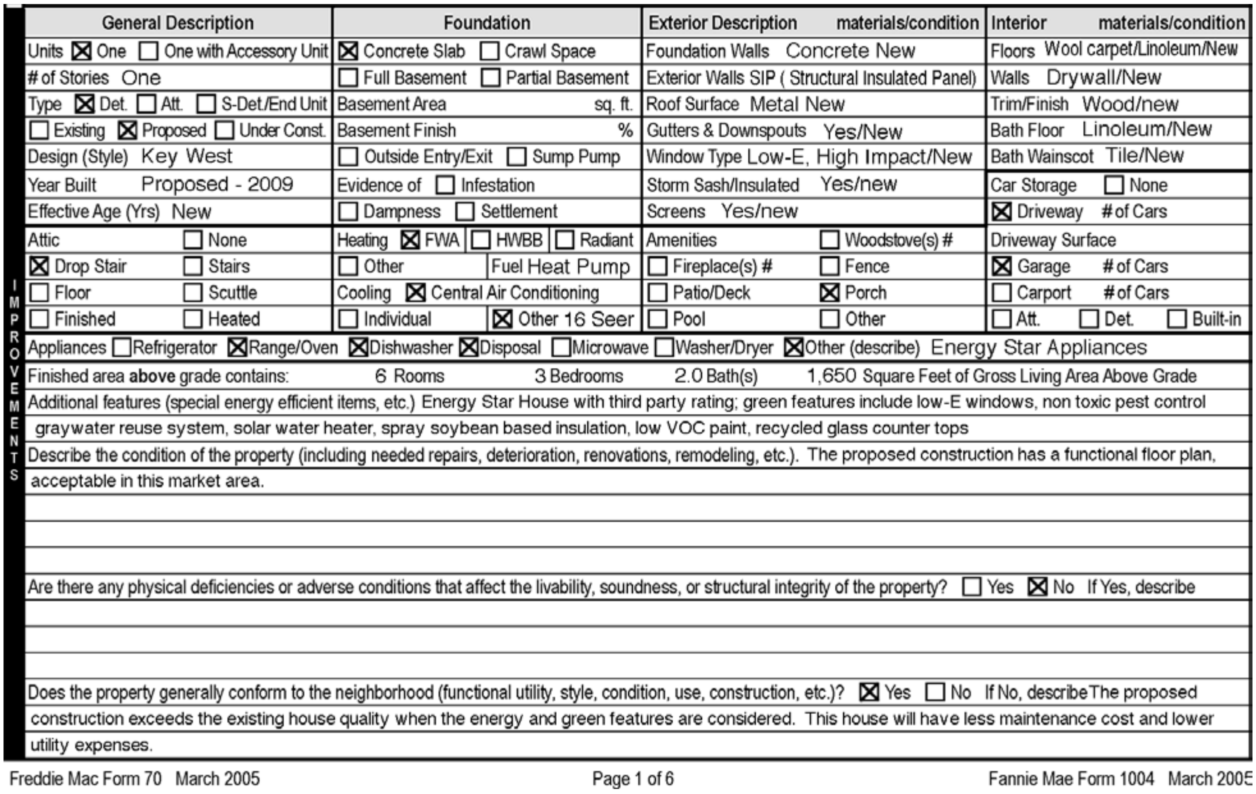
Having some basis for value or lack of contributory value is the main point addressed by Uniform Standards of Professional Appraisal Practice (USPAP) and by Fannie Mae in its mortgages. For example, comparing the HERS Index ratings of the comparables is a measurement of comparability. It would be ideal 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

General Description	Foundation	Exterior Description materials/condition	Interior materials/condition
Units ☒ One ☐ One with Accessory Unit	☒ Concrete Slab ☐ Crawl Space	Foundation Walls Concrete New	Floors Wool carpet/Linoleum/New
# of Stories One	☐ Full Basement ☐ Partial Basement	Exterior Walls SIP (Structural Insulated Panel)	Walls Drywall/New
Type ☒ Det. ☐ Att. ☐ S-Det./End Unit	Basement Area sq. ft.	Roof Surface Metal New	Trim/Finish Wood/new
☐ Existing ☒ Proposed ☐ Under Const.	Basement Finish %	Gutters & Downspouts Yes/New	Bath Floor Linoleum/New
Design (Style) Key West	☐ Outside Entry/Exit ☐ Sump Pump	Window Type Low-E, High Impact/New	Bath Wainscot Tile/New
Year Built Proposed - 2009	Evidence of ☐ Infestation	Storm Sash/Insulated Yes/new	Car Storage ☐ None
Effective Age (Yrs) New	☐ Dampness ☐ Settlement	Screens Yes/new	☒ Driveway # of Cars
Attic ☐ None	Heating ☒ FWA ☐ HWBB ☐ Radiant	Amenities ☐ Woodstove(s) #	Driveway Surface
☒ Drop Stair ☐ Stairs	☐ Other Fuel Heat Pump	☐ Fireplace(s) # ☐ Fence	☒ Garage # of Cars
☐ Floor ☐ Scuttle	Cooling ☒ Central Air Conditioning	☐ Patio/Deck ☒ Porch	☐ Carport # of Cars
☐ Finished ☐ Heated	☐ Individual ☒ Other 16 Seer	☐ Pool ☐ Other	☐ Att. ☐ Det. ☐ Built-in

Appliances ☐ Refrigerator ☒ Range/Oven ☒ Dishwasher ☒ Disposal ☐ Microwave ☐ Washer/Dryer ☒ Other (describe) Energy Star Appliances

Finished area **above** grade contains: 6 Rooms 3 Bedrooms 2.0 Bath(s) 1,650 Square Feet of Gross Living Area Above Grade

Additional features (special energy efficient items, etc.) Energy Star House with third party rating; green features include low-E windows, non toxic pest control graywater reuse system, solar water heater, spray soybean based insulation, low VOC paint, recycled glass counter tops

Describe the condition of the property (including needed repairs, deterioration, renovations, remodeling, etc.). The proposed construction has a functional floor plan, acceptable in this market area.

Are there any physical deficiencies or adverse conditions that affect the livability, soundness, or structural integrity of the property? ☐ Yes ☒ No If Yes, describe

Does the property generally conform to the neighborhood (functional utility, style, condition, use, construction, etc.)? ☒ Yes ☐ No If No, describe The proposed construction exceeds the existing house quality when the energy and green features are considered. This house will have less maintenance cost and lower utility expenses.

Freddie Mac Form 70 March 2005 Page 1 of 6 Fannie Mae Form 1004 March 2005

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.

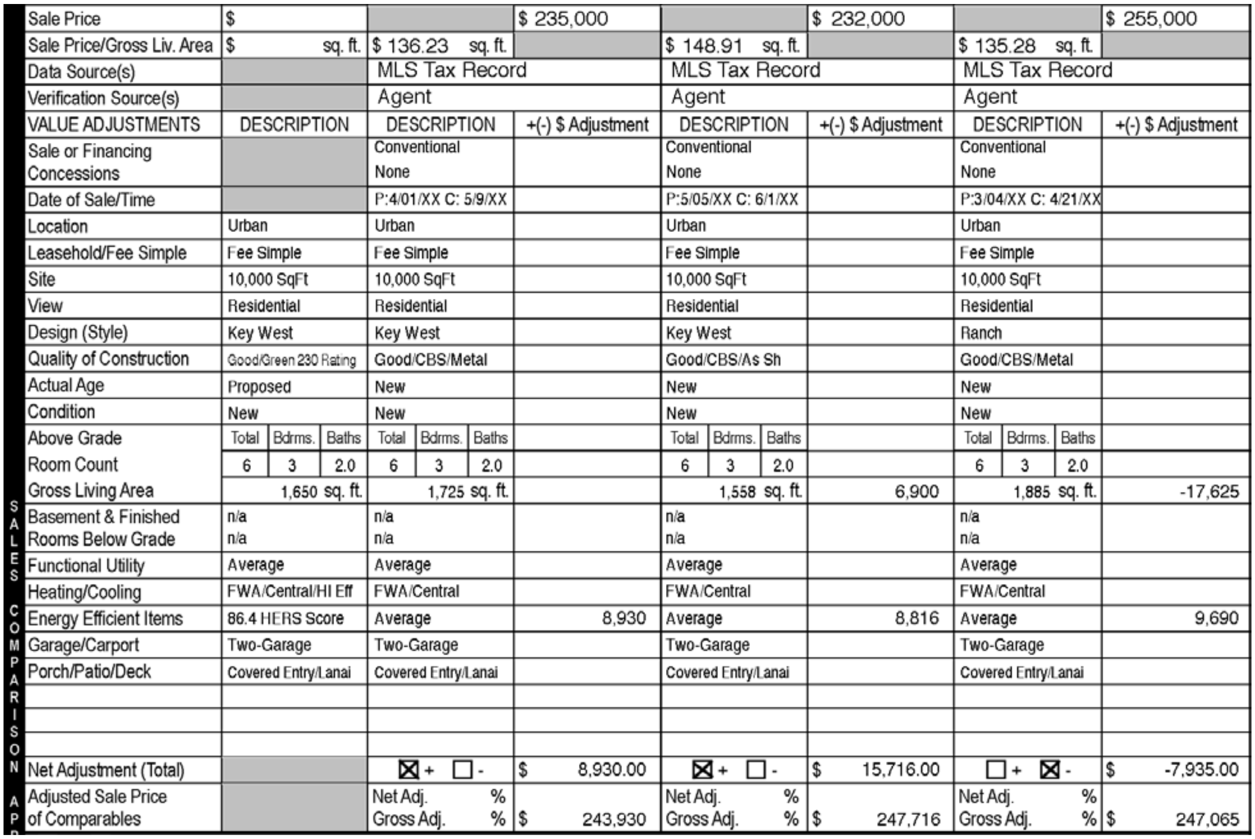
Also, keep in mind that building codes have changed in the last five years. The typical green or Energy Star house is built above the standard building code. This makes it extremely important to use new construction as comparables when appraising new green or Energy Star houses. The use of ten-year-old 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**



Sale Price	$		$ 235,000		$ 232,000		$ 255,000
Sale Price/Gross Liv. Area	$ sq. ft.	$ 136.23 sq. ft.		$ 148.91 sq. ft.		$ 135.28 sq. ft.	
Data Source(s)		MLS Tax Record		MLS Tax Record		MLS Tax Record	
Verification Source(s)		Agent		Agent		Agent	
VALUE ADJUSTMENTS	DESCRIPTION	DESCRIPTION	+(-) $ Adjustment	DESCRIPTION	+(-) $ Adjustment	DESCRIPTION	+(-) $ Adjustment
Sale or Financing Concessions		Conventional None		Conventional None		Conventional None	
Date of Sale/Time		P:4/01/XX C: 5/9/XX		P:5/05/XX C: 6/1/XX		P:3/04/XX C: 4/21/XX	
Location	Urban	Urban		Urban		Urban	
Leasehold/Fee Simple	Fee Simple	Fee Simple		Fee Simple		Fee Simple	
Site	10,000 SqFt	10,000 SqFt		10,000 SqFt		10,000 SqFt	
View	Residential	Residential		Residential		Residential	
Design (Style)	Key West	Key West		Key West		Ranch	
Quality of Construction	Good/Green 230 Rating	Good/CBS/Metal		Good/CBS/As Sh		Good/CBS/Metal	
Actual Age	Proposed	New		New		New	
Condition	New	New		New		New	
Above Grade	Total Bdrms. Baths	Total Bdrms. Baths		Total Bdrms. Baths		Total Bdrms. Baths	
Room Count	6 3 2.0	6 3 2.0		6 3 2.0		6 3 2.0	
Gross Living Area	1,650 sq. ft.	1,725 sq. ft.		1,558 sq. ft.	6,900	1,885 sq. ft.	-17,625
Basement & Finished Rooms Below Grade	n/a n/a	n/a n/a		n/a n/a		n/a n/a	
Functional Utility	Average	Average		Average		Average	
Heating/Cooling	FWA/Central/HI Eff	FWA/Central		FWA/Central		FWA/Central	
Energy Efficient Items	86.4 HERS Score	Average	8,930	Average	8,816	Average	9,690
Garage/Carport	Two-Garage	Two-Garage		Two-Garage		Two-Garage	
Porch/Patio/Deck	Covered Entry/Lanai	Covered Entry/Lanai		Covered Entry/Lanai		Covered Entry/Lanai	
Net Adjustment (Total)		☒ + ☐ -	$ 8,930.00	☒ + ☐ -	$ 15,716.00	☐ + ☒ -	$ -7,935.00
Adjusted Sale Price of Comparables		Net Adj. % Gross Adj. %	$ 243,930	Net Adj. % Gross Adj. %	$ 247,716	Net Adj. % Gross Adj. %	$ 247,065

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 ratings. 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.[9]

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.[10] The anticipated monthly energy savings is $59.58 with an energy savings contributory value estimated at $8,633.60.

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

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[9] *Selling Guide: Fannie Mae Single Family* (Fannie Mae, December 30, 2009), 513—514, available at http://www.efanniemae.com/sf/guides/ssg/.

[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.

Gross Rent Multipliers

	604 Brown St.	1294 Killen St
Neighborhood	Same	Same
Price	$244,000	$233,000
Monthly rent	$1,600	$1,500
GRM	152.5	155.3

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.

Paired Sales Analysis

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

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.

Builder Survey

Best Build, Inc.	$9,500
Quality Builders of Old	$8,200
Southern Builders	$9,200
Bob and Sons, Inc.	$7,500
ABC Builders	$7,800

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.

Study Conclusions

Summary of Value Indications for Energy Features

Fannie Mae Energy Report	$8,633.60
GRM analysis	$9,175.00
Paired sales analysis	$9,000.00
Survey of builders	$8,200.00

Incentives for Green and Energy-Efficient Features

IRS tax credit	$ 500
Utility rebate	1,500
Insurance discount (3%)	300
EEM closing cost reimbursement	1,000
Total	$3,300

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 3.8% 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.

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http://www.appraisalinstitute.org/education/green_energy_addendum.aspx

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Form 820.03: Residential Green and Energy Efficient Addendum

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This Program consists of the following courses:

- Introduction to Green Buildings: Principles & Applications
- Case Studies in Appraising Green Residential Buildings

- Case Studies in Appraising Green Commercial Buildings (coming in 2012)

Participants in any of the above courses also have access to AI Green Resources – one convenient webpage that allows you to tap a variety of green resources. Topics are expanded regularly and include legislation, national and state government sites and programs, databases, design, and solar energy. Many of these resources can also help appraisers when completing the Residential Green and Energy Efficient Addendum.

This free benefit is available only to class participants. Appraisal Institute Designated members receive indefinite access; all other class participants are granted two-year admittance. The link to this helpful resource is provided with the course materials.

The Green Resources Webpage will be updated regularly; we encourage course participants to check it frequently for new links and submit their own!

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Appraisal Institute Announces Support for New Solar Valuation Tool

Posted by Appraisal Institute Staff on Tue, Jan 31, 2012

The Appraisal Institute this week announced its support for a new tool that will assist appraisers and others seeking to establish the value of a property's solar-powered features. The spreadsheet was developed by Solar Power Electric and Sandia National Laboratories.

Finding a way to value residential and commercial properties with photovoltaic (PV) installations is a growing challenge facing the nation's real estate industry. As more homes and businesses turn to solar power, the need grows for ways to develop reliable and credible opinions of value of the installations and the power they generate.

PV Value works within a Microsoft Excel spreadsheet to determine the value of a PV system. This is done using an income capitalization approach whereby the energy value is calculated over the lifetime of the PV module warranty. Inputs to PV Value include the zip code of the location, local utility rate and characteristics of the PV system. An appraisal range of value estimate is returned as a function of a pre-determined risk spread. This tool can be used to value a PV system at any location in the U.S. through its interface with the National Renewable Energy Laboratory's PVWatts simulator.

The Appraisal Institute last September introduced its Residential Green and Energy Efficient Addendum, a form intended to help analyze values of energy-efficient home features. It is the first of its kind intended for appraisers' use. AI's addendum was designed to produce data that can be entered into the new solar spreadsheet.

The Appraisal Institute issued its form as an optional addendum to Fannie Mae Form 1004, the appraisal industry's most widely used form for mortgage lending purposes. The Appraisal Institute's addendum allows appraisers to identify and describe a home's green features, from solar panels to energy-saving appliances.

Click here to see the new solar valuation spreadsheet from Solar Power Electric and Sandia National Laboratories.

If you have an "opinion of value," please share your comments.

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http://www.appraisalinstitute.org/education/prof_dev_programs.aspx

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Participants who are eligible and who successfully complete a program will be placed on the Program's Registry located on the Appraisal Institute's website. Completion of a program shows potential clients and employers that participants have completed education and passed related course exams in the particular specialized topic.

NOTE: If you are a Designated or Associate member completing a Professional Development Program as an option for the ACE requirement, please be aware that you **MUST complete ALL of the courses in the Professional Development Program to receive credit for the ACE requirement**.

Valuation of the Components of a Business Enterprise

- Course Descriptions and Online Registration
    - *Fundamentals of Separating Real Property, Personal Property and Intangible Business Assets*
- Program Registry – Valuation of the Components of a Business Enterprise
- Program Registry – SBA Going Concern
- FAQs – Valuation of the Components of a Business Enterprise
- FAQs – SBA Going Concern

International Valuation of Fixed Assets

- Course Descriptions and Online Registration
    - Valuation in Challenging Markets
    - *International Valuation Standards Involving Real Estate*

    - *International Financial Reporting Standards for the Real Property Appraiser*
- FAQs
- Program Registry (COMING SOON)

Valuation of Sustainable Buildings

- Course Descriptions and Online Registration
    - Introduction to Green Buildings
    - Case Studies in Appraising Green Residential Buildings
    - Residential and Commercial Valuation in Solar **(Coming Soon!)**
    - Case Studies in Appraising Green Commercial Buildings
- FAQs
- Green/Sustainability Program Registry
    - Residential
    - Commercial

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- Program Description and Online Registration
- FAQs
- Program Registry

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- Program Registry

Litigation

- Course Descriptions and Online Registration
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    - Litigation Appraising: Specialized Topics and Applications
    - Condemnation Appraising: Principles & Applications
- FAQs
- Program Registry

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***Please Note:** On December 13, 2010, the name *Certificate Program of Completion* changed to *Professional Development Program*.

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An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California

Ben Hoen, Ryan Wiser, Peter Cappers and Mark Thayer

Environmental Energy Technologies Division

April 2011

This work was supported by the Office of Energy Efficiency and Renewable Energy (Solar Energy Technologies Program) of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231, by the National Renewable Energy Laboratory under Contract No. DEK-8883050, and by the Clean Energy States Alliance.

Disclaimer

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Prepared for the

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Clean Energy States Alliance

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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, *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

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[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.[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).

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[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,

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[5] More information about this product can be obtained from 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-

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[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;[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*);[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).[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*.[14]

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[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.

[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.

[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.

[14] This final screen was intended to remove homes that had unusually large appreciation or deprecations 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

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

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.[15] 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).[16]

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

	Non-PV Homes				
Variable	***n***	**Mean**	**Std. Dev.**	**Min**	**Max**
acre	70425	0.3	0.8	0.0	24.8
acregt1	70425	0.1	0.7	0.0	23.8
acrelt1	70425	0.2	0.2	0.0	1.0
ages2	70425	19	23.3	-1	108
ages2sqr	70425	943	1681	0	11881
asp2	70425	$ 480,862	$ 348,530	$ 85,007	$ 2,498,106
avtotal	70425	$ 497,513	$ 359,567	$ 10,601	$ 3,876,000
bath	70425	2.6	0.9	1	9
bgre_100	70425	0.0	1.2	-18.0	19.0
elev	70425	424	598	0	5961
lasp2	70425	12.9	0.6	11.4	14.7
pvage	70425	0	0	0	0
sd2	70425	9/30/2005	793 days	1/7/1999	6/30/2009
size	70425	0	0	0	0
sp2	70425	$ 584,740	$ 369,116	$ 69,000	$ 4,600,000
sqft_1000	70425	2.2	0.9	0.8	9.3
yrbuilt	70425	1986	23	1901	2009

	PV Homes				
Variable	***n***	**Mean**	**Std. Dev.**	**Min**	**Max**
acre	1894	0.4	1.0	0.0	21.6
acregt1	1894	0.1	0.9	0.0	20.6
acrelt1	1894	0.2	0.2	0.0	1.0
ages2	1894	17.3	24.5	-1	104
ages2sqr	1894	937	1849	0	11025
asp2	1894	$ 537,442	$ 387,023	$ 85,973	$ 2,419,214
avtotal	1894	$ 552,052	$ 414,574	$ 23,460	$ 3,433,320
bath	1894	2.9	1	1	7
bgre_100	1894	0.2	1.3	-10.0	17.9
elev	1894	414	584	0	5183
lasp2	1894	13.0	0.6	11.4	14.7
pvage	1894	1.5	2.0	-1.0	9.0
sd2	1894	3/28/2007	622 days	8/1/2000	6/29/2009
size	1894	3.1	1.6	0.6	10.0
sp2	1894	$ 660,222	$ 435,217	$ 100,000	$ 3,300,000
sqft_1000	1894	2.4	0.9	0.8	11.0
yrbuilt	1894	1989	25	1904	2009

Table 3: Summary Statistics of Repeat Sale Dataset

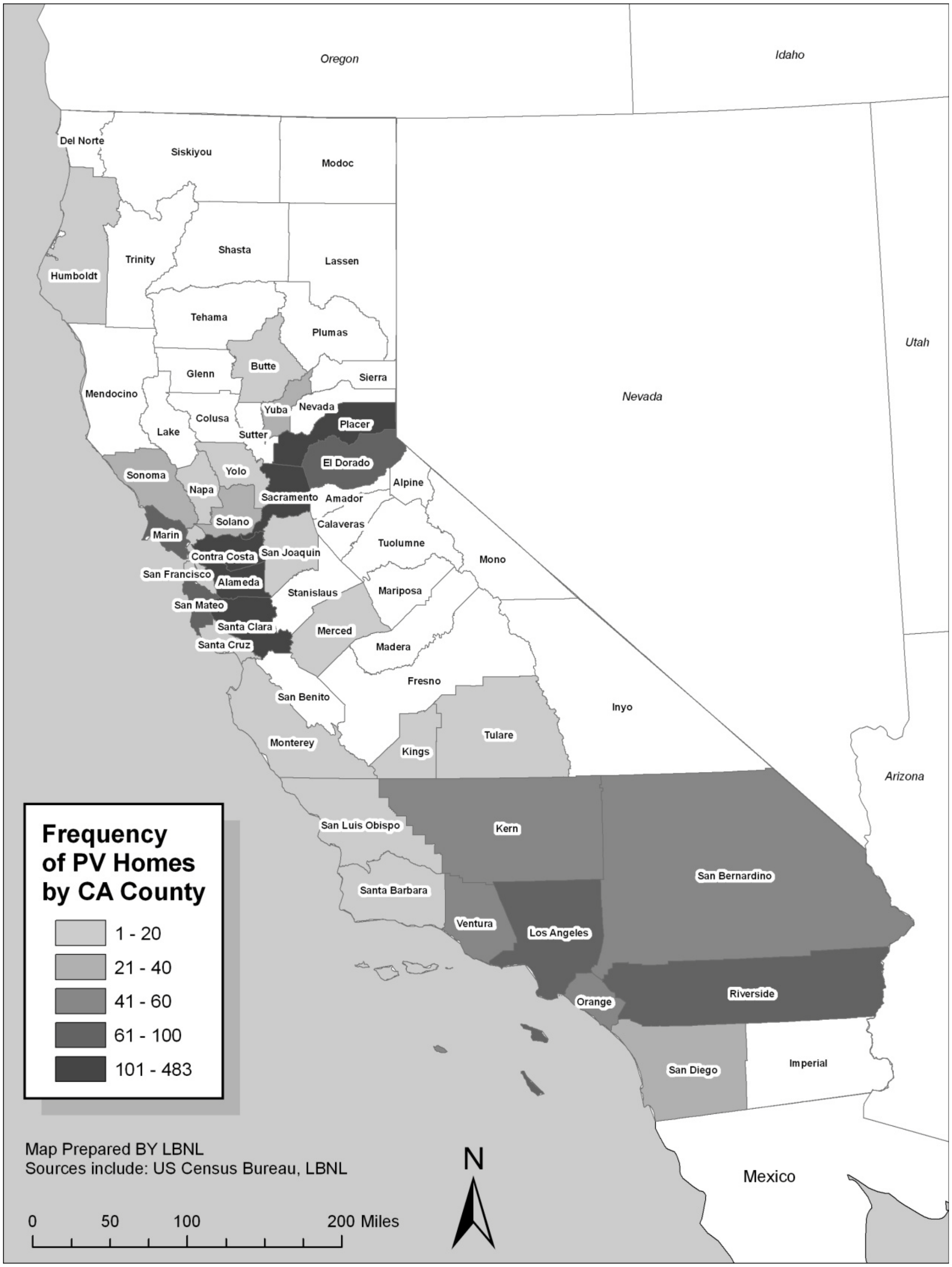
	Non-PV Homes				
Variable	***n***	**Mean**	**Std. Dev.**	**Min**	**Max**
acre	27919	0.3	0.7	0.0	23.2
acregt1	27919	0.1	0.6	0.0	22.2
acrelt1	27919	0.2	0.2	0.0	1.0
ages2	27919	23.6	22.7	0	108
ages2sqr	27919	1122.0	1775.0	1.0	11881.0
asp1	27919	$ 488,127	$ 355,212	$ 85,398	$2,495,044
asp2	27919	$ 481,183	$ 347,762	$ 85,007	$2,472,668
avtotal	27919	$ 498,978	$ 360,673	$ 35,804	$3,788,511
bath	27919	2.5	0.8	1	9
bgre_100	27919	0.0	1.3	-17.7	19.0
elev	27919	426	588	0	5961
lasp1	27919	12.9	0.6	11.4	14.7
lasp2	27919	12.9	0.6	11.4	14.7
pvage	27919	0	0	0	0
sd1	27919	5/5/2001	1780 days	11/1/1984	12/11/2008
sd2	27919	5/14/2006	786 days	3/11/1999	6/30/2009
sddif	27919	1835	1509	181	7288
size	27919	0	0	0	0
sp1	27919	$ 444,431	$ 287,901	$ 26,500	$2,649,000
sp2	27919	$ 577,843	$ 371,157	$ 69,000	$3,500,000
sqft_1000	27919	2.1	0.8	0.8	7.7
yrbuilt	27919	1982	23	1901	2008

	PV Homes				
Variable	***n***	**Mean**	**Std. Dev.**	**Min**	**Max**
acre	394	0.5	1.4	0.0	21.6
acregt1	394	0.2	1.3	0.0	20.6
acrelt1	394	0.2	0.2	0.0	1.0
ages2	394	34.6	25.6	1	104
ages2sqr	394	1918.0	2336.0	4.0	11025.0
asp1	394	$ 645,873	$ 417,639	$ 110,106	$2,339,804
asp2	394	$ 666,416	$ 438,544	$ 91,446	$2,416,498
avtotal	394	$ 682,459	$ 478,768	$ 51,737	$3,433,320
bath	394	2.6	0.9	1	7
bgre_100	394	0.1	1.6	-5.5	17.9
elev	394	479	581	3	3687
lasp1	394	13.2	0.6	11.6	14.7
lasp2	394	13.2	0.6	11.4	14.7
pvage	394	2.5	1.6	-1.0	9.0
sd1	394	11/22/1999	1792 days	11/30/1984	1/7/2008
sd2	394	1/9/2007	672 days	8/1/2000	6/29/2009
sddif	394	2605	1686	387	7280
size	394	4.03	1.94	0.89	10
sp1	394	$ 492,368	$ 351,817	$ 81,500	$2,500,000
sp2	394	$ 800,359	$ 489,032	$ 121,000	$3,300,000
sqft_1000	394	2.2	0.8	0.8	5.3
yrbuilt	394	1972	26	1904	2008

Table 4: Frequency Summary by California County

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

Figure 1: Map of Frequencies of PV Homes by California County



Map Prepared BY LBNL
Sources include: US Census Bureau, LBNL

Table 5: Frequency Summary by Home Type, Utility and Sale Year

Home Type *	**Non-PV**	**PV**	**Total**
New Home	26,938	935	27,873
Existing Home	43,487	897	44,384
Utility **	**Non-PV**	**PV**	**Total**
Pacific Gas & Electric (PG&E)	36,137	1,019	37,156
Southern California Edison (SCE)	14,502	337	14,839
San Diego Gas & Electric (SDG&E)	8,191	35	8,226
Sacramento Municipal Utility District (SMUD)	11,393	498	11,891
Other	202	5	207
Sale Year	**Non-PV**	**PV**	**Total**
1999	110	0	110
2000	379	1	380
2001	1,335	10	1,345
2002	6,278	37	6,315
2003	8,783	63	8,846
2004	10,888	153	11,041
2005	10,678	168	10,846
2006	9,072	173	9,245
2007	8,794	472	9,266
2008	9,490	642	10,132
2009	4,618	175	4,793

** 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:

Sales price = *f* (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.

(see e.g., Hoen et al., 2009).[18] 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.[19] A census block group generally contains between 200 and 1,000 households,[20] 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[21] 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.[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:

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

where

P_{itk} represents the inflation adjusted sale price for transaction *i*, in quarter *t*, in block group *k*,
α is the constant or intercept across the full sample,
T_t 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*,
β_1 is a parameter estimate for the quarter in which transaction *i* occurred,
β_2 is a parameter estimate for the census block group in which transaction *i* occurred,
β_3 is a vector of parameter estimates for home characteristics *a*,
β_4 is a parameter estimate for the PV fixed effects variable, and
ε_{itk} is a random disturbance term for transaction *i*,in quarter *t*, in block group *k*.

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[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 β_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:

$$\ln(\mathrm{P}_{\mathrm{itk}}) = \alpha + \beta_1(\mathrm{T}_{\mathrm{t}}) + \beta_2(\mathrm{N}_{\mathrm{k}}) + \sum_{\mathrm{a}} \beta_3(\mathrm{X}_{\mathrm{i}}) + \beta_4(\mathrm{PV}_{\mathrm{i}} \cdot \mathrm{SIZE}_{\mathrm{i}}) + \varepsilon_{\mathrm{itk}} \tag{2}$$

where

$SIZE_i$ is a continuous variable for the size (in kW) of the PV system installed on the home prior to transaction *i*,

β_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 β_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.[23] 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.[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).[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.

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[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.

[25] The procedure used, as described in the referenced paper, is coarsened exact matching (cem) in Stata, available at: 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.[26] Comparing the coefficient of the variable of interest (β_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

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[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

	Pre PV	**Post PV**	**Difference**
PV Homes	PV_1	PV_2	$\Delta PV = PV_2 - PV_1$
Non-PV Homes	NPV_1	NPV_2	$\Delta NPV = NPV_2 - NPV_1$
			$DD = \Delta PV - \Delta NPV$
1 and 2 denote time periods			

The base DD model is estimated as follows:

$$\ln(P_{itk}) = \alpha + \beta_1(T_t) + \beta_2(N_k) + \sum_a \beta_3(X_i) + \beta_4(PVH_i) + \beta_5(SALE2_i) + \beta_6(PVS_i) + \varepsilon_{itk} \quad (3)$$

where

PVH_i is a fixed effect variable indicating if a PV system is or <u>will be</u> installed on the home in transaction *i*,

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[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.

$SALE2_i$ is a fixed effect variable indicating if transaction *i* is the second of the two sales,

PVS_i is a fixed effect variable (an interaction between PVH_i and $SALE2_i$) 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,

β_4 is a parameter estimate for homes that have or will have PV installed (i.e., from Table 6 "$PV_1 - NPV_1$"),

β_5 is a parameter estimate if transaction *i* occurred as of the second sale (i.e., "ΔNPV"),

β_6 is a parameter estimate if transaction *i* occurred as of the second sale and the home contained PV (i.e., "$\Delta PV - \Delta NPV$" or "DD"), and all other terms are as were defined for equation (1).

The coefficient of interest is β_6, 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 (β_4) and the differences between the initial sale and the second sale of non-PV homes (β_5). 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

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[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:

$$\ln(P_{itk}) = \alpha + \beta_1\left(T_t\right) + \beta_2\left(N_k\right) + \sum_a \beta_3\left(X_i\right) + \beta_4\left(PV_i \cdot SIZE_i \cdot AGE_i\right) + \varepsilon_{itk} \qquad (4)$$

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, β_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 β_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 *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:[31]

$$\ln(P_{itk}) = \alpha + \beta_1(T_t) + \beta_2(N_k) + \sum_a \beta_3(X_i) + \beta_4(PV_i \cdot SIZE_i) + \beta_5(PV_i \cdot SIZE_i \cdot SIZE_i) + \varepsilon_{itk} \quad (5)$$

where

β_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 (β_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.[32] To test this directly using the full dataset, the following model is estimated:

$$\begin{aligned}\ln(P_{itk}) = \alpha + \beta_1(T_t) + \beta_2(N_k) + \sum_a \beta_3(X_i) + \beta_4(SQFT_i) + \beta_5(PV_i \cdot SIZE_i) + \\ \beta_6(PV_i \cdot SIZE_i \cdot SQFT_i) + \varepsilon_{itk}\end{aligned} \quad (6)$$

where

$SQFT_i$ is a continuous variable for the number of square feet for the home in transaction *i*,[33]

β_4 is a parameter estimate for the percentage change in sale price for each additional 1000 square feet added to the home,

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[31] Neither this nor the following model is coupled with robustness models in this paper.

[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.

[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.

β_5 is a parameter estimate for the percentage change in sale price for each additional kW added to a PV system,

β_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 β_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

Model Number	Model Name	Base Model	Robustness Model	Other Models	Dataset	Neighborhood Fixed Effects
1	Fixed - Base	X			Full	Block Group
1Ra	Fixed - Matched		X		Full Matched	Block Group
1Rb	Fixed - Subdivision		X		Full	Subdivision/Block Group
2	Continuous - Base	X			Full	Block Group
2Ra	Continuous - Matched		X		Full Matched	Block Group
2Rb	Continuous - Subdivision		X		Full	Subdivision/Block Group
2Rc	Continuous - PV Only		X		PV Only	Block Group
3	New Homes - Base	X			New	Block Group
3Ra	New - Matched		X		New - Matched	Block Group
3Rb	New - Subdivision		X		New	Subdivision/Block Group
4	Existing Homes - Base	X			Existing	Block Group
4Ra	Existing - Matched		X		Existing - Matched	Block Group
4Rb	Existing - Subdivision		X		Existing	Subdivision/Block Group
5	Difference-in-Difference (DD) - Base	X			Repeat Sales	Block Group
5Ra	Difference-in-Difference (DD) - Subdivision		X		Repeat Sales	Subdivision/Block Group
5Rb	Difference-in-Difference (DD) - Sddif < 5 Years		X		Repeat Sales w/ sddif < 5	Block Group
6	Age of System - Base	X			Existing	Block Group
6Ra	Age of System - Matched		X		Existing - Matched	Block Group
6Rb	Age of System - Subdivision		X		Existing	Subdivision/Block Group
7	Returns to Scale - Size			X	Full	Block Group
8	Returns to Scale - Square Feet			X	Full	Block Group

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.[34, 35] 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.[36]

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.[37] 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.

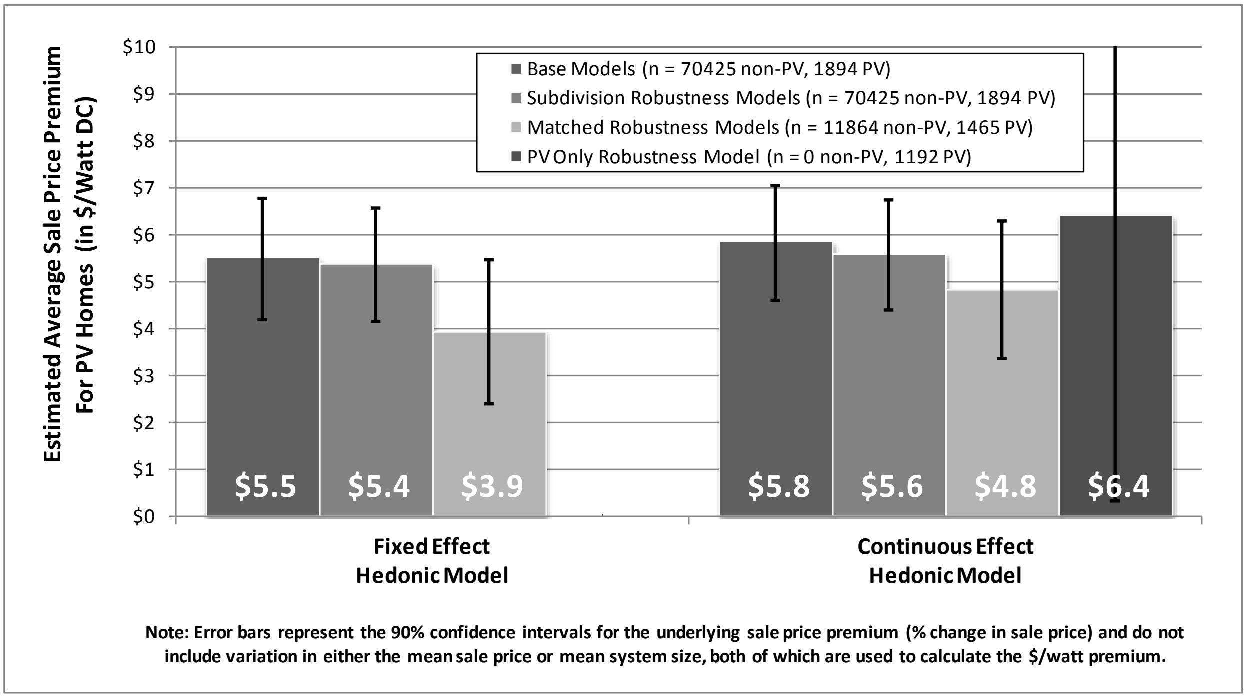
4.1. Fixed and Continuous Effect Hedonic Model Results

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



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.

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[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 area[40] – 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]

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[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 loose 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

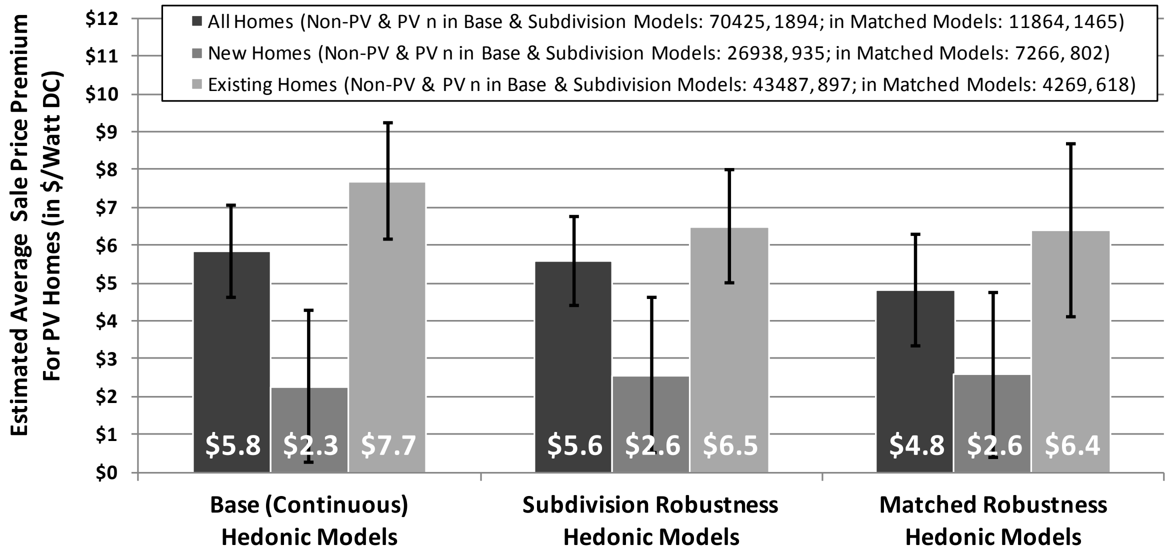
	Fixed			**Continuous**			
	Base	**Robustness Matched**	**Robustness Subdivision**	**Base**	**Robustness Matched**	**Robustness Subdivision**	**Robustness PV Only**
	Model 1	**Model 1Ra**	**Model 1Rb**	**Model 2**	**Model 2Ra**	**Model 2Rb**	**Model 2Rc**
pv	0.036***	0.024***	0.035***				
	(0.005)	(0.006)	(0.005)				
size				0.012***	0.010***	0.012***	0.013*
				(0.002)	(0.002)	(0.001)	(0.008)
sqft_1000	0.253***	0.205***	0.250***	0.253***	0.205***	0.250***	0.224***
	(0.001)	(0.006)	(0.001)	(0.001)	(0.006)	(0.001)	(0.010)
lt1acre	0.417***	0.514***	0.414***	0.416***	0.510***	0.413***	0.441***
	(0.009)	(0.040)	(0.010)	(0.009)	(0.040)	(0.010)	(0.066)
acre	0.016***	0.013	0.015***	0.016***	0.013	0.015***	-0.002
	(0.002)	(0.011)	(0.003)	(0.002)	(0.010)	(0.003)	(0.012)
ages2	-0.004***	-0.006***	-0.004***	-0.004***	-0.006***	-0.004***	-0.008***
	(0.0002)	(0.0012)	(0.0002)	(0.0002)	(0.0012)	(0.0002)	(0.0030)
ages2sqr	0.00003***	0.00004***	0.00003***	0.00003***	0.00004***	0.00003***	0.00004***
	(0.000003)	(0.000012)	(0.000003)	(0.000003)	(0.000012)	(0.000003)	(0.000033)
bgre_100	0.003***	0.015***	0.003***	0.003***	0.015***	0.003***	0.013***
	(0.001)	(0.004)	(0.001)	(0.001)	(0.004)	(0.001)	(0.005)
intercept	12.703***	12.961***	12.710***	12.702***	12.957***	12.710***	12.842***
	(0.010)	(0.044)	(0.012)	(0.010)	(0.043)	(0.012)	(0.073)
*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	72,319	13,329	72,319	72,319	13,329	72,319	1,192
Adjusted R^2	0.93	0.95	0.94	0.93	0.95	0.94	0.93
n (pv homes)	1,894	1,465	1,894	1,894	1,465	1,894	1,192
Mean non-pv asp2	$ 480,862	$ 480,533	$ 480,862	$ 480,862	$ 480,533	$ 480,862	$ 475,811
Mean size (kW)	3.1	3.0	3.1	3.1	3.0	3.1	2.7
Estimated $/Watt	$ 5.5	$ 3.9	$ 5.4	$ 5.8	$ 4.8	$ 5.6	$ 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



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.

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

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[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

	New Homes			**Existing Homes**		
	Base	**Robustness**	**Robustness**	**Base**	**Robustnes**	**Robustness**
		Matched	**Subdivision**		**Matched**	**Subdivision**
	Model 3	**Model 3Ra**	**Model 3Rb**	**Model 4**	**Model 4Ra**	**Model 4Rb**
size	0.006*	0.006*	0.006**	0.014***	0.011***	0.012***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
sqft_1000	0.247***	0.190***	0.250***	0.256***	0.238***	0.251***
	(0.002)	(0.006)	(0.002)	(0.002)	(0.015)	(0.002)
lt1acre	0.536***	0.279***	0.517***	0.373***	0.426***	0.376***
	(0.019)	(0.073)	(0.024)	(0.010)	(0.046)	(0.012)
acre	-0.007	0.338***	-0.009*	0.019***	0.011	0.017***
	(0.005)	(0.027)	(0.005)	(0.002)	(0.011)	(0.003)
ages2	-0.010	0.081***	-0.010*	-0.005***	-0.006***	-0.005***
	(0.006)	(0.017)	(0.006)	(0.000)	(0.002)	(0.000)
ages2sqr	0.00768***	-0.02443***	0.00715***	0.00004***	0.00004***	0.00004***
	(0.001676)	(0.004407)	(0.001604)	(0.000003)	(0.000014)	(0.000004)
bgre_100	0.008***	0.027***	0.007***	0.002	-0.002	0.002
	(0.001)	(0.003)	(0.001)	(0.001)	(0.009)	(0.001)
intercept	12.651***	12.585***	12.627***	12.820***	13.023***	12.833***
	(0.022)	(0.066)	(0.025)	(0.013)	(0.077)	(0.014)
*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

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.

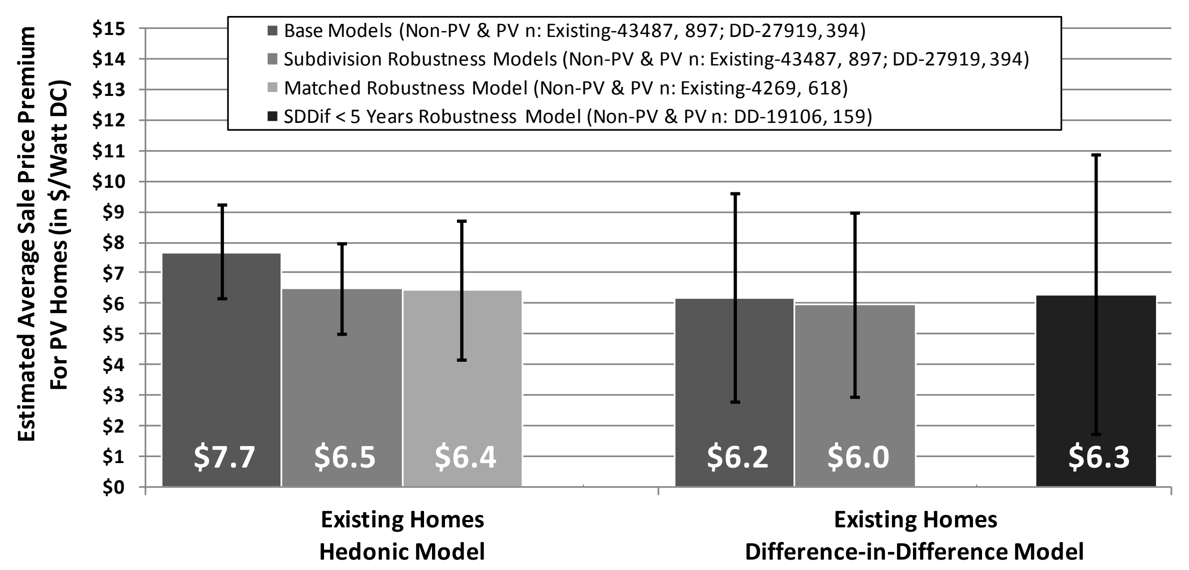
PVH estimates the difference in the first sale prices of homes that will have PV installed (as of the second sale date) relative to non-PV homes. The three models are consistent in their estimates, showing approximately a 2% premium for "future" PV homes, though only two of these estimates are statistically 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



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

	Difference-in-Difference		
	Base	**Robustness**	**Robustness**
		Subdivision	**Sddif < 5**
	Model 5	**Model 5Ra**	**Model 5Rb**
pvh	0.022*	0.024	0.022*
	(0.013)	(0.021)	(0.012)
sale2	0.023***	0.026***	0.019***
	(0.002)	(0.002)	(0.002)
pvs	0.051***	0.061**	0.049***
	(0.017)	(0.027)	(0.015)
sqft_1000	0.255***	0.256***	0.251***
	(0.002)	(0.002)	(0.002)
lt1acre	0.374***	0.385***	0.377***
	(0.011)	(0.013)	(0.012)
acre	0.012***	0.009**	0.011***
	(0.003)	(0.004)	(0.003)
age	-0.005***	-0.005***	-0.005***
	(0.0002)	(0.0003)	(0.0003)
agesqr	0.00004***	0.00004***	0.00004***
	(0.000003)	(0.000003)	(0.000003)
bgre_100	0.002*	0.000	0.001
	(0.001)	(0.001)	(0.001)
intercept	12.677***	12.594***	12.694***
	(0.013)	(0.015)	(0.014)

*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	28,313	19,265	28,313
Adjusted R^2	0.93	0.94	0.94
n (pv homes)	394	159	394
Mean non-pv asp2	$ 488,127	$ 450,223	$ 488,127
Mean size (kW)	4.0	4.3	4.0
Estimated $/Watt	$ 6.2	$ 6.3	$ 6.0

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

	Age of PV Systems for Existing Homes			Returns to Scale	
	Base	Robustness Matched	Robustness Subdivision	Size	Square Feet
	Model 6	Model 6Ra	Model 6Rb	Model 7	Model 8
size*1 year old	0.016***	0.016***	0.013***		
	(-0.004)	(-0.005)	(-0.004)		
size*2-4 years old	0.015***	0.010***	0.013***		
	(-0.002)	(-0.003)	(-0.002)		
size*5+ years old	0.012***	0.008**	0.008**		
	(-0.003)	(-0.004)	(-0.003)		
size				0.008**	0.021***
				(0.003)	(0.006)
sizesqr				0.001	
				(0.001)	
size*sqft_1000					-0.003
					(0.002)
sqft_1000	0.256***	0.238***	0.251***	0.253***	0.253***
	(0.002)	(0.015)	(0.002)	(0.001)	(0.001)
lt1acre	0.373***	0.426***	0.376***	0.416***	0.416***
	(0.010)	(0.046)	(0.012)	(0.009)	(0.009)
acre	0.019***	0.010***	0.017***	0.016***	0.016***
	(0.002)	(0.011)	(0.003)	(0.002)	(0.002)
ages2	-0.005***	-0.006***	-0.005***	-0.004***	-0.004***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
ages2sqr	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
bgre_100	0.002***	-0.002***	0.002***	0.003***	0.003***
	(0.001)	(0.009)	(0.001)	(0.001)	(0.001)
intercept	12.820***	13.024***	12.834***	12.702***	12.701***
	(0.013)	(0.078)	(0.014)	(0.010)	(0.011)
*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	4,887	44,384	72,319	72,319
Adjusted R^2	0.93	0.95	0.94	0.93	0.93
n (pv homes)	897	618	897	1,894	1,894
Mean non-pv asp2	$ 532,645	$ 590,428	$ 532,645	$ 480,862	$ 480,862
Mean size (kW)	3.8	3.7	3.8	3.1	3.1
Estimated $/Watt	$8.3 - $6.1	$9.3 - $4.9	$7.0 - $4.1	$ 6.3	$ 6.4
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)[43] 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.

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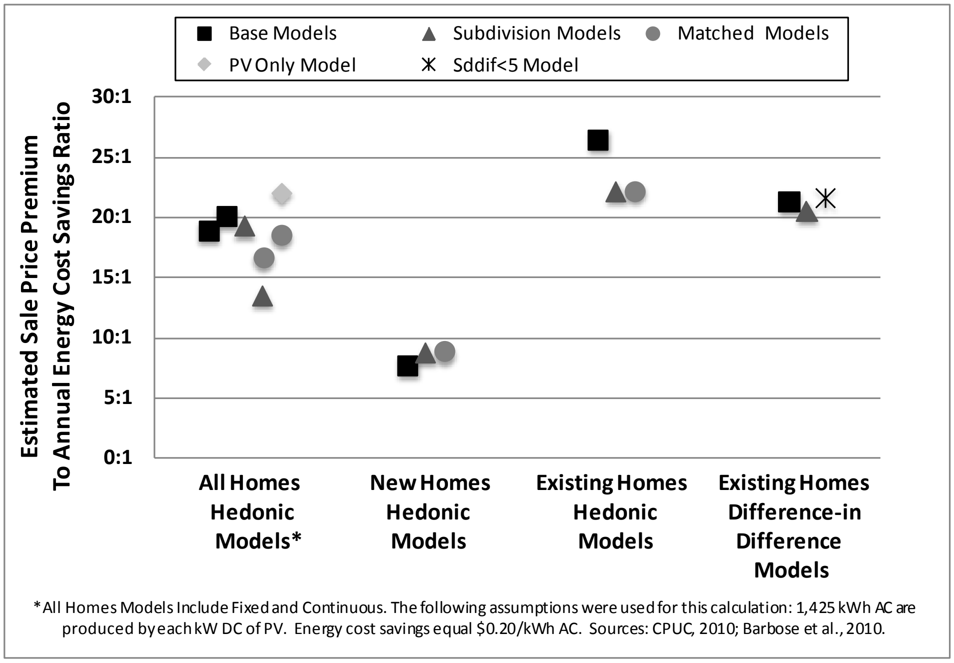
[43] The 1,425 kWh (AC) estimate is based on a combination of a 19% capacity factor (based on AC kWh and CEC-AC kW) from CPUC (2010), and an 0.86 conversion factor between CEC-AC kW and DC kW (Barbose et al., 2010).

Figure 5: Estimated Ratios of Sale Price Premium to Annual Energy Cost Savings



*All Homes Models Include Fixed and Continuous. The following assumptions were used for this calculation: 1,425 kWh AC are produced by each kW DC of PV. Energy cost savings equal $0.20/kWh AC. Sources: CPUC, 2010; 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.

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The California ENERGY COMMISSION

What is your Home ENERGY RATING?

know before you buy or sell

Lower your energy bills

Enjoy a safer, more comfortable
and durable home

Reduce your impact on the environment

Increase your home's sales appeal
and appraisal value

UPDATED FOR 2011

What is your Home ENERGY RATING?

> "Whether you are buying or selling a residential property, or staying in your current home, every Californian should know his or her home **energy rating.**"

The California ENERGY COMMISSION

Contents

What is your Home ENERGY RATING?

California is a national leader in promoting energy efficiency. As a result, our energy use per person has remained stable for over 30 years while the national average has steadily increased. Despite this success, we must continue to reduce energy use in our homes. The benefits are highly valuable — reducing energy use not only lowers your energy bills, but helps our electricity system remain reliable, even during high peak-load periods, while also protecting our environment.

In 2006, California established aggressive goals to reduce greenhouse gases that cause global warming. These goals will cut today's carbon emissions by 25 percent, so we can return to 1990 levels by the year 2020. Efforts to accomplish this goal represent important first steps in addressing the threat of global warming. We owe our children and grandchildren nothing less.

As you consider the sale or purchase of your home, this booklet asks that you recognize what energy efficiency measures have been built into the home, or ways to make further improvements to save energy and reduce peak electricity demand.

Your energy efficiency actions help make California a better, more environmentally sustainable place to raise your families.

Whether you are buying or selling a residential property, or staying in your current home, every Californian should know his or her home energy rating. Wasted energy wastes more than just your money – it changes our climate. The scientific community agrees that we must act now or risk facing an uncertain future.

The California Home Energy Rating System (HERS) Program provides a reliable way to estimate and compare the energy efficiency of California homes and identify wise energy saving improvements. This booklet explains how the HERS program works and helps you find a qualified professional to rate your own home. Once you know your home energy rating, you will be able to choose smart energy upgrades and investments that will benefit your family now… and generations to come.

During a real estate transaction, a California HERS Rating is a great way to disclose facts about the energy efficiency of a home.

Know the FACTS

Whether you are getting ready to sell your home – or preparing to buy one – knowing the energy efficiency facts about the property is a major consideration. As buyers become more aware of the benefits of an energy-efficient home, homes with a favorable home energy rating may be more attractive to buyers.

Selling?

A HERS rating will:

- Help determine facts about the energy efficiency of your home.
- Identify energy improvements that may make your home more attractive to buyers.
- Alert appraisers to add value for any energy improvements you may have made already.

Buying?

- Use a HERS rating to shop and compare the energy efficiency of homes you are considering.
- Learn about the most cost-effective options for lowering the energy bills in any home you are considering buying.
- Identify and qualify for energy efficiency financing.

Staying in your current home?

- Find out your HERS rating.
- Discover the best options for lowering your energy bills.
- Identify energy efficiency improvements that may also make your home more comfortable.
- Find resources to help finance your improvements.
- Improve your home's resale value.

Have you checked your ducts?

Heating and cooling ducts in an average California home leak almost 30 percent. That is why when heating or cooling equipment is replaced, testing the system's ducts for leaks is now required by building officials in many parts of the state.

If you are selling your home and had upgrades made without the required permits or duct testing, be sure to disclose this on your Real Estate Transfer Disclosure Statement. If you are preparing to buy a home that had duct work performed after October 2005, ask to see the duct testing report, or an explanation as to why such testing was not required.

For more information, visit:
www.energy.ca.gov/title24/changeout/

What is a HOME ENERGY RATING

You wouldn’t buy a new car without knowing its “miles per gallon” rating. So why buy a home without a “home energy rating?”

A Whole-House Home Energy Rating is a comprehensive evaluation of the efficiency of the entire home. The homeowner receives a written report that includes a numeric score or “rating” of the home, plus recommendations for improvements that will reduce energy bills and make the home more comfortable. Knowing the energy rating of your home is similar to knowing the miles per gallon rating of your car.

The California Energy Commission has developed the California Home Energy Rating System (HERS) Program to cover almost every type of residence in California. This includes new and existing single-family homes and multifamily buildings of three stories or less. Energy Commission-approved HERS Providers train, certify, and oversee a new type of service professional known as a “California Whole-House Home Energy Rater.”

Each California HERS Rater must follow standardized energy auditing procedures and use energy analysis software that meets the Energy Commission’s technical requirements. The HERS Rater will inspect and assess all the major energy efficiency features of your home:

- Air leaks (sealed or unsealed)
- Cooling system
- Heating system
- Water heating system
- Heating and cooling ducts and/or pipes
- Insulation (attic, walls, floor)
- Windows
- Attached lighting fixtures
- Major appliances
- Solar electricity generating systems (if any)
- Other energy uses

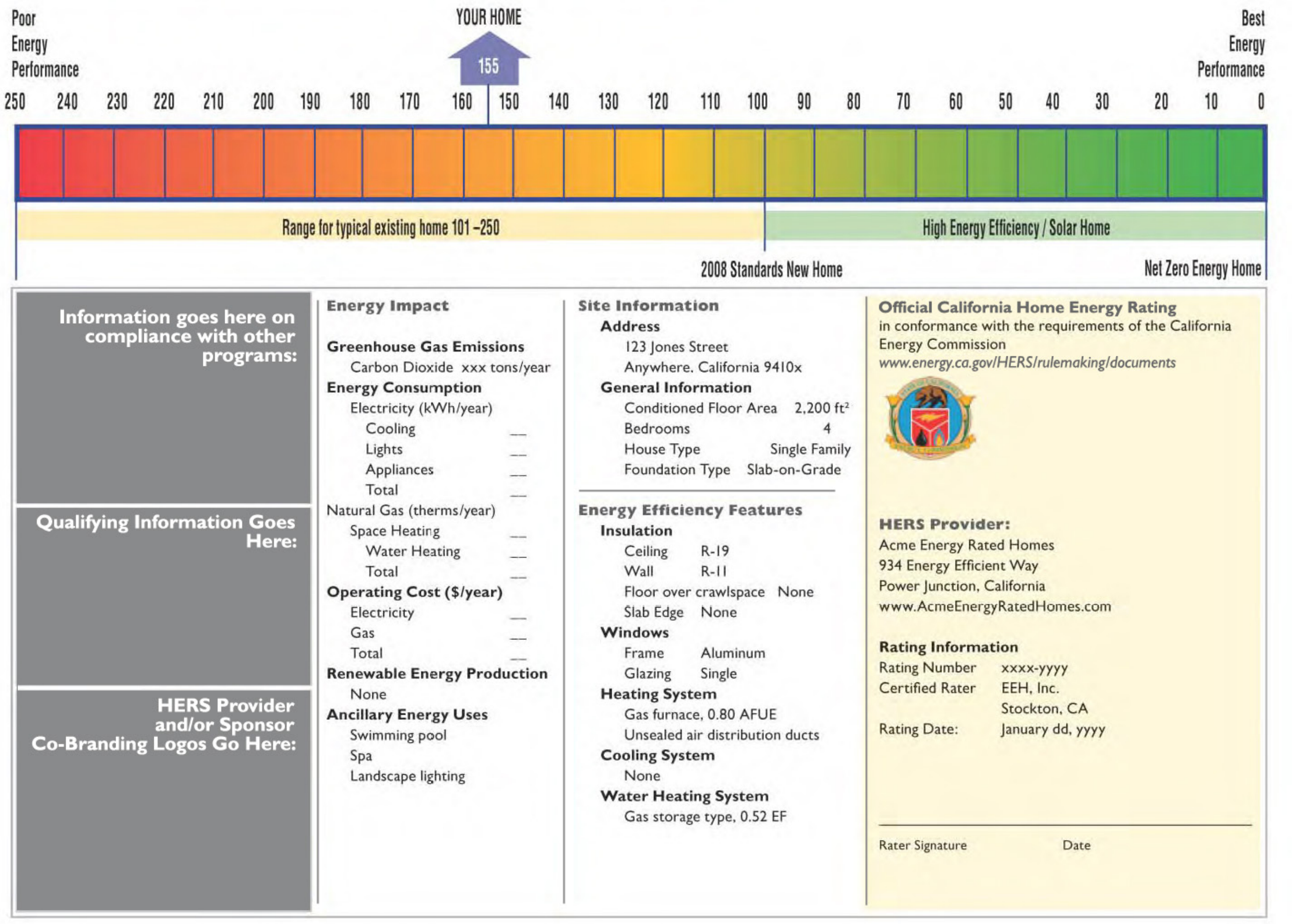
Your HERS report will identify the most cost-effective and appropriate energy efficiency improvements for your home. Only a properly prepared HERS Report will receive an official California Home Energy Rating Certificate with the California Energy Commission’s seal.

Rating costs vary depending on factors such as the size and features of your home and the extent of rater services needed. Ask your real estate agent for names of certified HERS Raters in your area or find an Energy Commission-approved HERS Provider at: www.energy.ca.gov/HERS/index.html or call the Energy Hotline at (800) 772-3300.

Your HERS Rating Certificate will:

- Display an official HERS Index efficiency rating on a 0 to 250-point scale.
- Itemize the home's major energy-efficiency features as determined by the HERS Rater.
- Estimate the home's annual energy use, operating cost, and greenhouse gas emissions.
- Calculate the amount of solar or other onsite renewable energy that the home may produce.

Understanding your HERS index



Poor Energy Performance

YOUR HOME

155

Best Energy Performance

250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

Range for typical existing home 101 –250

High Energy Efficiency / Solar Home

2008 Standards New Home

Net Zero Energy Home

Information goes here on compliance with other programs:

Qualifying Information Goes Here:

HERS Provider and/or Sponsor Co-Branding Logos Go Here:

Energy Impact

Greenhouse Gas Emissions
Carbon Dioxide xxx tons/year
Energy Consumption
Electricity (kWh/year)
Cooling __
Lights __
Appliances __
Total __
Natural Gas (therms/year)
Space Heating __
Water Heating __
Total __
Operating Cost ($/year)
Electricity __
Gas __
Total __
Renewable Energy Production
None
Ancillary Energy Uses
Swimming pool
Spa
Landscape lighting

Site Information

Address
123 Jones Street
Anywhere, California 9410x
General Information
Conditioned Floor Area 2,200 ft²
Bedrooms 4
House Type Single Family
Foundation Type Slab-on-Grade

Energy Efficiency Features

Insulation
Ceiling R-19
Wall R-11
Floor over crawlspace None
Slab Edge None
Windows
Frame Aluminum
Glazing Single
Heating System
Gas furnace, 0.80 AFUE
Unsealed air distribution ducts
Cooling System
None
Water Heating System
Gas storage type, 0.52 EF

Official California Home Energy Rating
in conformance with the requirements of the California Energy Commission
www.energy.ca.gov/HERS/rulemaking/documents

HERS Provider:
Acme Energy Rated Homes
934 Energy Efficient Way
Power Junction, California
www.AcmeEnergyRatedHomes.com

Rating Information
Rating Number xxxx-yyyy
Certified Rater EEH, Inc.
Stockton, CA
Rating Date: January dd, yyyy

Rater Signature Date

What is your Home Energy Rating?
How low can it go?

A lower HERS Index indicates a more energy efficient home.
A home with a HERS Index of:

- "250" or more is likely to have very high energy bills, and many opportunities for efficiency improvements.
- "100" uses the same energy as a new home that meets California's 2008 Building Energy Efficiency Standards.
- "0" is a super-efficient "Net Zero Energy Home" that consumes no more energy than it produces with solar or other onsite renewable sources.

HERS Recommendations

Your HERS report will contain detailed recommendations so that you can learn about all the improvements that are cost-effective and appropriate for your particular home. Here are a few examples:

Test and seal air leaks in building envelope
A pressure test will show where the air is leaking out so you can make your home less drafty.

Increase attic insulation to R-38
Properly installed insulation makes your home quieter and more comfortable.

Test and seal air duct leaks
Almost every home in California has leaky ducts, typically wasting 30 percent or more.

Tune-up the heating and cooling system
Proper maintenance saves energy and improves comfort and safety.

Upgrade to a correctly sized ENERGY STAR® furnace
A new ENERGY STAR® furnace will run more quietly and keep you warm all winter for less money.

Hire a Professional

Don’t trust just anyone to make your improvements. Trying to save a little can sometimes cost you more in the long run. Instead, find one or more licensed specialty contractors who have the knowledge, tools, and skills to do each job right. You may want to consider a “building performance” contractor who is a licensed general contractor and is specially trained and certified to help address all of the energy and comfort improvement opportunities in your home and make them work together as an efficient system. The Contractors State License Board website www.cslb.ca.gov provides more information on how to choose a qualified contractor.

Making WISE IMPROVEMENTS

Do it Yourself

Some improvements are so easy and inexpensive, you don’t need a HERS rating to know they pay back quickly:

- Replace incandescent bulbs with ENERGY STAR® compact fluorescent lamps (CFLs).
- Replace all nightlights and holiday lights with light-emitting diodes (LEDs).
- Choose ENERGY STAR® appliances, computers, and televisions.
- Install low-flow showerheads and faucet aerators.
- Insulate the first 5 feet of pipes from the cold and hot water heater.
- Add or repair weather stripping on all doors and windows.
- Use caulk and spray foam to fill all visible air gaps.
- Clean or replace furnace air filters monthly.
- Plant shade trees.

Energy Wise HABITS

These no-cost tips will help reduce the energy consumption in your home:

- Turn off lights and computers when not in use.
- Use a power strip for televisions, DVD players, VCRs, and chargers, and turn off power to the strip when not in use.
- Recycle burned-out CFL bulbs, fluorescent tubes, televisions, computer monitors, and all other electronic waste.
- Unplug and recycle any inefficient old refrigerators and freezers.
- Use appliances efficiently. Use your dishwasher and clothes washer for full loads only. Use the cold water setting on your clothes washer when possible.
- Turn down the water heater to 120 degrees Fahrenheit.
- Use your drapes properly. In the summer, close your drapes during the day. In the winter, open your drapes during the day and close your drapes at night.
- Open your windows for natural ventilation on cool summer mornings and nights.

A $100 per month reduction in your utility bills frees up enough cash to pay for a $17,000 increase in your mortgage (assuming 6 percent interest over 30 years).

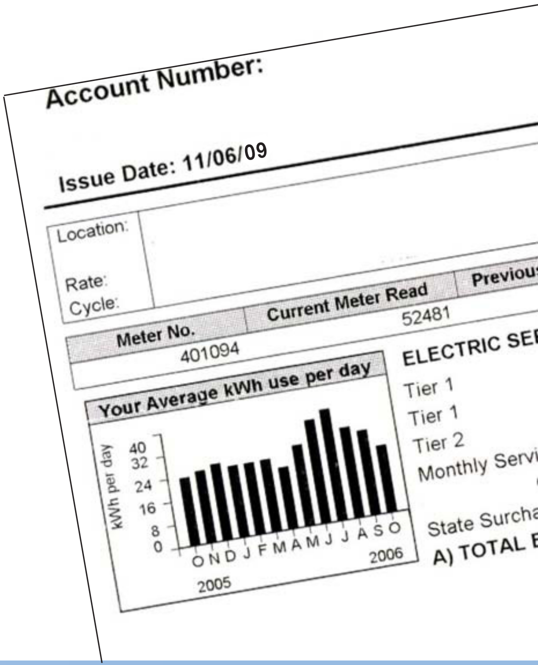
Utility Bills & RATINGS

Home energy efficiency ratings are designed to help you focus on the physical features of the house – not on other factors that can affect energy consumption like unusual weather or personal energy use habits.

Utility bills give a personal perspective: the history of how much energy the occupants of the home actually used over a period. Unless you consider a rating coupled with the utility bills, you may get only half of the story.

As a potential buyer, you should always ask to see the previous occupant's energy bills. While sellers are not obligated to share their utility bills, many will if asked.

If the old bills have not been saved, current occupants can access their records by calling the local utility or by setting up an account on the utility's website. Your HERS Rater can assist you in obtaining the bills and will consider them to establish a more complete picture of your home energy use to make the best recommendations for improvements. A Home Buyers' Energy Checklist that helps buyers ask questions related to the home's energy use is available at: www.energy.ca.gov/HERS/index.html.



Account Number:

Issue Date: 11/06/09

Location:

Rate:
Cycle:

Meter No.	Current Meter Read	Previou
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ELECTRIC SE
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Tier 1
Tier 2
Monthly Servi

State Surcha
A) TOTAL E

Energy efficiency is different than energy consumption. Efficiency depends upon the physical features of the home and all the equipment it contains. Consumption is reduced through efficiency but also depends on the energy use behavior of the occupants. Wasteful habits, unusual weather, or malfunctioning equipment can drive up energy bills, even in the most energy-efficient house in the neighborhood.

After your mortgage payment, your energy bill is often the second largest monthly home ownership expense.

Financing your IMPROVEMENTS

Principal
+ Interest
+ Taxes
+ Insurance
+ Energy

True cost of owning your home

If you are buying or refinancing and looking for a way to finance your energy improvements, you should get advice from a knowledgeable real estate agent or lender about the many new options now available. The federal government, Fannie Mae/Freddie Mac, and many major lenders are introducing new products to help you fund your energy efficiency improvements. Some cities and counties also have programs that allow homeowners to finance efficiency improvements and solar installations over 20 years.

You may also be able to qualify for an Energy Efficient Mortgage (EEM). An EEM is a loan program that recognizes the importance of the energy efficiency of a home and allows for cost-effective energy upgrades to be financed in the mortgage. A HERS rating is required to qualify for an EEM. These loans provide borrowers the opportunity to make energy efficiency improvements to their homes and gain several desirable benefits including:

- Provide the ability to roll the cost of your efficiency improvements into a low mortgage rate.
- May stretch your debt-to-income qualifying ratio.
- Enjoy your improvements and energy savings right away.
- Earn a higher resale price when you sell.

Best of all, you get to enjoy all the benefits of your home improvements for the same total monthly cost (PITI+E)...or maybe even less.

EEM programs are available from:

- Federal Housing Authority (FHA)
- Veterans Administration (VA)
- Conventional lenders (Fannie Mae, Freddie Mac)
- Other home-buyer or refinancing programs

Combine an EEM with other programs and you may be able to borrow up to $40,000 or more for efficiency improvements. Ask a knowledgeable lender if an EEM is right for you.

Another way to finance energy improvements is through an equity loan or equity line of credit. If your HERS rating is low enough, some lenders may offer a “green” mortgage or equity line of credit at a discount relative to their regular interest rates or points. Shop around to see if these products make sense for you. Utilities also offer financial incentives such as re-bates, for energy smart improvements, such as:

- Added insulation
- ENERGY STAR® appliances
- Refrigerator recycling
- High-efficiency heating and air conditioning systems
- Compact fluorescent light fixtures
- Whole-house fans, cool roofs, swimming pool pump motors, and more

Contact your local utility for information on their program offerings. Manufacturers also offer discounts or rebates on efficient products so check their websites or with a retailer for possible offers.

Efficiency
ADDS VALUE

It's no secret; energy efficiency features may make your home more valuable and sell faster.

Federal tax credits now available include:

10 percent of the cost, up to $500 or a specific amount from $50-$300, through 2011 (existing homes only) for:

- Windows and Doors
- Biomass Stoves
- Insulation
- Roofs
- HVAC
- Water Heaters

30 percent of the cost, with no upper limit through 2016 (existing homes and new construction) for:

- Geothermal Heat Pumps
- Small Wind Turbines (Residential)
- Solar Energy Systems

For more news on energy efficiency tax credits, visit: **www.energystar.gov/taxcredits**

Did You Know?

- A study of energy-efficient homes in The Appraisal Journal showed that a $1 reduction in annual energy bills resulted in more than $10 increase in resale value.
- A past president of the California Association of Real Estate Appraisers recommends that appraisals account for any efficiency improvements because they "so contribute to the habitability, enjoyability and economic stability of the home."
- FHA authorizes the cost of energy efficiency measures to be added to the mortgage.
- Home builders find that homes with efficiency and solar electricity upgrades sell faster and at higher prices than similar homes nearby.

Make sure your real estate agent knows about any efficiency improvements you have made, let buyers know your home is "Energy-Rated," and give the appraiser a copy of your HERS Report.

The energy used in the average home produces roughly twice as much greenhouse gas pollution as the average car (US EPA).

Once you have made all appropriate energy efficiency improvements, you may also want to consider solar electric generation.

If you have already decided on the size of solar electric system, investing in energy efficiency measures first will allow your solar system to power more of your home's electricity need. Plan ahead and don't oversize your new solar electric system to power an energy-inefficient house. Your HERS Rater will show you how.

California has set a goal to generate 3,000 megawatts of new, solar-produced electricity by 2017 — moving the state toward a cleaner energy future and lowering the cost of solar systems for all consumers. The California Solar Initiative offers incentives up to 30 percent off the installed cost of a solar system for a typical home. This discount may be combined with any federal tax credits or other incentives available.

Visit
www.gosolarcalifornia.ca.gov
for details.

ACKNOWLEDGEMENTS

CALIFORNIA
ENERGY COMMISSION

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Need Help? Call the Energy Hotline
(800) 772-3300 or (916) 654-5106

CEC-400-2009-008-BR-REV1
June 2011

Prepared by:
Architectural Energy Corporation
San Francisco, California
Contract No. 400-05-020

Photo on page 4 courtesy of The Energy Conservatory.
Photos on page 7 courtesy of: National Renewable Energy Laboratory, CertainTeed, and Carrier.

CUT HERE

The California ENERGY COMMISSION

Property Address:

I have received a copy of the **WHAT IS YOUR HOME ENERGY RATING?** booklet (CEC-400-2009-008-BR-REV1)

Buyer's Signature	Printed Name	Date
Buyer's Signature	Printed Name	Date
Buyer's Agent Signature	Printed Name	Date
	Broker's Name	
Seller's Signature	Printed Name	Date
Seller's Signature	Printed Name	Date
Listing Agent's Signature	Printed Name	Date
	Broker's Name	

ALL SIGNERS SHOULD RETAIN A COPY OF THIS PAGE FOR THEIR RECORDS

California Civil Code Section 2079.10 states that if this booklet is provided to the buyer by the seller or broker, then this booklet is deemed to be adequate to inform the home buyer about the existence of California Home Energy Rating Program.

For more information, visit: www.energy.ca.gov/HERS/index.html

MAIN MENU

- Home

LOGIN

Username: DEER

Username

LOGIN

Password: 2008

Database for Energy Efficient Resources

The Database for Energy Efficient Resources (DEER) contains information on selected energy-efficient technologies and measures. The DEER provides estimates of the energy-savings potential for these technologies in residential and nonresidential applications. The database contains information on typical measures -- those commonly installed in the marketplace -- and data on the costs and benefits of more energy-efficient measures. Energy-efficient measures provide the same energy services using less energy, but they usually cost slightly more.

The 2008 versions of the Database for Energy Efficiency Resources (DEER) have been developed by the California Public Utilities Commission (CPUC) with funding provided by California ratepayers.

Last Updated (Wednesday, 14 October 2009 08:43)

WHO'S ONLINE

We have 4 guests and 1 member online

CSS XHTML

ACEEE
American Council for an Energy-Efficient Economy

How Does Energy Efficiency Create Jobs?

November 14, 2011 - 1:31pm

By Casey Bell, Senior Economic Analyst

With unemployment hovering at a stubborn 9%, it is no wonder that job creation has become a hot topic. It is nearly impossible to read the news without encountering an article describing how a policy or industry creates a given number of jobs. Often, job creation is used as a justification for public sector investment in a program, policy, institution, or project. You may also see numbers from the energy industry proclaiming the ways their particular resource creates jobs. These claims, however, rarely or clearly explain how job creation assessments are carried out and what the jobs numbers actually mean.

For many years, ACEEE has done analyses and written reports on the role of energy efficiency in creating jobs. Recently, we released a fact sheet, "How Does Energy Efficiency Create Jobs?," that seeks to de-mystify how net job impacts should be estimated, and demonstrate how investments in cost-effective energy efficiency improvements can yield a net positive benefit for the nation's overall employment.

A recent New York Times column raised a question on whether or not *anybody,* be they politicians or CEOs, can actually "create" jobs. The article points out that in many cases, policies or investments are not creating new jobs but, at best, are simply shuffling them around amongst different industries, and asserts that **"**jobs are not the cause of a healthy economy; they're a byproduct." It concludes that we need to find a way to train Americans for jobs that will help them earn a living wage, which is an argument of merit. Yet, there are also ways we can streamline our energy use and alter our spending patterns to free up additional funds to support higher levels of employment overall, as well as promote a healthier and more robust economy.

Net Jobs vs. Gross Jobs

Energy efficiency, for the most part, creates *net* gains in employment (defined below), which extend well beyond the jobs that shift among industries. It does so in two ways. First, an initial effort or investment will create opportunities for workers (e.g., an investment in infrastructure improvements). This stimulates opportunities for the construction sector and industries that support it. Second, energy bill savings that stem from the initial effort or investment will free up the funds to support additional employment throughout the economy. In other words, energy efficiency investments not only inject funds into the economy to stimulate job creation, but they also have the potential to alleviate systemic unemployment by reducing energy bills and making those dollars available to support broader economic activity.

Readers should be aware that other analysts often opt to report job creation in terms of *gross* jobs (defined in Table 1) without assessing impacts relative to a "business as usual" case—in other words, *the number of jobs that would have been supported on average across all sectors of the economy by that same investment amount*. This approach ultimately inflates the estimates by neglecting to provide context (i.e., a power plant may support 100 jobs, but the economy might be able to support 170 jobs if funds were not required to keep the plant running). In this scenario, saying that the power plant creates 100 jobs is misleading.

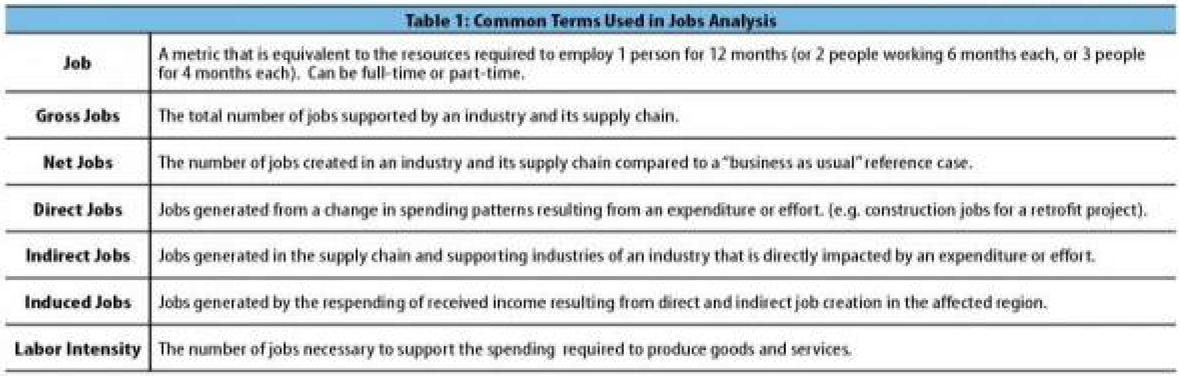
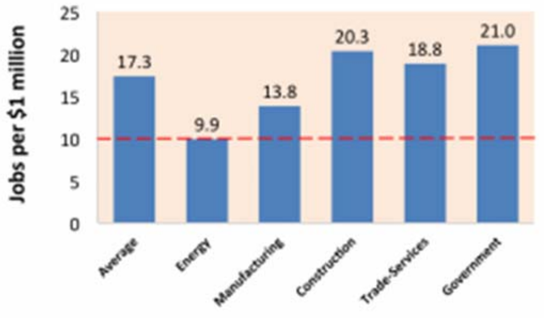


Table 1: Common Terms Used in Jobs Analysis

Job	A metric that is equivalent to the resources required to employ 1 person for 12 months (or 2 people working 6 months each, or 3 people for 4 months each). Can be full-time or part-time.
Gross Jobs	The total number of jobs supported by an industry and its supply chain.
Net Jobs	The number of jobs created in an industry and its supply chain compared to a "business as usual" reference case.
Direct Jobs	Jobs generated from a change in spending patterns resulting from an expenditure or effort. (e.g. construction jobs for a retrofit project).
Indirect Jobs	Jobs generated in the supply chain and supporting industries of an industry that is directly impacted by an expenditure or effort.
Induced Jobs	Jobs generated by the respending of received income resulting from direct and indirect job creation in the affected region.
Labor Intensity	The number of jobs necessary to support the spending required to produce goods and services.

How Does Energy Efficiency Impact Employment and Create Jobs?

Figure 1. Jobs per Million Dollars of Revenue by Key Sectors of the US Economy



To understand how a cost-effective energy efficiency investment can create *net* jobs, it is important to consider how efficiency diverts funds away from less labor-intensive sectors of the economy in order to support greater overall employment. On average, $1 million spent in the U.S. economy supports approximately 17 total jobs (including direct, indirect, and induced jobs—defined in the example below). It is important to note that the $1 million expenditure does not divide neatly into workers' salaries (17 people are not making $59,000 a year as a result of this investment).

Investments directed towards a specific industry may support greater or fewer jobs depending on the industry (you can see in Figure 1 that manufacturing supports approximately 14 jobs per $1 million investment, while the trade-services sector supports just under 19 jobs).

So, an investment in energy efficiency will first create opportunities for workers in industries that are more labor intensive than average (as you'll see in our example, a retrofit project will create jobs in the construction sector, which supports approximately 20 jobs per $1 million, compared to the all-sector average of 17). Then, it will continue to support jobs year after year by saving energy. The energy savings generated by the investment diverts spending away from power generation and distribution, which supports just under 10 total jobs per $1 million (see Figure 1) back into the overall economy (which supports 17 jobs per $1 million).

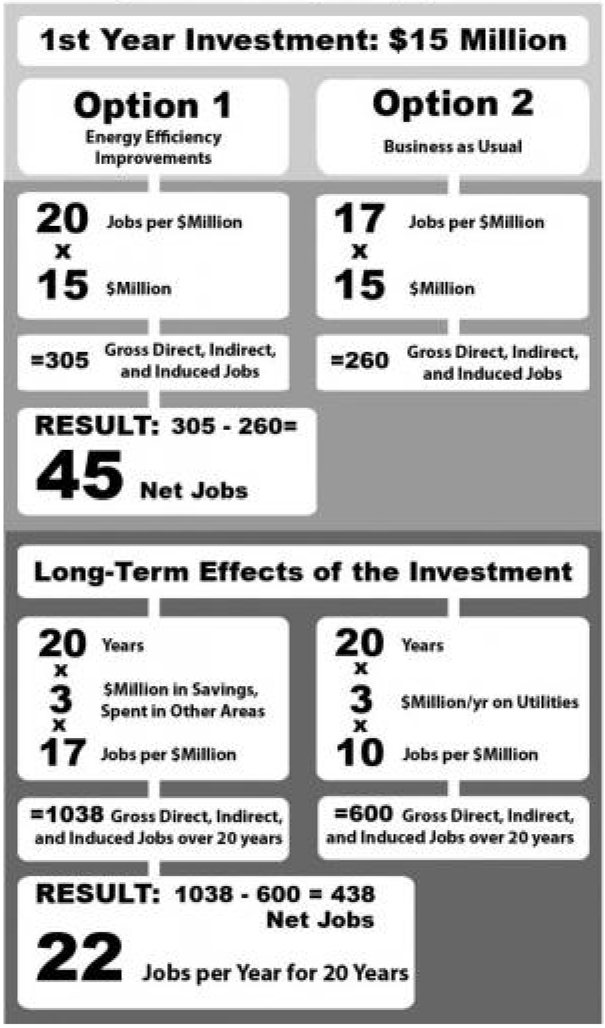
Let's Look at an Example:

A city decides to use $15 million of its revenue to improve energy efficiency in public buildings. These improvements will save the city $3 million a year for the next 20 years.

Three types of jobs are created from this investment. First, a construction contractor will have to hire workers to install the desired energy efficiency measures. These contractor jobs are the *direct* jobs resulting from the investment. In addition, the workers will require materials that they have to purchase from other companies (e.g., insulation, tools). These purchases create jobs throughout the economy for manufacturers and service providers who supply the building industry. These supply-chain jobs are the *indirect* jobs resulting from the investment. Finally, workers in these direct and indirectly created jobs may choose to spend their earnings on goods and services in the local economy, creating *induced* jobs.

In our example, we can assume that funds will be redirected from their “business as usual” spending pattern and channeled into the construction industry, which is more labor intensive than the average sector of the economy. This will support approximately 20 (direct, indirect, and induced) jobs per $1 million investment. In this case, the tradeoff (from spending that supports 17 jobs per $1 million to spending that supports 20 jobs per $1 million) results in an additional 45 jobs in the year the upgrade occurs (see Figure 2).

Figure 2: $15 Million for Energy Efficiency Improvements



Additionally, energy efficiency generates energy bill savings over the life of the investment, which frees up funds to support more jobs in the economy by shifting jobs in the energy generation and distribution industries (lower labor intensity: 10

jobs per $1 million) to jobs in all other industries (higher labor intensity: 17 jobs per $1 million on average). We assume that our investment will save $3 million a year for 20 years and thus achieve a net gain of 22 jobs per year (see Figure 2). Please note that to simplify our calculations in this demonstrative example we assumed that energy savings would be recognized immediately in the first year of the investment, which is often not the case. For many of our analyses, we assume that energy savings are recognized at least six months to one year after the efficiency measures are implemented.

As you can derive from Figure 2, the "business as usual" (pre-efficiency) scenario supports 860 gross jobs (260 + 600) in the first year, which sounds like a lot of jobs (and 600 gross jobs year after year for the next 19 years). However, you can also see that the efficiency scenario supports 1,343 gross jobs (305 + 1038) in the first year (and 1,038 gross jobs year after year for the next 19 years), which is greater than the number of jobs supported by "business as usual." Therefore, energy efficiency creates 67 net jobs in the first year, and continues to support an additional 22 net jobs year after year for the 20-year life of the investment.

How Does ACEEE Determine the Number of Jobs Created by a Given Policy, Program, Institution, or Project?

In recent years, ACEEE has explored how energy efficiency policies can drive net job creation using our in-house **D**ynamic**E**nergy **E**fficiency **P**olicy **E**valuation **R**outine (DEEPER) modeling system. DEEPER evaluates the economy-wide impacts of a variety of energy efficiency, renewable energy, and climate policies at the local, state, and national level. It is a dynamic input-output (I/O) model of the U.S. economy that leverages information about how different institutions—households, industries, businesses, and governments—trade goods and services with one another to estimate the impact that a given policy or investment will have on the larger economy.

DEEPER utilizes jobs coefficients (e.g., the multipliers show in Figure 1) from the **Im**pact Analysis for **Plan**ning (IMPLAN) Modeling System's data set. Our definition for jobs (see Table 1) is consistent with their definition, which they derive from the Bureau of Labor Statistics and the Bureau of Economic Analysis. Also, the IMPLAN multipliers account for leakages, or money that will be spent outside the region's economy.

Over the last 10 years, one of ACEEE's priorities has been to estimate potential jobs and other economic impacts from pending federal energy efficiency legislation. A study performed in 2010 by Laitner, et al. suggested, for example, that adopting a particular suite of Senate-proposed energy efficiency policies could result in a net gain of approximately 700,000 jobs by 2030, and just over 1 million jobs by 2050. Early in 2012 ACEEE will release our analysis on the pending energy efficiency legislation introduced by Senators Jeanne Shaheen

(D-NH) and Rob Portman (R-OH) and the Implementation of National Consensus Appliance Agreements Act (INCAAA). While policymakers may not be able to wave a magic wand and instantly create new jobs for the unemployed, they can support legislation and investments that will save energy and make our economy stronger.

Skip Laitner contributed to this post.

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RESOURCES

FEDERAL DATA

FERC Natural Gas Storage

This website provides reports on and access to a public dataset of natural gas storage fields in the US. Projects that have filed applications with FERC to develop new natural gas storage fields are listed on the website.

NOAA Global Earth Observation — Integrated Data Environment (GEO-IDE)

This NOAA developed and managed website provides access to environmental datasets that are built upon common data standards and common data analysis technologies. Two applications available on the site are the RAMADDA Data Repository and the ERDDAP search tool that provides users with multiple ways to search for datasets that are pertinent to specific environmental data, location, temporal resolution, etc.

The Office of Scientific and Technical Information (OSTI)

OSTI collections, preserves, and disseminates R&D results, including scientific research data, emanating from U.S. Department of Energy-funded projects at DOE labs and facilities, including DOE-funded grantees. Research data discovery tools DOE Data Explorer and Energy Citations Database are available providing users with metadata for DOE research dataset announcement notices.

U.S. Energy Information Administration

The Energy Information Administration is the statistical branch of the Department of Energy that collects and analyzes data on all energy resources and markets.

NON-FEDERAL DATA

California Appliance Efficiency Database

This database contains information on appliances that meet California's energy efficiency standards. Searchable fields include appliance category, manufacturer, brand, model number, and energy performance. Efficiency data reported varies by appliance type (example: Heat pump(SEER and HSPF), Lighting products (lumens/watt), Fans (CMF/watt)).

California Commercial Energy End-Use Survey (CEUS)

This consultant report for the California Energy Commission presents the findings of a 2006 survey that was conducted to assess the utilization of energy by the commercial sector in the State of California. The report details the survey methodology, data collected, and modeling and simulations that were conducted on the data generated from the survey.

California Database for Energy Efficiency Resources (DEER)

The Database for Energy Efficient Resources (DEER) provides information on a comprehensive group of energy efficiency measures commonly installed in the residential and nonresidential market sectors. The database contains estimates of a measure's natural gas and electrical gross impacts, incremental cost, and effective useful life. The savings estimates are based on either engineering calculations, building simulations, measurement studies and surveys, econometric regressions, or a combination of approaches. The DEER data serves as a starting point in the planning and forecasting of the impacts and cost-benefits analysis of energy efficiency programs in California. DEER datasets provide input data for running simulations on relative impact of technology implementation and scale of use in varying buildings or facilities. Accordingly the DEER database has datasets in varying temporal resolutions, multiple energy and resource units, and includes weather/climate related variables for technologies that are weather-dependent.

California Energy Consumption Data Management System

The California Energy Consumption Data Management System provides searchable dataset to highlight energy consumption (electricity and natural gas) by entity (utility type and sector), by county and sector, and planning area and sector. Data reported in million kWh and million of therms per year.

California Renewable Portfolio Standard-Eligible Investor Owned Utility Contract Database

This database provides information on each power plant that has submitted an application to CEC for RPS eligibility and signed a power purchase contract with an investor owned utility. Information is broken down by each contract, providing facility, developer, size, technology, location, delivery date, price, and CEC resolution information.

New York: Empire State Oil & Gas Information System

This website provided by the State of New York is an information system to search and map data on wells and drilling that has occurred in NY State. Also included are annual reports that summarize data, and information on revenue generated from oil and gas well leasing.

North Carolina Green Technologies Database

This website is sponsored by the North Carolina State Energy Office and municipal NGOs to support a database of projects that implement green building technology in their design. The database is sortable by technology/strategy type, location, building type, and is searchable by keyword.

NYSERDA Monitored Performance and Operational Statistics

This represents the New York State Energy Research and Development Authority (NYSERDA) monitored performance data and operational statistics for distributed generation/combined heat and power demonstration projects. New York state has 324 DG/CHP units running in their pilot program, with 173 providing monitoring date to the system. Monitoring data includes location, hourly generation data, equipment information, and fuel type.

GENERAL REFERENCES

Building Rating.org

Buildingrating.org provides a searchable library of documents and resources to aid with building energy efficiency ratings and evaluation. A map of existing domestic and international policies provides links to pre-defined queries of local, state, and federal policy documents.

Carbon Cycle 2.0

The Carbon Cycle 2.0 website is a collaborative site generated by Lawrence Berkeley National Lab that provides a portal for consumers, researchers, and the general public to provide information on research related to energy and carbon emission reduction topics.

Database of State Incentives for Renewables & Efficiency (DSIRE)

DSIRE is a database of existing federal, state, and local incentives to implement energy efficiency and renewable energy technology for all 50 states, Washington DC, and US territories. DSIRE provides some data analysis (summary visualization) of incentives that are offered by federal, state, and local government entities.

Electricity Sector Information Sharing and Analysis Center (ES-ISAC)

The Electricity Sector Information Sharing and Analysis Center serves the electricity sector by facilitating communications between electricity sector participants, federal governments, and other critical infrastructures. It is the job of the ES-ISAC to promptly disseminate threat indications, analyses, and warnings, together with interpretations, to assist electricity sector participants take protective actions. (from ES-ISAC website) ES-IAC is maintained by NERC.

Natural Association of Regulatory Utility Commissioners (NARUC)

The NARUC website provides information on each state and territory's public utility commission. Information on state-by-state public utility policy and NARUC policy that is intended for application across multiple states is provided on the website.

NERC Assessments and Tools

This site provides links to NERC's assessment reports. Reports within this section provide information on electricity transmission infrastructure reliability under various scenarios (seasonal reliability, impact of variable generation), and the site describes software developed by NERC to analyze NERC datasets to plan projects and infrastructure management and upgrades.

NREL Energy Analysis Division

The National Renewable Energy Laboratory's Energy Analysis division develops models and tools that aid with energy development planning and analysis. Tools and models provided or maintained by NREL Energy Analysis include Open EI (collected datasets), specific renewable energy technology analysis tools, economic benefit analysis tools, market analysis tools, and policy analysis tools.

NREL Renewable Energy Certificate and Green Power Markets

NREL's Energy Market Analysis group has examined the dynamics and growth of renewable energy certificate and green power markets within the United State and internationally. Annual analyses reports and publications that have been generated since 2007 are posted on this website.

NREL Technology and Program Market Data

This website contains information generated by NREL's Energy Analysis group on the market for various renewable energy technologies. Some technology reports are updated on an annual basis with the latest reports being published in 2009.

OMB Sustainability and Energy Scorecards

This website provides links to each federal agency's sustainability and energy scorecard. The scorecard provides primarily qualitative information and some quantitative information on each respective agency's progress in meeting their sustainability plans, required under Executive Order 13514.

US Department of Energy – Energy Efficiency & Renewable Energy: National Weatherization Training Portal

The US Department of Energy's Buildings site provides information on technical and financial resources and programs that contribute research and development into building energy efficiency and use of renewable energy technology on buildings. The buildings website provides links to the EERE Buildings Energy Data Book and a searchable publications library.

Are There Rebound Effects from Energy Efficiency? – An Analysis of Empirical Data, Internal Consistency, and Solutions

Of the rigorously-framed hypotheses claiming that large negative rebounds exist, we measure them against the data, which refute the hypotheses. Rebounds at the end-use level are small and decrease over time. Rebounds at the economy-wide level are trivially small, and might well be a net positive.

by David B. Goldstein, Sierra Martinez, and Robin Roy

Every few years, a new report emerges that tries to resurrect an old hypothesis: that energy efficiency policy paradoxically increases the amount of energy we consume. This paper attempts to develop a rigorous and scientifically sound hypothesis for rebound theory. It shows that many of the hypotheses on which the recent papers promoting rebound effects are based are neither scientific nor testable. Further, the formulations of previous rebound hypotheses are biased toward only discovering negative second order effects of efficiency policies. We provide an unbiased formulation of rebound theory and call for balanced research into both positive and negative second order effects.

David Goldstein *co-directs the Natural Resources Defense Council's Energy Program. He was instrumental in developing energy efficiency standards for new buildings and appliances in the US, Russia, Kazakhstan, and China. He received a Ph.D. in Physics from the University of California at Berkeley, is a Fellow of the American Physical Society and the recipient of its Leo Szilard Award for Physics in the Public Interest. He received a MacArthur Fellowship in 2002.* **Robin Roy** *is Director of Building Energy and Clean Energy Strategy at NRDC. He was formerly Project Director & Fellow at Congress's Office of Technology Assessment. Dr. Roy received a PhD in Civil Engineering from Stanford University.* **Sierra Martinez** *is an energy attorney at NRDC. He holds a J.D. from Stanford Law School and has guest lectured at UC Berkeley School of Law on energy regulation and the environment.*

Of the rigorously-framed hypotheses claiming that large rebounds exist, we measure them against the data. The data refute the hypotheses. Rebounds at the end use level are small and are decreasing over time. Rebounds at the economy-wide level are trivially small, and very well might be a net positive effect.

We then assess the rebound theorists' solutions to climate change. We find some of the solutions inconsistent with rebound theory itself. We also find that regardless of the extent to which rebound theory may be true, once an emissions cap is instituted, efficiency policies only enhance that solution.

Last, we analyze the qualitative nature of rebounds and find that they are largely providing basic energy services to low income communities and those in developing countries. Rebound theorists have yet to explain how recommendations of less reliance on energy efficiency does not require maintenance of lower standards of living for many poor and developing populations around the world.

I. Introduction

Reducing our greenhouse gas emissions is essential if we are to combat climate change.[1] Efficiency has played and will play an essential role in achieving those goals.[2] However, rebound theorists argue that efficiency cannot make much of a difference in solving our climate change problems. Given the importance of climate change, we find it imperative that any theory that would challenge what is increasingly recognized as our most effective tool to combat climate change—energy efficiency—be subject to careful standards of scientific scrutiny.

In this paper we analyze the structure of the various hypotheses concerning rebound effects, and find that many are so loosely stated that they are incapable of being tested, or of yielding unambiguous and meaningful predictions. In some cases, hypotheses that rebounds can occur for some end uses in some countries are conflated with hypotheses that rebounds occur universally. For more rigorous statements of rebound hypotheses, we compare these hypotheses to the facts, and find that the data and logic do not support the claims of significant economy-wide losses due to rebound. We find that rebound is at most small and gets smaller as efficiency increases. Finally, we note that rebound, to the limited extent that it occurs, represents a net increase, not a loss, in consumer welfare. These findings reinforce the urgency with which we must deploy efficiency measures to address the threats of climate change.

After a hiatus of several years in academic and policy-related discussions of possible second-order effects of efficiency policies, several recent news articles have emerged arguing that efficiency programs cannot possibly save as much as one would think.[3] These articles present a particular version of possible second order effects by looking at "rebound" effects,[4] which assumes that

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[1] Lenny Bernstein, et al., *Climate Change 2007: Synthesis Report: An Assessment of the Intergovernmental Panel on Climate Change* (2007) http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

[2] *See, e.g.*, International Energy Agency, World Energy Outlook 2009, which shows efficiency as the dominant component of a program to stabilize CO2 emissions at 450 ppm.

[3] David Owen, *The Efficiency Dilemma*, New Yorker, 78 (Dec. 27, 2010) [hereinafter "Owen"]; John Tierney, *When Energy Efficiency Sullies the Environment*, New York Times, (Mar. 7, 2011) [hereinafter "Tierney"]; *Not Such A Bright Idea*, The Economist, (Aug. 26, 2010); Jesse Jenkins, Ted Nordhaus, and Michael Shellenberger, *Energy Emergence: Rebound & Backfire as Emergent Phenomena* (Breakthrough Inst., Feb. 2011) [hereinafter "BTI"]; Steve Sorrell, *The Rebound Effect: An Assessment of the Evidence for Economy-Wide Energy Saving From Improved Energy Efficiency* (UK Energy Research Centre, Oct.. 2007) [hereinafter "Sorrell"].

[4] There are many terms in addition to "rebound" to describe these theories, including "snap back," "take back," "backfire," and "bounceback," among others.

the sign of the effect is negative, (i.e., that the second order effects all cause savings to be reduced instead of increased).[5] They also leave the impression that rebound effects are consistent and universal across uses and levels of efficiency.

Several of these articles note that the original idea was introduced in the 19th century under the name of "Jevons's Paradox." Jevons asserted that increases in efficiency of coal processes would cause coal consumption to increase, to a level that would exceed previous consumption levels.[6] What Jevons failed to address was that future consumption levels could also exceed previous consumption levels absent any improvements in efficiency, due to technological innovation and its consequent economic growth, which were emergent and poorly understood processes at the time. Further, Jevons lived during a time in which energy costs composed a much larger share of GDP than presently.[7] Additionally, Jevons limited his scope to the industrial sector, in which the share of energy costs were, and are, larger than many other sectors. These conditions would give the impression of high sensitivities to energy costs. As energy costs decrease as a share of total costs, sensitivity to energy prices decreases, as does the rebound effect.[8] However, we now live

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For purposes of this paper, "rebound" will be used to describe all these effects, with the term "backfire" reserved for rebounds of greater than 100 percent of the savings. See Sec. III, at 4, below, for further description.

[5] There is variation in terminology of "positive" versus "negative" rebound (or second order) effects. In this paper, we use "positive" second order effects to mean that savings were greater than expected, and "negative" to mean that savings were less than expected.

[6] "It is very commonly urged, that the failing supply of coal will be met by new modes of using it efficiently and economically. . . . [However, it] is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth. As a rule, new modes of economy will lead to an increase in consumption." William Stanley Jevons, *The Coal Question*, 2nd ed., 122-123 (1866). Available at: http://wesurroundthemmelbourne.com/Downloads/ClimateChange/TheCoalQuestion.pdf. In fact, rebound was not the major thesis of his book, which addressed a wide variety of issues concerning coal, nor was rebound demonstrated with anything more analytical than a few individual coal uses and technologies. These were all cases where the uses that Jevons found to be rebounding were new technologies that had not consumed much or any coal in the past. In contrast, current theories of rebound address only efficiency measures aimed at processes or end uses that already use substantial amounts of energy.

[7] Jevons observed the British economy at an anomalous point in time, when its energy intensity was at or near its peak over the last 500 years. In 1865, energy intensity was over four times as high as it was in 2000. In 1865, energy intensity was >9 kWh (of final energy consumption)/£2,000 GDP and was about 2 kWh/£2,000 in 2000. Roger Fouquet and Peter Pearson, *Five Centuries of Energy Prices*, World Econ., vol. 4, no. 3, 2003) [hereinafter "Fouquet"]. *See also,* Imperial College London, *Energy History, Development, and Sustainability*, ESS Conference, Fig. 4, UK Energy Intensity, Final Use Energy Consumption Per Unit Real GDP, 1500-2000 (Dec. 2003), available at: http://www.scj.go.jp/ja/int/kaisai/ess2003/pdf_pre/s33_pearson.pdf.

[8] International Energy Agency, *The Experience with Energy Efficiency Policies and Programmes in IEA Countries: Learning from the Critics"* 6 (Aug. 2005) [hereinafter "IEA/Geller"]. Envtl. Protection Agency, Natl. Hwy. Traffic Safety Admin., *Final Rulemaking To Establish Light Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards*, Joint

in a world in which energy costs are a much smaller portion of total costs and we apply efficiency to all sectors, not just the industrial sector. Many experts have since found that Jevons erred.[9]

The theory resurfaced in a 1980 article by Khazzoom, who claimed that energy savings from appliance efficiency regulations might be much lower than engineering calculations would estimate.[10] This article, along with most of those that have followed, relied heavily on conjecture, rather than on empirical data.[11] It also relied heavily on a faulty assumption: that consumers would respond to reductions in the operating cost of appliances but would fail to respond to increases in the purchase price. Efficiency standards would cause both price changes, but Khazzoom did not analyze those effects.[12] We know that consumers do respond strongly to purchase price, because unexploited short paybacks do exist with consumers often exhibiting hurdle rates in excess of 30 percent[13]; and mainstream analyses of the effect of standards do show reductions in product sales in response to product price increases[14]. Failure to consider all capital costs and exclusive reliance on operating costs renders the Khazzoom analysis incomplete, biased and unproven.[15]

In section II, we present the various versions of rebound and backfire theory that we have collected from the literature. We find that some theories fail to meet scientific standards because they cannot be tested. While demonstrating this

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Technical Supporting Document, 4-19 (Apr. 2010) [hereinafter "EPA/NHTSA"].

[9] "Jevons wasn't wrong about nineteenth-century British iron smelting, [Schipper] said; but the young and rapidly growing industrial world that Jevons lived in no longer exists." Owens, 79 (quoting personal conversation with Schipper). "[V]arious studies suggest that this effect [rebound] is minimal – a loss of no more than 1 or 2 percent of the direct energy savings." IEA/Geller, 8. More generally, "This provocative claim [backfire] would have serious implications for energy and climate policy if it were correct. However, the theoretical arguments in favour of the postulate rely upon stylized models that have a number of limitations, such as the assumption that economic resources are allocated efficiently. . . .Since a number of flaws have been found with both the theoretical and empirical evidence, [backfire] cannot be considered to have been verified." Sorrell, vii.

[10] J. Daniel Khazzoom. *Economic Implications of Mandated Efficiency Standards for Appliances*, Energy J., vol. 1, no. 4, 21-39 (Oct. 1980).

[11] In fact, some rebound theorists have resisted the application of data and facts to their theories: "[N]o single, widely accepted methodology exists to quantify rebound effects at the scale of aggregation most relevant to climate and energy resource depletion concerns . . . [E]fforts to study and quantify rebound effects face inherent epistemological challenges, particularly at all but the simplest of microeconomic scales. . . . [T]he study of rebound at macroeconomic scales, . . . may be properly considered the domain of theoretical inquiry." Jenkins, 25;."

[12] Khazzoom refused to consider the capital cost increase: "I do not deal with the capital cost of appliances with higher efficiency. This should not affect the result." Khazzoom, s*upra* note 10.

[13] Energy Info. Admin., *Assumptions to the Annual Energy Outlook 2010* (DOE/EIA-0554, Apr. 2010), available at http://www.eia.doe.gov/oiaf/aeo/assumption/residential.html.; EPA/NHTSA, 4-19.

[14] *See, e.g.*, DOE analysis, *infra* note 32.

[15] "Since a number of flaws have been found with both the theoretical and empirical evidence, the K-B [Khazzoom-Brookes] postulate cannot be considered to have been verified." Sorrell, vii.

failure, we try to take a more scientific approach by selecting and shaping rigorous hypotheses concerning second-order effects of efficiency policies. We also attempt to improve them by including a more comprehensive analysis about the sign[16] and the mechanisms of the second order effects. We caution against the overreliance on economic theory because many of the critical assumptions of economic theory for conditions necessary to make markets work are conspicuously absent in the energy efficiency arena.[17] Thus, we rely only sparingly on economic theory or model-based results.

In Section III, this paper discusses the evidence that informs the most rigorous, testable, and internally-consistent forms of the rebound hypotheses. We find that the evidence consistently disproves the hypotheses that large rebound effects are likely at the end-use level and on an economy-wide basis. Some modest forms of rebound hypotheses are consistent with evidence in a limited number of cases. Such hypotheses of negative rebound have been analyzed in detail by IEA[18] and EPA.[19] These data show that rebound is generally small to trivial. This paper does not disagree with these findings. In addition to rebound hypotheses, others have hypothesized that second-order effects can be positive.[20] However, these hypotheses have not been tested, or were tested in limited fashion, like the Prius effect.[21] We conclude that further studies are warranted to

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[16] Sorrell acknowledges: "in some cases individual component of the rebound effect may be negative [i.e. savings are greater than expected]. It is theoretically possible for the economy-wide rebound effect to be negative ('super conservation'), . . ." Sorrell, UKERC Review of Evidence for the Rebound Effect, Supplementary Note: Graphical Illustrations of Rebound Effects, 2 (Oct. 2007). However, Sorrell does not investigate data supporting this conclusion.

[17] "[A] number of standard neoclassical assumptions . . . are poorly supported by empirical evidence." Sorrell, 53. "Challenges to the existence of market barriers have, for the most part, failed to provide a testable alternative explanation for the evidence, which suggests that there is a substantial 'efficiency gap' between a consumer's actual investments in energy efficiency and those that appear to be in the consumer's own interest." William H. Golove and Joseph H. Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies To Promote Energy Efficiency* xi (LBL-38059, Mar. 1996) (finding numerous market barriers in the energy service markets, including misplaced incentives, lack of access to capital, flaws in the market structure, and imperfect information) available at: http://eetd.lbl.gov/ea/emp/reports/38059.pdf. Energy Modeling Forum, *Markets for Energy Efficiency*, EMF Rept. 13, vol. 1 (Sept. 1996) (finding common ground among various stakeholders that market barriers are widespread and exist in energy markets, preventing energy markets from allocating available resources efficiently) available at: http://emf.stanford.edu/research/emf13/.

[18] IEA/Geller, *supra* note 8.

[19] EPA/NHTSA, *supra* note 8. Note that the estimates of rebound were estimated without attempting to control for the effect of decreasing location efficiency on the amount households drive; location efficiency decreased throughout the period that fuel economy was increasing.

[20] "[I]n some cases individual component of the rebound effect may be negative [i.e. savings are greater than expected]. It is theoretically possible for the economy-wide rebound effect to be negative ('super conservation'), . . ." Sorrell, 3.

[21] Edmund Fantino, *Choice, Conditioned Reinforcement, and the Prius Effect*, The Behavior Analyst, vol. 31, no. 2, (Fall 2008); Jack N. Barkenbus, *Eco-driving: An Overlooked Climate Change Initiative*, Energy Pol., . 767-76, vol. 38, issue 2, (Feb. 2010) (showing that eco-driving can result in 10 percent to 25 percent savings).

explore initial evidence that positive second-order effects exist in some cases.

Section IV analyzes three energy and climate policy solutions that rebound theorists have proposed. First, some rebound theorists propose that reversing our efficiency progress, making energy use *less* efficient, is the solution. This paper finds that increasing *in*efficiency would not in fact decrease energy consumption, based on all available data. Second, some rebound theorists propose that increasing the supply of cleaner generation sources is the solution. We agree that increasing renewable or other low-emissions generation is a valuable strategy to combat climate change; however, we find that within rebound theory, supply-side solutions might also induce increases in energy consumption. Third, some rebound theorists propose that some combination of instituting a cap on absolute consumption or emissions, in conjunction with energy pricing policy, is the solution. We agree with this policy in part, and discuss why the issue of potential rebounds from efficiency may have less policy relevance than meets the eye.

Section V addresses the qualitative nature of rebounds. Rebounds mean that consumers are increasing their energy consumption. However, rebounds also mean that consumers are receiving increased energy services at lower cost. These services contribute to higher standards of living, such as being able to maintain thermal comfort in a home. Rebounds are a benefit to consumer welfare. Thus, an attempt to use rebound theory to disparage efficiency policy would necessarily reduce economic welfare by reducing the value of energy services, and largely affect low-income communities disproportionately. A carbon emissions strategy that ultimately requires much of the population to live a sub-standard lifestyle, with decreased energy services, is an untenable strategy. On the other hand, energy efficiency offers a strategy that allows people to live at a higher standard of living, with increased energy services, while decreasing consumption and carbon emissions. Instead of discrediting energy efficiency, rebound theorists concerned about emissions and economic welfare should promote accelerating energy efficiency policies.

II. Framing Hypotheses of Rebound and Other Second-Order Effects

There are numerous versions of the rebound hypothesis in the literature. Many of them are difficult to define, as acknowledged by rebound theorists themselves.[22] Thus, we attempt to clarify and strengthen the various versions of rebound theory in the literature.

A. Magnitude and Scope

We provide two factors to help organize the various hypotheses: magnitude and scope. The magnitude of the hypotheses refers to how much of the energy is consumed due to the efficiency improvement. If the amount of energy is less than 100 percent of the savings, the hypothesis is considered just "rebound."[23] If the amount is greater than 100 percent, it is considered

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[22] Regarding macroeconomic rebound theory: "there is no single accepted framework to rigorously define these dynamics . . . ." BTI, 23.

[23] "'If you increase the productivity of anything, . . . demand goes up.' Nowadays, this effect is usually referred to as 'rebound'" Owen, 79; Sorrell, vii.

"backfire."[24] Jevons's Paradox was a backfire theory because he claimed that energy efficiency actually increased consumption, the result of rebounding over 100 percent.

The scope of the hypothesis refers to the level at which the analysis is being conducted: the micro or macro level. A micro-level hypothesis would be at the level of the individual consumer increasing their energy demand due to the cheaper price of operating the efficient appliance. A macro-level hypothesis would be consumers reinvesting their bill savings into other sectors of the economy. We find that these two factors help keep the various hypotheses organized.

B. Rebound Hypotheses

At the outset, we note that a simple reading of economic theory would assert that large cost effective energy efficiency resources—that is, efficiency measures whose present value of benefits greatly exceeds their present value of costs—are not supposed to exist.[25] The limits of classical economic theory in allowing cost-effective energy efficiency require that we use it only cautiously and self-consistently in analyzing that efficiency. Thus, the analyses of policies must be performed in a context that recognizes the array of market failures that allow the large efficiency resource to exist in the first place.

1. Hypothesis A

The first hypothesis is the strong version of the rebound hypothesis, backfire, with rebound exceeding 100 percent of savings, as noted by Owen and others.[26] We will call this Hypothesis A: "With fixed real energy price, energy efficiency gains will increase energy consumption above where it would be without these gains."[27]

Let us analyze the scientific rigor of this hypothesis. First, the concept of "energy efficiency gains" is insufficiently defined in order to test or refute. "Energy efficiency gains" could include those efficiency gains that occur from normal business decisions in the economy or they could be limited to improvements caused by policy. We will start with "energy efficiency gains" that are not attributed to any policy driver,

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[24] "[W]here increased consumption more than cancels out any energy savings, as 'backfire.'" Owen, 79; "In some cases, the overall result can be what's called 'backfire': more energy use than would have occurred without the improved efficiency." Tierney, .2. "Behavioural responses such as these have come to be known as the energy efficiency "rebound effect". While rebound effects vary widely in size, in some cases they may be sufficiently large to lead to an overall increase in energy consumption – an outcome that has been termed 'backfire'." Sorrell, v.

[25] Simple economics argue against the existence of energy efficiency: if there were $20 bills lying on the ground, people would already be picking them up. But note: "In particular, the possibility of 'win-win' policies, such as those aimed at encouraging energy efficiency, may be excluded if an economy is assumed to be at an optimal equilibrium." Sorrell, 53. The presence of market barriers and market failures prevent the use of all cost-effective energy efficiency, in the absence of market intervention. Golove finds that neoclassical economic theory, on which many rebound theorists base their beliefs, (see BTI's reliance on neoclassical economic theory at 6, 9, 10, 11, 23, 25, 32, 41-46), fall short of identifying the full list of market barriers and failures, and finds additional barriers under transaction cost economics. Golove, 24.

[26] Owen, 79 (citing H. Saunders, *The Khazzoom-Brookes Postulate and Neoclassical Growth*, Energy J. 113-148, vol 13(4), (1992)).

[27] Saunders, *Id.*.

such as the improvement in the fuel economy of commercial aircraft. Thus, we have Hypothesis A1: “With fixed real energy price, energy efficiency gains, from any cause, will increase energy consumption above where it would be without these gains.” This hypothesis in not refutable, since:

- “[W]here it would be without these gains” is not calculable, even approximately. Energy efficiency has increased in the American economy 57 percent over the last 60 years.[28] It would be extremely difficult to estimate, in a repeatable way,[29] what energy consumption *would have been* if efficiencies had remained constant for the last 60 years. A robust hypothesis, given Jevons’s observations dating back to 1865, would need to provide a method to estimate what energy consumption would have been if efficiencies had remained constant for the last century and a half. The complexity of an economic model of all the energy uses and predictions for each where energy use would be if efficiency were held constant creates an insurmountable requirement. The fact that demand for energy services is always shifting would further complicate the process. Fundamental choices would have to be made that create irresolvable ambiguities. For example, we would have to estimate how far people would travel if a jet plane had the speed and efficiency of a horse-drawn cart.[30] For all intents and purposes, this requirement is unattainable, so the theory is not refutable.

Energy efficiency offers a strategy that allows people to enjoy a higher standard of living, with increased energy services, while decreasing consumption and carbon emissions.

- The condition of fixed real energy price has never been met for very long in practice, so this condition to Hypothesis A1 prevents us from analyzing such a theory with much data. At best, we could try to predict what would have happened in both the “would be” scenario and the real world scenario based on price elasticities, which leads to immense indeterminacy because estimates of price elasticity may vary by factors of 12 and more.[31] These estimates are further hampered by the fact that efficiency effects energy price.

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[28] In 1949, the U.S. economy required 19.6 TBtu to produce $1 billion (in 2000$); whereas in 2008, it only required 8.4 TBtu to produce $1 billion. For data through 2004: US Department of Energy, Energy Intensity Indicators in the U.S., Economy-wide Total Energy Consumption (May 2008). Available at: http://www1.eere.energy.gov/ba/pba/intensityindicators/trend_data.html. For data from 2005-2008: US Department of Energy, State Energy Database System Consumption, British Thermal Units, 1960–2008, (June 2010). Growth in post-2004 years normalized to May 2008 data in order to maintain consistency across data sources. Both sources combined hereinafter referred to as “DOE Intensity.”

[29] Here “repeatable” means in a way where two different analysts would derive the same result.

[30] Sorrell acknowledges this difficulty: “[A]s the time horizon extends, the effect of [fundamental] changes on the demand for the energy service becomes increasingly difficult to separate from the effect of income growth and other factors.” Sorrell 2009, 1357.

[31] Sorrell cites to studies showing long-run elasticities of demand ranging from -0.05 to -0.6. Sorrell, 45 (citing Sweeney (1984) and Kauffman (1992)).

In conclusion, we cannot measure or calculate where it would be without these gains.

2. Hypotheses A2 & A3

Let us frame a narrower version—Hypothesis A2: "With fixed real energy price, energy efficiency gains *due to policy interventions* will increase energy consumption above where it would be without these gains." This hypothesis rectifies the problem of determining the cause of the efficiency gains, but fails to be testable for two reasons. First, as was the case with previous hypotheses, the condition of fixed real energy price makes it impossible to use long time periods for data. Second, there is considerable disagreement about what energy consumption would have been without any individual policy, both at the microeconomic level and at the macro level. For example, analysts do not agree on what automobile fuel economy would have been without the 1975 CAFÉ standards, or how many compact fluorescent lamps would be in use today without utility-based incentive programs.

At the macroeconomic level, many analysts assume that without any policy, energy use would grow proportionally to GDP. While this assumption may be correct in limited cases, theory does not necessitate that energy use be a fixed fraction of GDP. This is not true for other broad resource categories, such as food, metals, transportation, etc. Nevertheless, we can frame a hypothesis that assumes these problems away: Hypothesis A3 asserts that: "energy efficiency gains *due to policy interventions* will increase energy consumption above where it would be if energy use were proportional to GDP." This hypothesis is capable of being tested. As we show in Section III, it is refuted by the data.

3. Hypothesis B

Let us try a weaker form of the hypothesis—Hypothesis B: "With fixed real energy price, energy efficiency gains will decrease energy use by less than would be predicted."

This is also fatally ambiguous, because it begs the question of what would be predicted. In fact, most predictive models *already incorporate elasticities of demand that model several rebound effects*. Thus, if heating equipment becomes more efficient, somewhat higher thermostats are predicted. Models like the National Energy Modeling System (NEMS)[32] balance supply and demand at a lower price due to efficiency policies and cause predicted energy consumption for other end uses to increase through price elasticity. Whether these modeled effects are correctly done is another question, but some level of rebound is already predicted. Thus, Hypothesis B might be claiming that current energy models incorporate rebound, and that there is nothing new to add. Or it might be claiming that some other effect beyond current models is in play. Or it might be critiquing models other than NEMS. Without answering these questions, we cannot adequately define or test Hypothesis B.

4. Hypothesis C

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[32] As documented below, rebound effects are already incorporated in to energy forecasting models in use at the Departments of Energy, both in the NEMS model and in models used by individual programs. Available at: www.eia.doe.gov/oiaf/aeo/overview/residential.html#consumption.

A modified version of the previous hypothesis would say that: “energy efficiency gains from policy will increase energy consumption above where it would be, assuming the difference between proposed efficiency versus constant efficiency.”[33] Hypothesis C is a well-framed and testable hypothesis. We discuss testing it in Section III and show that the data disprove it.

However, Hypothesis C’s formation contains a weakness: it assumes a sign of the effect without any reason. As we will show, there are reasons based on non-economic motivators of human behavior to expect positive rebound effects as well as negative ones.

5. Hypothesis D: Other second order effects

Every previous hypothesis assumes that the second order effects will be negative, i.e., decrease what the savings were expected to be. We think this assumption should be questioned. Let us introduce Hypothesis D: “energy efficiency gains from policy will result in energy consumption being *different* from where it would be assuming the difference between proposed efficiency versus constant efficiency.” This formulation does not presume the sign of the effect. Such an absence of presumption is important, because if the hypothesis suggests *a priori* a sign of the second-order effects of efficiency policies, data analysis may be restricted to searching for the expected sign and may ignore data with the unexpected sign,[34] a point acknowledged by rebound theorists.[35]

Evaluating Hypothesis D would require considerable disaggregation, since the effects will be different for each end use and since there are a number of economy-wide or industry-wide effects that are possible. Simple price elasticity adjustments to account for reductions in the price of energy services would probably be insufficient to account for actual behaviors, since customers are so heterogeneous.[36]

Here are some examples of possible second-order effects about which we do not know *a priori* the sign of the effect:

- Assume energy policy makes homes use less energy. Will home size increase or decrease?

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[33] Variants of Hypothesis C might allow the predicted savings from efficiency policy to be modified slightly by including, as NEMS does, some small end-use rebounds and some overall price elasticities due to energy price reductions caused by efficiency policy.

[34] E.g., if we hypothesize that a beam of alpha particles shot at a gold foil will cause them to deviate slightly from their path without the foil, we will fail to set up instruments to measure the existence of alpha particles that are scattered backward, and fail to discover, as Ernest Rutherford did around 1910, that atoms are made up of small nuclei at the center of clouds of electrons, rather than that they are a “plum pudding” of electrons and positively charged particles, and that therefore can scatter incident particles back toward their source.

[35] “Most estimates of the direct rebound effect assume that the change in demand following a change in energy prices is equal to that following a change in energy efficiency, but opposite in sign. . . . In practice . . . these assumptions may be incorrect.” Sorrell, et al., Empirical Estimates of the Direct Rebound Effect: A Review, Energy Policy, Vol. 37, 1356-1371, 1362 (Jan. 2009) [hereinafter “Sorrell 2009”]. , 1362.

[36] *E.g.*, the behaviors of a household after a home retrofit performed on an uninsulated home heated to 18C would likely be far different than those of a household in an already modestly efficient home that could afford to heat to 23C before the retrofit.

    - Alternate A: it gets bigger because the present value of energy is enough lower to allow the buyer to pay for more home.
    - Alternative B: it gets smaller because the energy efficient investment increases the cost of construction and consumers bid up the price of the efficient home due to anticipated energy savings and non-energy benefits of the efficiency investments. Buyers can no longer qualify for a loan at the higher cost and have to buy an equally-priced, smaller home.
- Building codes increase insulation levels and reduce summer solar heat gain:
    - Occupants can afford more thermal comfort.
    - Occupants can maintain reasonable comfort levels without running the AC or furnace.
- More efficient lighting is installed in an office with an improvement in lighting quality:
    - Occupants leave lights on because the costs are lower.
    - Occupants turn the lights off aggressively because the improved appearance of the lights reminds them of the energy use, its costs, and its consequences.
    - Alternative C: occupants' rent does not depend on the energy management and there is no change in operations.
- More drivers purchase hybrid cars:
    - Travel is less expensive so people travel more, increasing energy consumption.
    - Drivers are so fascinated by the performance (and dashboard) of their cars that they practice eco-driving and increase fuel economy compared to their previous habits, consuming less energy than anticipated.
- Consumers have more money in their pockets because of savings from energy efficiency:
    - They re-spend the money on a market basket of goods and services with the same energy intensity as the economy as a whole.
    - They re-spend the savings on air travel and an SUV and other energy-intensive choices.
    - They reduce debt and increase savings, a service less energy-intensive than the general economy.
    - They discover how beneficial efficiency works and spend their saved money on additional savings or on other clean energy choices.

Rebound theory argues that when efficiency improvements cause the price of energy to fall, consumers will demand more of it.
However, this is not necessarily the case.

These are only a few examples where either from individual experiences or logic one could infer reasons for positive rebound and other reasons for negative, with no data yet that determine which effects are greater.

Further, the very assumptions behind rebound theory suggest that these positive rebound effects might very well occur. Rebound theory argues that when efficiency improvements cause the price of energy to fall, consumers will demand more of it. However, this is not necessarily the case, given the complexity of energy markets.

Instead, when the price of energy falls, the supply might fall. This is documented as the "de-investment" effect, and acknowledged by rebound theorists.[37]

While these suggestions are speculative, the speculation is similar to those supporting rebounds: either may happen and at varying frequencies but we cannot know without measurement. While this paper does not call for unending research into every second order effect, it does call for a balanced approach in researching second order effects.

III. Data Do Not Support Large Rebound Hypotheses

First, there is a paucity of data that support large rebound hypotheses.[38] Rebound theorists acknowledge the lack of reliable data supporting the theory.[39] Where there are data, they reveal that rebound effects are small and decreasing. Additionally, none of these data include the positive second order effects discussed in Section II, so represent the highest end of rebound estimates.[40]

A. Micro Level Data Do Not Support Large Rebounds

The data show that rebounds are small, diminishing over time, and difficult to measure. "[E]mpirical evidence suggests that the size of the rebound effect is very small to moderate."[41] Further, "most of the direct energy savings from technical improvements in energy efficiency in OECD countries remain even after the direct rebound effect is accounted for."[42] These findings from a U.S. Department of Energy and International Energy Agency combined study provide the most comprehensive data and analysis on rebounds. The study found rebound effect of 0 percent for residential appliances, 0-2 percent for commercial lighting, and 5-12 percent for residential lighting.[43] Given that utility energy efficiency programs, research and development, and codes and standards have focused heavily in

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[37] "[I]f demand is not sufficiently elastic, final market prices may remain lower following efficiency improvements, driving a 'disinvestment effect', which may actually decrease long-term energy demand." BTI, 22.

[38] "[D]espite growing research activity, the evidence remains sparse, inconsistent and largely confined to a limited number of consumer energy services in the United States . . . "The methodological quality of many quasi-experimental studies is poor, [and] the estimates from many econometric studies appear vulnerable to bias." Sorrell 2009, 1364. "In summary, the accurate estimation of direct rebound effects is far from straightforward." Sorrell 2009, 1363.

[39] "Evidence for the scale of macroeconomic composition effects is very limited." BTI, 23. "The available evidence for all types of rebound effect is far from comprehensive." Sorrell, 7. "There are very few studies of rebound effects from energy efficiency improvements in developing countries." Sorrell, 8. "[T]he empirical evidence for both [direct rebound effects in developing countries and from producers] is weak." Sorrell, 9.

[40] *I.e.,* the bias of searching for negative data leads to an overestimate of the rebound effect. "[There are] a number of potential sources of bias with econometric estimates that may lead to the direct rebound effect to be overestimated." Sorrell 2009, 1357. "Both theoretical considerations and the limited empirical evidence suggest that direct rebound effects are significantly smaller for [certain] household energy services." Sorrell 2009, 1362.

[41] IEA/Geller, 6.

[42] *Id.*

[43] *Id.*

these sectors and end uses, these results carry great explanatory weight. Additionally, the data showed a rebound effect of 0-20 percent for industrial processes, 10-30 percent for residential space heating, <10 percent-40 percent for residential water heating, and 0-50 percent for residential space cooling.[44] In transportation, EPA and DOT conducted a thorough and comprehensive survey of rebound estimates and found that in 2000-2004 the rebound effect in transportation was 6 percent[45], and ultimately proposed to use a 10 percent rebound estimate.[46] These data demonstrate that to the extent rebounds occur, they are small.

The empirical evidence reveals that in addition to being small, rebounds are diminishing with time. As efficiency increases, the rebound effect decreases because: (1) energy costs as a share of total costs decreases, decreasing sensitivity to energy prices;[47] (2) incomes increase, decreasing sensitivity to energy prices;[48] and (3) there are limits to end-use-specific energy services demanded, against which rebounds are measured.[49] As measured in transportation, rebound was estimated at 22 percent for 1966-2001, but decreased to 11 percent looking only at the later years 1996-2001, and decreased further to 6 percent looking at 2000-2004.[50] The empirical evidence shows that the magnitude of the rebound effect is declining over time.[51]

B. Macro Level

1. Survey of the Data Does Not Support Rebound Theory

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[44] *Id.*

[45] Actually, the rebound in travel is likely to be even smaller, because none of the studies controlled for the fact that as cars became more fuel-efficient, land use patterns in America and throughout most of the world became less location efficient. The consequent increase in travel demand over time would be hard to distinguish from a rebound statistically without explicitly including it in the regressions.

[46] Envtl. Protection Agency, National Highway Traffic Safety Administration, Final Rulemaking To Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Joint Technical Support Document, EPA-420-R-10-901, 4-19 (Apr. 2010).

[47] "[T]he sensitivity of travel demand to fuel cost per mile has fallen over time as fuel cost as a fraction of the total cost of owning and operating a vehicle has declined . . . ." IEA/Geller, 6 (citing Green 1992).

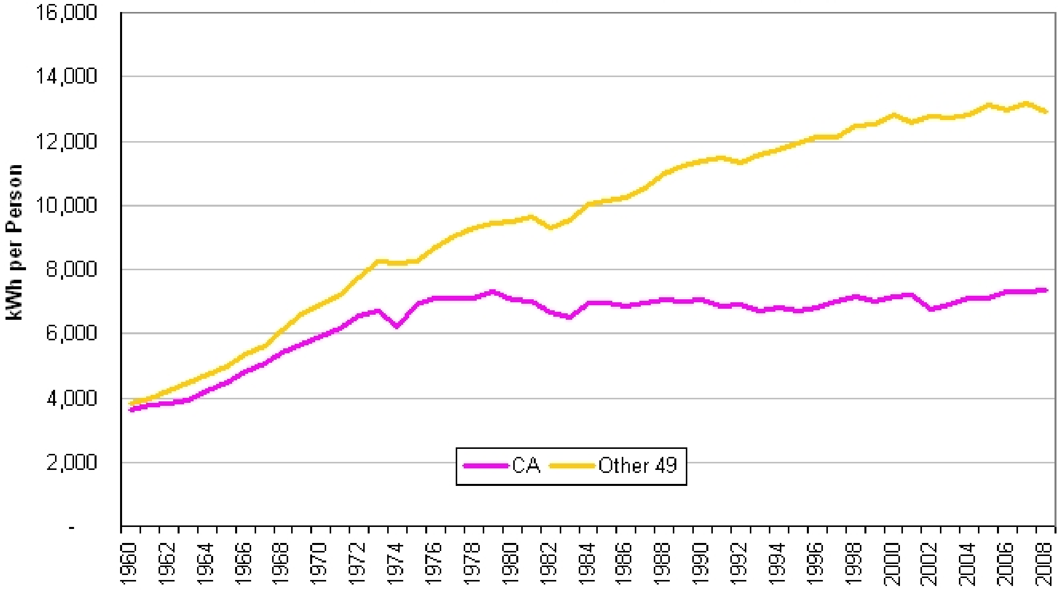
[48] [The] sensitivity of travel demand to fuel cost per mile has fallen over time . . . as incomes have risen . . . ." IEA/Geller (citing Green).

[49] Rebound, measured as a percentage of expected savings, decreases because there are finite and maximum levels of energy services demanded per end use. *E.g.,* there are a finite number of hours to drive during the day, and an absolute level of heat desired in a home, beyond which consumer would not or cannot increase consumption. Thus, the percentage of energy demand caused by rebound can only continue to decrease. "[A]s the consumption of a particular energy service increases, saturation effects should reduce the direct rebound effect. For example, direct rebound effects . . . should decline rapidly once whole-house indoor temperatures approach the maximum level for thermal comfort." Sorrell 2009, 1357.

[50] EPA/NHTSA, 4-19 (citing Greene).

[51] "[T]he magnitude of rebound effect is declining over time." EPA/NHTS, 4-19 (citing Greene).

Figure 1: Electricity Consumption Per Capita



Source: Energy Info. Admin., *State Energy Database System, Consumption, Physical Units 1960-2008*, (June 2010), available at: http://www.eia.doe.gov/states/_seds.html.

The data at the macro level show that rebound is trivially small, at rebound theory's best, and some data suggest the second order effects could be positive, at rebound theory's worst. The dearth of data at the macroeconomic or economy-wide level is greater than micro-level data.[52] The most comprehensive survey of the literature shows that the economy-wide rebound effect is about 0.5 percent.[53] In other words, "more than 99 percent of the direct energy savings from energy efficiency improvements remain after the economy-wide effects are taken into account."[54]

2. State Comparison Data Does Not Support the Rebound Theory

Given the rebound Hypothesis C: "energy efficiency gains from policy will increase energy consumption above where it would be assuming the difference between proposed efficiency versus constant efficiency," we can test it on an economy-wide level. The results refute it.

California embarked on a broad set of policy reforms to encourage efficiency and promote renewable energy in 1974, and has continued since. The California Energy Commission has estimated the cumulative electricity savings produced by these policies, using conservative assumptions, at about 15 percent of load.[55] Figure 1 shows the results of both these policies and all second order effects. The reduction in electricity use compared to the rest of the US is not smaller than what the policies were estimated to produce, it is greater. It is approximately four times as great.[56] In addition to being 400 percent of

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[52] "[N]o single, widely accepted methodology exists to quantify rebound effects at the . . . total economy-wide rebound [level] at a global scale." BTI, 25.

[53] IEA/Geller, 7 (citing Lietner 2000).

[54] IEA/Geller, 7.

[55] Calif. Energy Commn., *Energy Action Plan II, Implementation Roadmap for Energy Policies*, 5 (Oct. 2005) (stating 15 percent of demand in 2003 saved by efficiency policies).

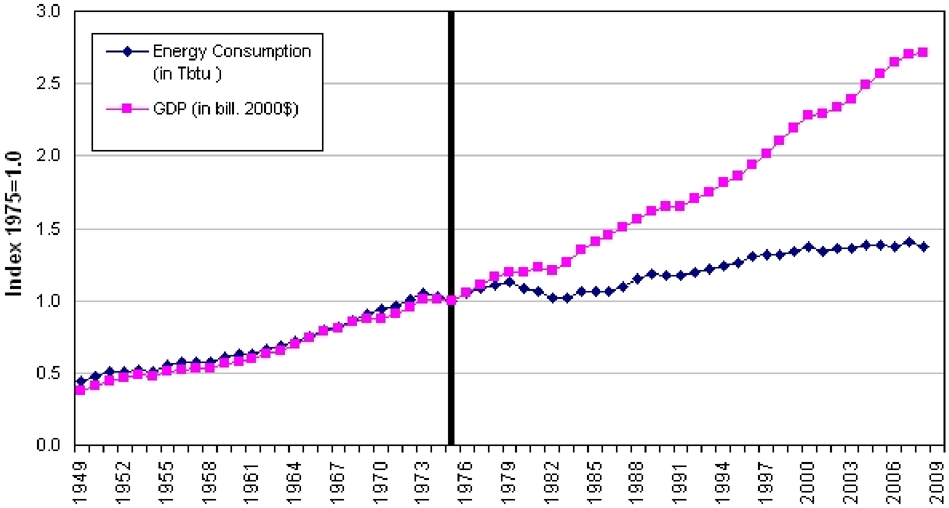
[56] CEC estimated 40,000 GWh saved in 2003 due to efficiency policies. Given a population of 35.251MM in 2003 for California, that represents 1,134 kWh per capita due to efficiency policies. US Census Bureau. Since 1975, the rest of the US has increased its

expected results, realized savings are not compared here to a base case of roughly constant efficiency but compared to a base case of other states, some of which are also pursuing efficiency policies and all of which save energy due to spillover effects of California policies on efficiency.

Similar, but about 50 percent smaller, results are documented for New York State.[57] Several other states and regions demonstrate that stronger energy efficiency policies result in energy consumption that is indeed lower than in states without such policies.[58] So, if anything is rebounding, it is the influence of energy efficiency policies: They are causing a whole economy to save much more than one would expect.

Further, two detailed statistical studies of California found that the majority of this difference could be explained by other factors[59] that are not related directly to energy efficiency but causing decreases in consumption. This analysis refutes Hypothesis C, which predicts that other factors must be causing additional increases in consumption, not decreases[60].

Figure 2: Energy Intensity of US Economy 1949-2008



Black line delineates year of index, where both values equal 1, and approximately, the beginning of some efficiency policies in the US. Source: DOE Intensity, *supra* note 28.

Last, it is hard to find a case showing the opposite: a jurisdiction that has implemented energy efficiency policies that are shown by careful analysis to be saving enough energy to be visible at the first order level, but which has no reductions in intensity or other macro indicators in the long run.

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consumption 4,695 kWh per capita, while California has remained flat. Energy Info. Admin., *State Energy Database System, Consumption in Physical Units* (2010), available at: http://www.eia.doe.gov/states/_seds.html. Thus, the increase in the rest of the US is 4.14 times the savings in California.

[57] National Academy of Sciences, *Real Prospects for Energy Efficiency in the United States* (2010).

[58] See differences between Vermont or Massachusetts versus Kentucky or Wyoming. Energy Info. Admin., *supra* note 56.

[59] *See* Anant Sudarshan, *Deconstructing the 'Rosenfeld Curve': Why is Per Capita Residential Energy Consumption in California so Low?* (US Assn. Energy Econ., USAEE-IAEE WP 10-063, Dec. 2010). Anant Sudarshan, *Deconstructing the 'Rosenfeld Curve': The Problem with Energy Intensities?*, (US Assn. Energy Econ., USAEE-IAEE WP 10-057, Nov. 2010).

[60] Proponents of Hypothesis C might argue that the other factors that clearly are not consequences of energy efficiency policy should be controlled for, rather than considered part of the results. If such an argument were correct, it would undermine the ability to test Hypothesis C: different analysts could have different interpretations of which parameters might be second-order effects.

3. The Macro “GDP-Dependence” Theory Is Not Supported by Data

Hypothesis A3 is based on the assumption that energy tends to increase in proportion to GDP. This assumption is derived from the correlation that historically, societies’ GDPs increased as did energy consumption.[61] The data show that economies can, and do, decrease their energy intensity beyond the status quo.[62] In the U.S., energy intensity dropped twice as much in the 13 years after energy efficiency became a policy priority than it did in the previous 25 years.[63] In China, energy intensity increased twice as fast as GDP before implementing energy efficiency policies; then dropped precipitously afterwards.[64] Energy intensity in the major OECD countries all decreased from 1973 to 1998.[65] And in last 500 years of the British economy, energy intensity has varied incredibly, more than doubling from 1700 to 1850, then dropping to its lowest levels ever by 2000, about one-fifth the level of its peak.[66] Even Jevons observed, and Owen recognized,[67] that economic productivity of energy consumption can increase, which decreases the energy intensity of an economy. By decreasing our energy intensity, we can in fact move towards unhinging our economy from energy that we currently depend upon.

In conclusion, energy consumption and GDP were previously believed to have an unchangeable causal relationship based on observed positive correlations of absolute levels. However, the data show that many advanced

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[61] We note that such a simple correlation ignores the proportion in which GDP and energy increase. The energy intensity of the US economy in post-World War II was actually decreasing, despite both GDP and energy consumption increasing. From 1949 through 1973, energy intensity (measured by the E/GDP ratio) declined by 11 percent.” DOE Intensity, *supra* note 28.

[62] “Believers in an unbreakable link between energy use and GDP assigned the immutability of a physical law to this historical relationship, but found their belief shattered by events. From 1973 to 1986, U.S. primary energy consumption stayed flat, but GDP rose 35 percent in real (inflation-adjusted) terms. These believers had forgotten that people and institutions can adapt to new realities, and historically-derived relationships (like the apparent link between energy use and GDP that held up for more than two decades in the post-World War II period) can become invalid . . . .” Jonathan Koomey, *Avoiding ‘the Big Mistake’ in Forecasting Technology Adoption*, 2 (LBNL-45383, Apr. 2000), available at: http://enduse.lbl.gov/Info/LBNL-45383.pdf.

[63] From 1949-1973, US energy intensity declined by 11 percent. Between 1973 and 1985, the E/GDP ratio decreased by 28 percent. DOE Intensity*, supra* note 28.

[64] From 1952 to 1980, energy demand grew twice as fast as GDP. From 1980 to 2002, after efficiency policies took effect, GDP grew much faster. Levine et al., *The Greening of the Middle Kingdom: The Story of Energy Efficiency in China*, LBNL-2413E, Figures 3a, 3b, (May 2009). Available at: http://china.lbl.gov/sites/china.lbl.gov/files/LBNL-2413E.Story_of_EE_in_China.pdf.

[65] *Annually*, between 1973 and 1998, US and Norway decreased their energy intensity over 2 percent; UK, Japan, Germany, Denmark, and Sweden all decreased over 1.5 percent; Australia, France, and Italy decreased over 1 percent; and Finland decreased over 0.5 percent. On average, these OECD countries decreased their energy intensity 1.6 percent per year. IEA/Geller, 3.

[66] Fouquet, 101.

[67] “[W]e can extract vastly more economic benefit from a ton of coal than nineteenth-century Britons did, ...” Owen, 82 (citing conversation with, though not endorsing, Schipper).

economies and also China have been able reduce their energy intensities over sustained periods, while increasing overall GDPs. The hypothesis (A3) that we cannot decrease our energy intensity without decreasing absolute GDP is disproven by the facts. It is indeed possible to decrease our dependence on energy consumption through energy efficiency.

IV. Rebound Solutions

In addition to needing a scientifically rigorous hypothesis, rebound theorists must be able to provide the equivalent in a solution if we are to decrease our energy consumption or associated emissions. Most rebound theorists agree that reducing energy consumption and GHG emissions is a worthy objective.[68] However, they believe that energy efficiency will either: a) help us to reduce our absolute energy consumption or GHG emissions less than we expect, but will still help somewhat, or b) will not help us. For those that agree that efficiency helps, the data above suggests we should not only continue pursuing efficiency as the primary strategy to reduce energy consumption, but accelerate it. For those that do not, they propose the following alternate solutions.

A. The Model T Solution

Backfire theorists believe that efficiency causes increased consumption of absolute energy; consequently, backfire theorists must necessarily believe that *in*efficiency causes decreased consumption of absolute energy. Regarding this conundrum, Amory Lovins joked, "[W]e should mandate inefficient equipment to save energy."[69] However, this is the logical conclusion of believing that efficiency causes increased consumption. There are presently mandates in place that increase efficiency. If these efficiency requirements are the problem, there must be a mandate to remove the efficiency requirements. Such a mandate increases inefficiency relative to the status quo. This is one proposed solution by backfire theorists and rebound theorists.

Owen proposes this solution, in the form of a Model T example[70]: "If the only motor vehicle available today were a 1920 Model T, how many miles do you think you'd drive each year . . . ?"[71] The explanation of the Model T solution, or switching to inefficient products, is that the Model T was (a) more costly to drive per mile, given inferior fuel efficiency compared to present fleet-wide averages and (b) delivered many fewer energy services (such as acceleration and air conditioning); therefore, the consumer would choose to drive less. First, this solution has yet to show results that would support it—e.g., we have not seen data that show Hummer drivers drive less than Prius drivers. Additionally, the Model T solution faces an extra hurdle: due to the new *in*efficiency, driving less would not necessarily decrease total energy consumption—drivers would first need to drive some amount less just to offset the new

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[68] "Decreasing reliance on fossil fuels is a pressing global need." Owens, 85. Tierney, 3. *See* Sorrell, 1; BTI, 4-5.

[69] Robert Bryce, *Energy Tribune Speaks with Amory Lovins*, Energy Tribune, (Nov. 9, 2007). Available at: http://www.energytribune.com/articles.cfm?aid=672.

[70] While he later recognizes the political inability to enact such a solution, he never disavows it on substantive grounds. Owen, 85.

[71] Owen, 85.

inefficiencies, then, they would need to drive an additional amount less than that to actually decrease absolute consumption. In the Hummer example, the data would need to show that Hummer owners not only drive less, but that they consume less energy overall than Prius drivers—a tall order. These empirical and theoretical hurdles render this solution ineffective to reduce our climate emissions and energy consumption.

B. The Energy Price Solution

Owens foregoes the Model T solution in favor of the energy price solution,[72] as does Tierney.[73] The energy price solution states that increasing the cost of energy consumption will decrease demand.[74] Efficiency advocates believe a cap on greenhouse gas emissions is the appropriate mechanism to internalize some environmental costs into the price of energy. The cap might cause the price of energy to increase, as emissions permits are limited. Rebound enthusiasts believe that this price will be high, since one of the most effective means of lowering it—energy efficiency—is believed not to work, or to work less effectively than modeled. Environmentalists believe any price increase will be modest. But the important observation is that this solution—pricing the externality of emissions by placing a cap on them, makes as much policy sense if one rejects rebounds as it does if one accepts them. We should all be satisfied to let that experiment work its way through the economy, since we will be better off economically with strong efficiency policies[75] and a cap that meets environmental needs.[76]

C. The Supply-Side Solution

Rebound theorists have also proposed a supply side solution, which does not intend to decrease consumption, but rather to decrease GHG emissions through the supply of clean energy.[77] On this solution, we fully agree. Pursuing renewable energy is a priority strategy in reducing our GHG emissions

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[72] "No one's going to 'mandate inefficient equipment,' but, unless we're willing to do the equivalent—say, by mandating costlier energy—increased efficiency, . . . , can only make our predicament worse." Owens, 85.

[73] "it makes more sense [compared to efficiency] . . . to impose a direct penalty for emissions, like a tax on energy generation from fossil fuels. . . . [consumers] respond to a gasoline tax simply by driving less." Tierney, 3.

[74] "Carbon/energy pricing needs to increase over time, . . . simply to prevent carbon emissions from increasing. It needs to increase more rapidly if emissions are to be reduced." Sorrell, 9.

[75] As acknowledged by rebound theorists: "[S]uch efforts [cost-effective EE] make for excellent economic policy, as they are well suited to accelerate economic growth and modernization and expanding welfare." BTI, 11.

[76] Which agrees with some in the rebound field: "Carbon/energy pricing may be insufficient on its own, ... A policy mix [including efficiency] is required." Sorrell, 9.

[77] "Efforts to reliably reduce greenhouse gas emissions or dependence on depleting fossil fuels would be prudent to avoid the risk of overreliance on energy efficiency measures. Such efforts should therefore focus primarily on shifting the means of energy production (rather than end use), relying on zero-carbon and renewable energy sources to diversify and decarbonize the global energy supply system." BTI, p.52. "[I]f your immediate goal is to reduce greenhouse emissions, then . . . it makes more sense to look for new carbon-free sources of energy." Tierney, 3.

regardless of what one expects concerning efficiency gains.

However, suggesting cost-effective[78] clean energy supply[79] expansions as a solution to the problem of rebounds is not entirely self-consistent. According to rebound theory, increases in low-cost supply[80] would be expected to increase demand, and some cases such increases have been observed. A good example is in the transportation sector, where studies demonstrate supply-side rebounds or "induced demand" —the idea that as road supply increases, the cost per use will decrease, and demand will increase. In these studies the cost was indirect in the form of cost of traffic congestion. They show that increasing capacity of roads results in less-than-expected reductions in congestion. As lane-miles increase, some amount of vehicle- miles-traveled increases also. The estimates of induced demand vary widely, from 0.2-0.8 in some studies, depending on how wide the boundaries are in the particular study.[81] However, induced demand in the transportation sector must be higher than energy rebound effects because there is no cost to the consumer directly when increasing lane-miles, whereas there is cost to the consumer directly when investing in new energy supply. Additionally, the estimate of induced demand has increased over time, whereas rebounds have decreased. In sum, the effects of induced demand reveal inconsistencies[82] in the rebound theorists' proposed supply-side solutions.

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[78] Here, "cost-effective" is defined as being less than the marginal cost of new energy resources, and we assume that prices properly reflect those marginal costs.

[79] *E.g.*, in many places of California, wind is a cost-effective source of clean energy supply because it costs less than the benchmark for marginal resources. The Renewable Energy Transmission Initiative estimates wind to cost between 6 and 11.6 cents/kWh whereas the CPUC estimates the market price referent to be between 8.5 and 14.4 cents/kWh. RETI, Phase 2B, Final Report, Figure 1-1 Typical Cost of Generation Ranges (May 2010). Available at: http://www.energy.ca.gov/2010publications/RETI-1000-2010-002/RETI-1000-2010-002-F.PDF. CPUC, Resolution E-4298, Table 1: Adopted 2009 Market Price Referents, (Dec. 2009). Available at: http://docs.cpuc.ca.gov/word_pdf/FINAL_RESOLUTION/111386.pdf.

[80] As the price of renewables decreases, we expect this inconsistency to be a larger problem for rebound theory.

[81] Robert Cervero, *Road Expansion, Urban Growth, and Induced Travel: A Path Analysis*, J. Am. Plan. Assn. 69, no. 2, 145 (2003); Robert Cervero and M Hansen, Induced Travel Demand and Induced Road Investment: A Simultaneous Equation Analysis, J. Transpt. Econ. Pol. 36, no. 3, 469-490 (2002) [hereinafter "Cervero 2002"]; Lewis Fulton et al., "A statistical analysis of induced travel effects in the US Mid-Atlantic region," J. Transp. and Statistics 3, no. 1, 1-14 (2000); Kent M. Hymel, Kenneth A. Small, and Kurt Van Dender, *Induced demand and rebound effects in road transport*, Transp. Research Part B: Methodological 44, no. 10, 1220-1241 (2010). In general, and not surprisingly, the wider the boundaries of the study (the greater the geographic extent of travel that was measured), the higher the induced traffic.

[82] In addition, we note an inconsistency regarding GHG emissions between supply- and demand-side solutions. Rebound theorists would hold that rebounds from low-cost clean energy supply do not create additional GHG emissions because the rebounds are being demanded from the new supply of

V. The Meaning of Rebounds

The main concern of rebound theory is that consumers might increase their energy consumption, relative to the level that could possibly be reached by an energy efficiency improvement—i.e., consumers might, through income or substitution effects, demand more energy services than previously demanded. Let us analyze the people to whom rebounds apply, the nature of these newly-demanded energy services, and the full set of consequences that results from opposing them.

Through income or substitution effects, the consumers that are demanding new energy services are those who either could not previously afford them or viewed the benefits as less than the cost. However, due to greater unsatisfied demand among low income communities, the consumer groups that account for the greatest rebounds are low-income communities.[83] Within this group, the now lower price of energy services allows the consumer to purchase an increased level of energy services. Through the income effect, the low-income consumer can demand new energy services, as her budget is expanded. Both mechanisms allow consumers, largely those who were unable to pay for it, to demand new energy services.

Theory suggests that rebounds apply largely to those who need energy services the most, those in the developing world.[84] Rebounds require consumers to have unsatisfied demand. The place where there is the greatest unsatisfied demand is in the developing world. Thus, large rebound should occur largely in the developing world. In fact, according to what empirical data exists,[85] the consumers that are demanding new energy services are largely located in the developing world.

Let us analyze the nature of these services. The end uses with high rebounds were: residential water heating, space heating, and space cooling. In other words, people were demanding basic energy services, like being able to heat their home, pump water, and have hot water.[86] These are energy services that improve consumers' quality of life and raise their standard of living. These services are mostly the basic energy services that those in the developed world already enjoy, a fact acknowledged by rebound theorists.[87]

If rebound theory were correct, energy efficiency would be a most effective policy for economic

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clean energy. If so, the same must hold for efficiency: rebounds from low-cost energy efficiency are being demanded from the new supply of energy efficiency; thus, also resulting in no increase of GHG emissions.

[83] "One important implication is that direct rebound effects will be higher among low-income groups, since these are further from satiation in their consumption of many energy services. Sorrell 2009, 1357 (citing Milne and Boardman, 2000).

[84] "Rebound effects may be expected to be larger in developing countries." Sorrell, 7. "The abundance of such 'marginal consumers' in developing countries points to the possibility of large rebounds in these contexts, ..." Sorrell 2009, 1357. While demand for energy services is typically inelastic in developed countries (Greening et al., 2000; Sorrell, 2007), (Laitner, 2000), demand for even basic energy services is largely unfulfilled across much of the developing world." BTI, 22

[85] Sorrell, 36 (citing Zein-Elabdin 1997).

[86] IEA/Geller, 6.

[87] BTI, 22.

development and improvement of the quality of life for the poorest of people in the poorest countries. Rebounds, if real, would provide basic energy services to those who vitally need them.

Projections of global energy demand assume that poor nations continue to strive for maximizing economic development, and thus are based on projections of rapidly growing energy service demands. But these demands should not be construed as rebound effects without evidence, and there is almost no evidence that supports a hypothesized link to efficiency policy.

Any energy reduction strategy that ultimately requires much of the population to maintain a lower standard of living is an untenable strategy. Advocates of policies based on rebound theory have yet to explain how recommendations of less reliance on energy efficiency policy avoid such a consequence.[88] Energy efficiency is a strategy that allows people to live a higher standard of living, with increased energy services, while decreasing their energy consumption. If these advocates agree that populations need not maintain lower standards of living, and are still concerned about reducing energy consumption, they should not disparage efficiency, but rather work to accelerate it.

VI. Conclusions

We have shown theories that predict large rebounds are difficult to specify in terms that are scientific and testable. We frame the most scientifically rigorous versions possible. We also propose unbiased formulations that would measure both positive and negative rebounds. We call for a balanced approach to research on second order effects.

Of the testable hypotheses, we analyze the available data. Those data show that end-use level rebounds are small, that economy-wide rebounds are trivial, and may be positive. They also show that negative rebounds are decreasing over time, as efficiency increases.

Assessing rebound theorists' proposed solutions to climate change, we find that even if one believed that economy-wide rebounds not accounted for in energy models were significant, it would not change the policy prescriptions compared to what the energy efficiency advocacy community has been promoting: a combination of a greenhouse gas emissions cap and energy efficiency policies.

We analyze the qualitative nature of rebounds and find that efficiency policies are largely providing basic energy services to low-income communities and those in developing countries, and that rebounds would amplify this effect. We find that energy efficiency provides a solution that allows us to reduce energy consumption without stifling the standard of living for many poor and developing populations around the world. ■

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[88] Jevons himself indicated that the ultimate solution requires a lower standard of living: "It is thence simply inferred that *we cannot long continue our present rate of progress*. [A]fter a time we must either sink down into poverty, adopting wholly new habits, ..." Jevons, 18.

http://www.earthadvantage.org/resources/library/research/certified-homes-outperform-non-certified-homes-for-fourth-year/

Certified Homes Outperform Non-Certified Homes for Fourth Year

Existing Homes with a Certification Earn 30% More

PORTLAND, Ore., June 8, 2011 - **Earth Advantage Institute**, a nonprofit green building resource, announced the results of its annual certified home analysis in the Portland metropolitan region for the 2010 to 2011 year. The study is part of the organization's research efforts that include gathering data on green building valuation.

Existing homes with a sustainable certification sold for 30 percent more than homes without such a designation, according to sales data provided by the Portland **Regional Multiple Listing Service**(RMLS) to Earth Advantage Institute. This finding is based on the sale of existing homes between May 1, 2010 and April 30, 2011 in Multnomah, Clackamas, Columbia, and Washington Counties in Oregon, and Clark County in Washington.

Better sales prices were also seen for newly constructed homes with a sustainability certification. As a group, new homes with a sustainability certification in the six-county Portland metropolitan area sold for 8 percent more than new non-certified homes.

This result continues a four-year trend in which new homes with a third-party certification for sustainable construction and energy performance have consistently sold for more than newly constructed homes that had not been certified. The term "certified home" includes homes that received an Earth Advantage New Homes, **ENERGY STAR**, or a **LEED® for Homes** designation, or a combined Earth Advantage/ENERGY STAR certification. Sales information is reported by participating real estate brokers to RMLS. The Portland metropolitan area region includes Multnomah, Clackamas, Columbia, Washington and Yamhill Counties in Oregon and Clark County in Washington. There were no certified new home sales in Columbia and Yamhill Counties that enable comparisons in those areas.

Differences clearly exist among the counties within the metropolitan area. The county exhibiting the greatest difference between new certified and new non-certified homes was Clackamas, where homes with a certification sold for 23.3 percent more than non-certified new homes. Clark County was the one area in the metropolitan region where newly constructed certified homes did not sell for more. However, certified existing homes in Clark County did perform better than their non-certified counterparts. As a group, existing homes with a sustainability certification in Clark

County sold for an average of $288,400 versus $222,900 for homes without such a certification, or 29 percent more. Table One summarizes the information received, for both new and existing homes, across the metro region.

Table One: Average Sales Price 2010 - 2011

New Homes	**Clackamas**	**Columbia**	**Multnomah**	**Washington**	**Yamhill**	**Clark County WA**
Non certified	$305,647	$200,732	$292,837	$313,040	$239,147	$296,567
Certified home	$376,763	N/A	$348,240	$329,810	N/A	$254,172
Price premium	23.27%	N/A	18.92%	5.36%	N/A	-14.30%
Existing Homes						
Non certified	$299,696	$174,144	$277,449	$259,835	$209,264	$222,918
Certified home	$372,591	$138,000	$448,886	$354,245	$315,000	$288,363
Price premium	24.32%	-20.76%	61.79%	36.33%	50.53%	29.36%

Source: RMLS Portland May 2011

Portland RMLS was the first regional multiple listing service in the country to provide sales information for homes with green certification, at the request of Earth Advantage Institute. RMLS began tracking information in 2007.

Two important trends are shown by the four years of sales data. First, the market share of certified homes among all newly constructed homes stayed consistent, with 18 percent of the new homes in the Portland market receiving a sustainability certification. Second, a notable price premium for certified homes as a group was observed in each year.

Table Two: Market Summary May 2007 - April 2011 Portland Metro Region

	Number of certified new homes sold	**Total New homes sold**	**Market share among all new homes**	**Price premium**
May 1, 2007 to April 30, 2008	833	6125	13.6%	20.5%
May 1, 2008 to April 30, 2009	674	4135	16.3%	12%
May 1, 2009 to April 30, 2010	118	597	19.8%	14%
May 1, 2010 to April 30, 2011	408	2237	18.2%	18.9%

"This is important news for builders and home buyers alike," said Dakota Gale, the sustainable finance program manager at the Earth Advantage Institute. "While it must be noted that the data are supplied by real estate agents themselves through standard RMLS forms, and are based on averages, not comparables, we can still see a consistent trend that third-party certification continues to result in a higher sales price, even during the past year when home sales were down."

About Earth Advantage Institute

Earth Advantage Institute works with the building and design industry to help implement sustainable building practices. Its nonprofit mission is to create an immediate, practical and cost-effective path to sustainability and carbon reduction in the built environment. The organization achieves its objectives through a range of innovative certification, education and technical services programs.

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RISING ELECTRICITY COSTS: A Challenge For Consumers, Regulators, And Utilities

Electricity is the lifeblood of the U.S. economy. It powers our homes, offices, and industries; provides communications, entertainment, and medical services; powers computers, technology, and the Internet; and runs various forms of transportation. Not only is electricity the most flexible and most controllable form of energy, its versatility is unparalleled.

Clearly, electricity is a crucial commodity we all take for granted. We scarcely think about it, unless we don't have it. Fortunately, almost without exception, electricity is there for us when we flip the switch—Americans enjoy the benefits of the world's most reliable electric system.

What's more, continuing advances in more efficient electric technologies make electricity cleaner and more valuable. And still, it remains one of the true "bargains" among crucial U.S. commodities. Today, electricity costs are generally inexpensive, comprising a modest part of most customers' monthly expenses.

Within the next few years, regulators and utilities in several states will be revisiting electricity rates that have been frozen for years. The new rate proceedings are needed to fund new infrastructure investments and to ensure electric rates cover today's higher fuel and operating costs. Devising ratemaking strategies that address the new realities of today's energy markets will be a challenge. But, they are a necessary step if the electric utility industry is to make the long-term investments needed to help ensure reliable, affordable, and increasingly clean electricity.

EDISON ELECTRIC INSTITUTE

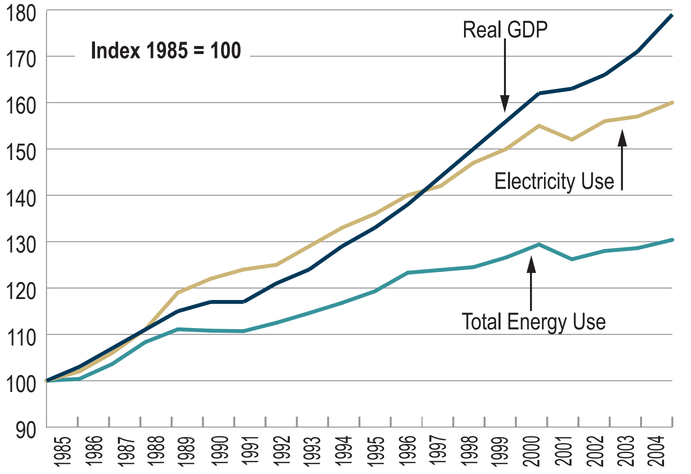
Electricity: A Great Value

Today's high-technology society demands electricity to power nearly all new products that come to market. Electricity and the many technologies that it powers enhance the quality of life for their users, and contribute to the progress and success of our nation. Electricity intensity in the U.S. economy (measured by electricity consumption per dollar of real gross domestic product) is significantly related to the general level of economic activity, as illustrated in Figure 1.

Electricity prices—unlike the prices for most other popular consumer goods—did not keep pace with the rate of inflation for many years, despite an ever-increasing national appetite for electricity. In fact, from 1985 to 2000, electricity prices rose, on average, by 1.1 percent per year, while inflation rose at a rate of 2.4 percent per year during this timeframe.[1] (Economists consider 2 percent retail price inflation normal in our economy, although price inflation has varied dramatically over the past 60 years.)

Since 2000, electricity prices have increased at a 2.5 percent annual rate, which is slightly higher than the 1.99 percent rate of inflation. Even with recent price increases, the growth rate for electricity prices remains comparable to, and even lower than, other important goods. As Figure 2 illustrates, the price of one kilowatt-hour of electricity (in nominal dollars) has increased by just 27 percent since 1985, while the prices of most other consumer goods have risen at much higher levels. This evidence points to an industry that has become more efficient itself—both in management and in technology.

Figure 1: **U.S. Economic Growth Is Linked to Electricity Growth**



1985 represents the base year. Graph depicts increases or decreases from the base year.

Source: U.S. Department of Energy, Energy Information Administration (EIA)

Continuing advances in more efficient electric technologies have made electricity a more valuable commodity. Today's electricity is also much cleaner than it was in the 1980s. In fact, since 1980, electric utilities have reduced air emissions significantly, while electricity use has increased by 77 percent, as illustrated in Figure 7 on page 7.

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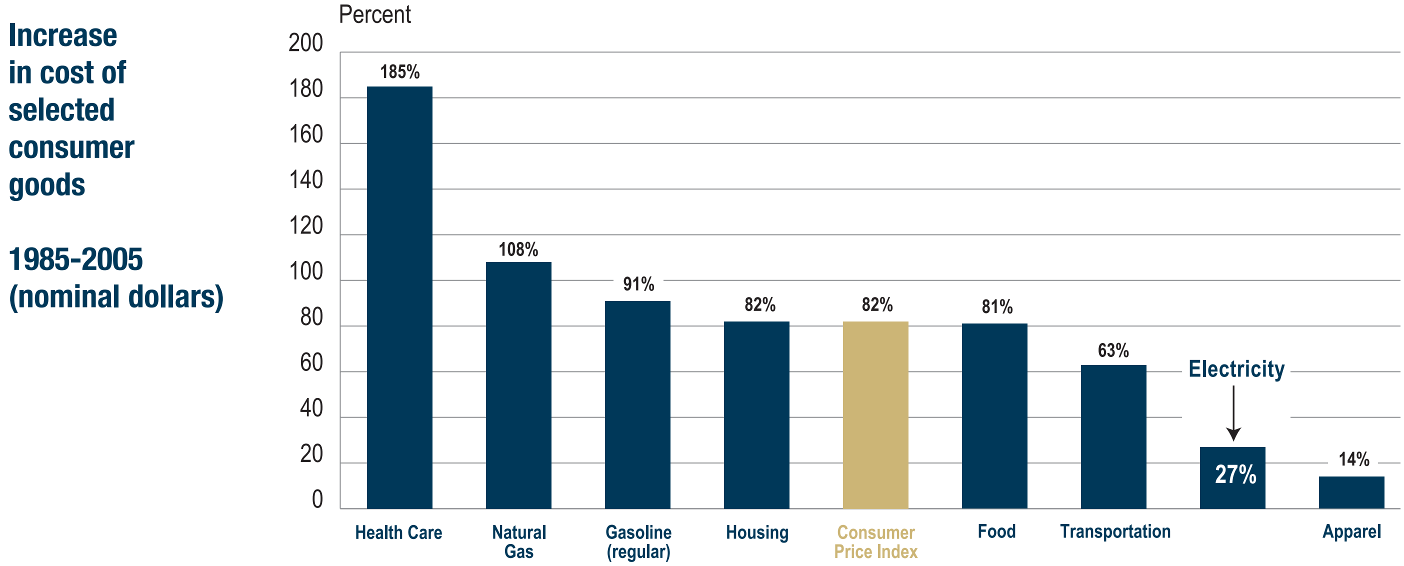
[1] Mark Newton Lowry, David Hovde, and Steve Fenrick. Assessing Rate Trends of U.S. Electric Utilities. Pacific Economics Group, LLC. January 2006. Page 7.

Figure 2: **Electricity: A Great Value**



Sources: U.S. Department of Labor, Bureau of Labor Statistics (BLS), and U.S. Department of Energy, Energy Information Administration (EIA)

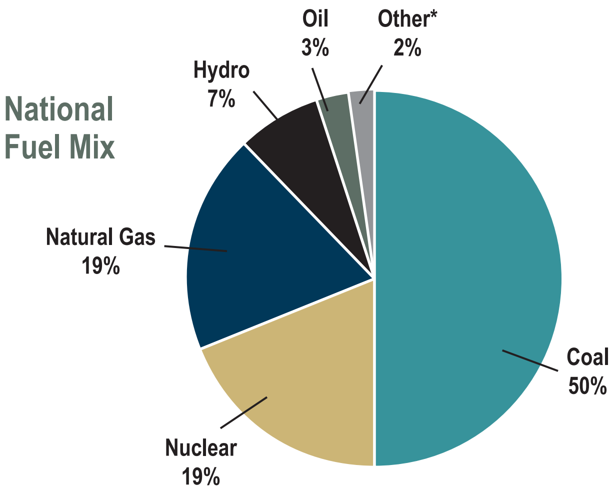
Fuel Diversity Is Key to Affordable and Reliable Electricity

The greatest attribute of electricity is its ability to be generated from many diverse fuel sources, as illustrated in Figure 3. These include coal, nuclear energy, natural gas, oil, hydropower, and other renewable energy resources such as wind and solar. Fuel diversity is key to affordable and reliable electricity.

Across the United States, a diverse mix of fuel is used to generate electricity. Several factors influence an electric utility's decision to use particular fuels. These include the price and the availability of supply. Figure 4 illustrates the diversity of fuel use and shows how the electricity generation mixes in various regions of the country differ.

An important long-term solution to high fuel costs is to maintain the diversity of our nation's available fuel resources to ensure that we do not become too dependent on one fuel source. But, this requires higher capital costs and new infrastructure investments.

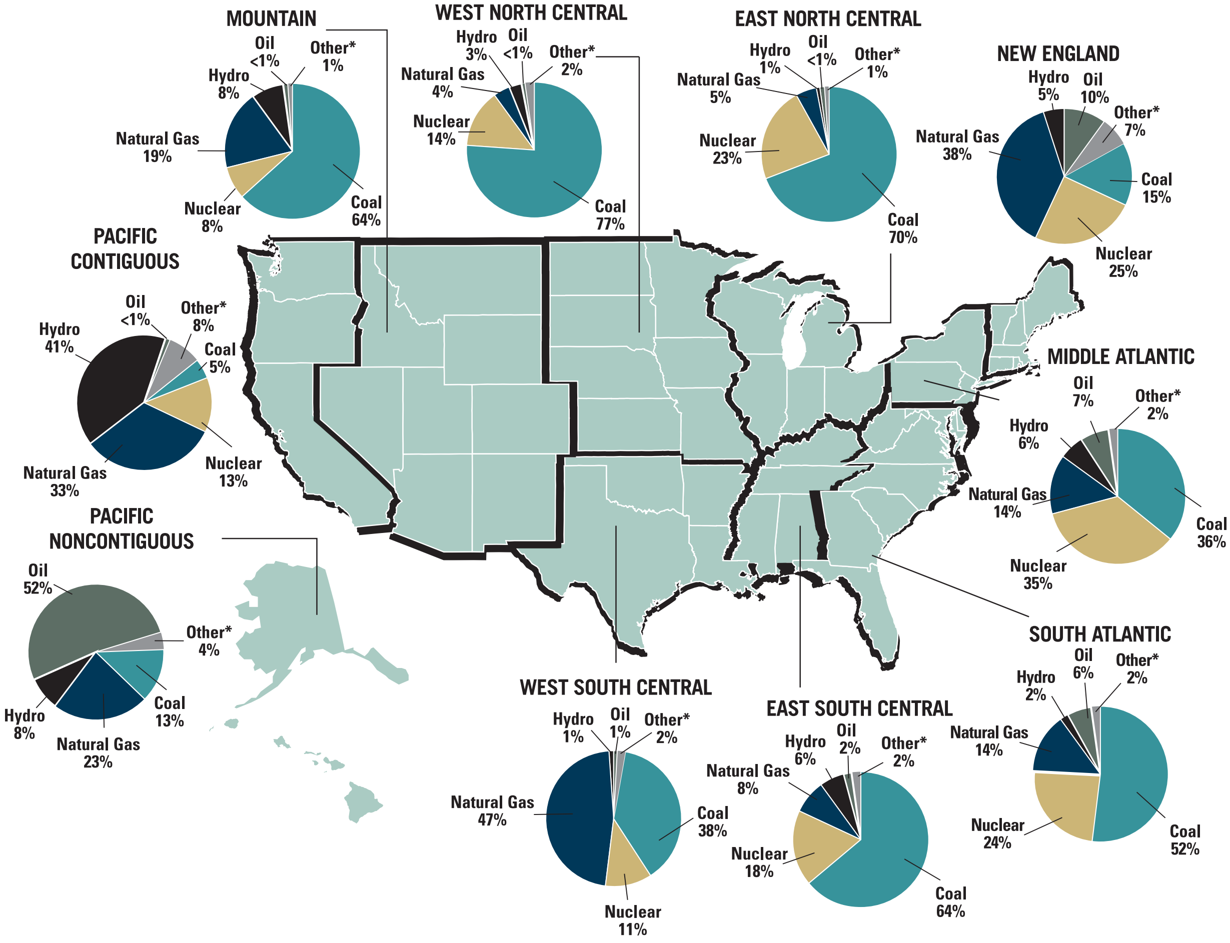
Figure 3: **Electric Utilities Use a Diverse Mix Of Fuels to Generate Electricity**



* "Other" includes generation by agricultural waste, batteries, chemicals, geothermal, hydrogen, landfill gas recovery, municipal solid waste, non-wood waste, pitch, purchased steam, solar, sulfur, wind, and wood.

Source: U.S. Department of Energy, Energy Information Administration (EIA), 2005 preliminary data

Figure 4: **Different Regions of the Country Use Different Fuel Mixes to Generate Electricity**



* "Other" includes generation by agricultural waste, batteries, chemicals, geothermal, hydrogen, landfill gas recovery, municipal solid waste, non-wood waste, pitch, purchased steam, solar, sulfur, wind, and wood.

Sources: U.S. Department of Energy, Energy Information Administration, Monthly Power Plant Report (EIA-906, formerly EIA-759), and Electric Power Monthly (2005 Preliminary).

Continuing Advances in Energy Efficiency Make Electricity Even More Valuable

The increased efficiency of electric products further demonstrates the value of electricity in our society. Today's modern appliances are often larger, offer more features, and use less energy than their older counterparts. At the same time, technological advancements have created many new uses for electricity that continue to enrich our lives.

APPLIANCES

Refrigerators/freezers (shipment weighted averages) made in:

	1972	2004
Size (cubic feet):	18.16	21.52
Annual energy usage:	1,726 kWh	500 kWh
Average hourly usage:	197.0 W	57.1 W

Stand-alone freezers made in:

	1981	2004
Size (cubic feet):	25.53	21.43
Annual energy usage:	837 kWh	448 kWh
Average hourly usage:	95.5 W	51.1 W

Clothes washers made in:

	1988	2003
Size (cubic feet tub volume):	2.61	3.01
Energy usage per cycle:	2.74 kWh	1.97 kWh

Source: Association for Home Appliance Manufacturers

ROOM AIR CONDITIONERS

Room air conditioners are rated on a federal energy efficiency rating called the Energy Efficiency Ratio, or EER. Technology advancements allow the units to run more efficiently and decrease energy usage.

Room air conditioners made in:

	1982	2004
Average cooling capacity:	10,801 Btu/hr	9,735 Btu/hr
EER:	7.14	9.71
Annual energy use:	1,135 kWh/yr	752 kWh/yr

Source: Association for Home Appliance Manufacturers

PERSONAL COMPUTERS

The number of households with personal computers in the United States more than tripled from 1993 to 2001, according to the Energy Information Administration. From 1997 to 2001, the number of households with computers increased 92 percent, while the amount of electricity used to operate the computers increased by less than 64 percent.

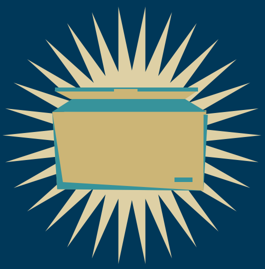
Personal Computers in the United States:

Year	# of Households* (Millions)	Annual PC Electricity Consumption (million MWh)
1993	22.6	N/A
1997	35.6	11.3
2001**	68.4	18.5

***Number of households with at least one computer.**

****Latest available data.**

Source: U.S. Department of Energy, Energy Information Administration, Residential Energy Consumption Survey



Today's Electric Utility Rate Environment

The electric utility industry is among the country's most capital-intensive sectors, with many of its costs stemming directly from investments in and maintenance of the power plants, transmission and distribution lines, equipment, and structures that are used to deliver electricity. Utilities typically cannot recover their costs when they are incurred; instead, they are required by regulatory authorities to spread out their costs to customers over the physical life of the investment—sometimes as long as 30 years—under the assumption that there will be a stable customer base.

While all electric utilities use similar methods to generate electricity, each operates differently to meet the unique needs of its service area. Variables such as regulatory policy, customer demographics, usage patterns, fuel availability, and geographic conditions have a major impact on the cost of providing service, and, therefore, on electricity prices.

Most of the revenue utilities receive is used to pay operating and maintenance costs. Purchased power and fuel are the largest operating expenses for an electric utility; taxes are the next largest expense. The cost of salaries, materials, supplies, services, and a variety of other expenses also must be met. In addition, the utility must be compensated for the cost of depreciation, amortization, and the cost of capital, which includes the return paid to debt and equity investors for the use of their money.

Today, the electric utility industry is facing steadily increasing costs to generate and deliver electricity to American homes, businesses, and industries. While electric utilities make continuous efficiency improvements and are working closely with regulators to contain costs and to keep electricity prices as low as possible, the bottom line is that rising costs are becoming inevitable throughout the United States.

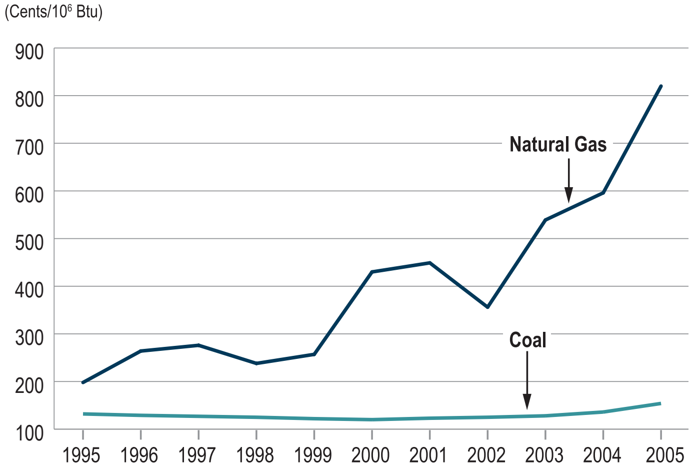
The Costs to Generate Electricity Are Rising

Electric utilities use a variety of fuels to generate electricity. Fuel prices greatly affect the price of electricity. After peaking in the early 1980s, fuel prices trended downward until 1999. Economists point to these decreasing fuel prices as an important reason for the lower, more stable electricity prices during this time period.[2]

However, as illustrated in Figure 5, fossil fuel prices have risen considerably since 1999, particularly for natural gas. The average price electric utilities paid for natural gas rose from $2.57/million Btu in 1999 to $8.20/million Btu in 2005. Coal prices to electric utilities also have increased each year, rising from $1.22/million Btu in 1999 to $1.54/million Btu in 2005.[3]

Electric utilities take steps to help shield customers from these rising fuel costs. For example, they frequently try to mitigate market volatility by "hedging," or entering into long-term, fixed contracts at set prices. But not all companies have this option, and such forward contracts cannot cover all of their fuel needs. At some point, customers inevitably will see these rising fuel costs that electric utilities must pay reflected in their electric bills.

Figure 5: **Average Cost of Fossil Fuels**
1995-2005



The years 2002 and beyond include data for electric utilities, independent power producers, and commercial and industrial combined heat and power producers. The years prior to 2002 include data for electric utilities only.

U.S. Electric Utility: Owns and/or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, distribution, or sale of electric energy primarily for use by the public. This includes shareholder-owned utilities, public power, and cooperatives.

Source: U.S. Department of Energy, Energy Information Administration (EIA)

Demand for Electricity Is Growing

While efficiency improvements have had a major impact in meeting national electricity needs relative to new supply, the demand for electricity continues to increase. According to the U.S. Department of Energy's Energy Information Administration (EIA), consumer demand for electricity is projected to grow at an average rate of 1.5 percent per year through 2030. Overall, electricity consumption is expected to increase 45 percent by 2030.[4]

To meet this increasing demand for electricity and to ensure fuel diversity and reliability, electric utilities must invest in new baseload power plants. According to EIA, 347 gigawatts (GW) of new capacity—both electric power sector capacity and customer-owned distributed generation—will be needed by 2030. Based on EIA assumptions, if all of this new capacity is built, costs would be in excess of $300 billion (2005$). It is likely that electricity

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[2] Pacific Economics Group, p. 12.

[3] U.S. Department of Energy, Energy Information Administration.

[4] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006*, February 2006.

demand could be 200 GW more than otherwise expected, were it not for energy conservation and efficiency programs.

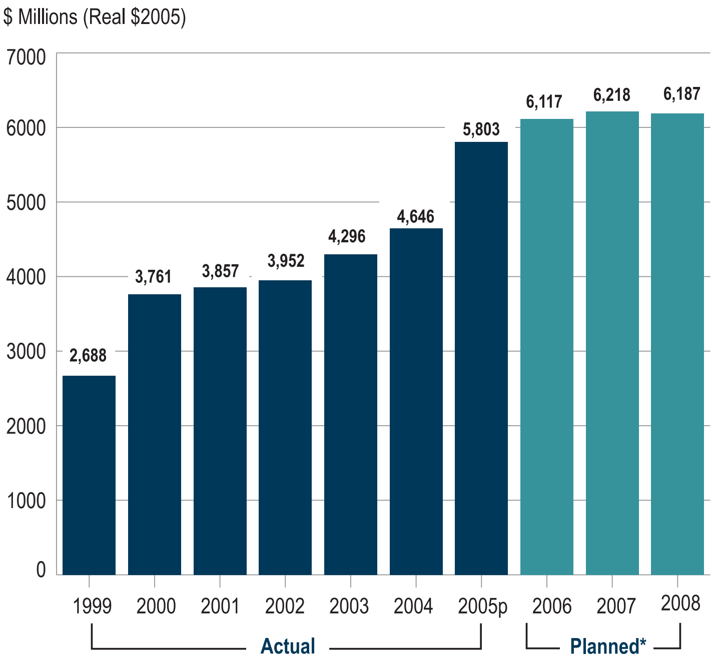
The utility industry has been planning for the additional capacity needed to meet long-term growth in electricity demand and to mitigate exposure to high fuel prices. According to EIA, coal is expected to be the primary fuel for electricity through 2030, with its share of total generation increasing from 50 percent in 2004 to 57 percent in 2030.

EIA also projects that nuclear generating capacity will increase—from about 100 GW in 2004 to 109 GW in 2030. The projected increase in nuclear capacity includes 3 GW expected to come from uprates at existing plants and 6 GW from newly constructed plants.

Infrastructure Investment Costs Are Growing

In addition to building new power plants, electric utilities must reinforce the nation's electricity delivery infrastructure, namely, the high-voltage transmission lines, substations, and distribution systems that carry electricity to the customer. Though we continue to enjoy the world's most reliable electric system, the reality is that more investment is needed to ensure that we have a robust network of "pipes and wires" to keep it that way.

Figure 6: **Actual and Planned Transmission Investment 1999-2008**



p = preliminary

Note: In 2004 and 2005, the industry exceeded investment projections in its transmission capital budgets. The *Handy-Whitman Index of Public Utility Construction Costs* used to adjust for inflation from year to year. Data represents both vertically integrated and stand-alone transmission companies.

*Planned total industry expenditures estimated from 95% response rate to EEI's Electric Transmission Capital Budget & Forecast Survey. Actual expenditures from EEI's Annual Property & Plant Capital Investment Survey and FERC Form 1s.

Source: Edison Electric Institute

This presents challenges. First, investment in power lines lagged behind growth in demand for electricity during the 1980s and 1990s. Second, regulatory rules and market structures were revised in many areas of the country to create more competitive power markets at the wholesale level. This has increased demand for use of the transmission grid. In order to build the system to better meet current and future demand, to alleviate congestion, and to reinforce system reliability, electric utilities have earmarked billions of additional dollars for investment in the coming decade.

As illustrated in Figure 6, investment in transmission has increased 116 percent since 1999, and electric utilities are planning to invest an additional $18.5 billion through 2008 on transmission infrastructure—a 25-percent increase over the previous three years.

Environmental Compliance Costs Are Significant

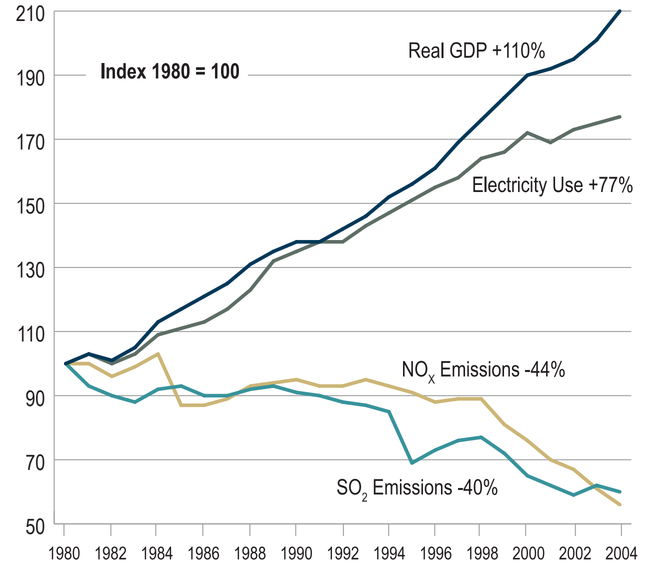
Still another major financial challenge looms for the electric utility industry—the massive price tag for compliance with environmental regulations. All electric utilities are subject to literally hundreds of environmental rules, including dozens of federal and state air and water quality requirements created in the wake of the Clean Air Act and Clean Water Act.

The combined impact of these regulations—and newer regulations—is the annual expenditure of billions of dollars to help ensure protection of the air, land, and water. From 2002-2005, the electric utility industry as a whole spent $24 billion on compliance with federal environmental laws; state and local rules drive that total even higher.

Electric utilities are more than ready to do their share to help preserve and improve our nation's environmental quality, and the evidence is there to support that. As illustrated in Figure 7, since 1980, air quality in the United States has improved dramatically, and emissions of nitrogen oxides (NO_X) and sulfur dioxide (SO_2) have fallen significantly—all during a time in which demand for electricity increased.

But the costs associated with continuous environmental improvements are significant. For example, according to the U.S. Environmental Protection Agency, complying with two new federal regulations—the Clean Air Interstate Rule and the Clean Air Mercury Rule, which are aimed at further reducing power plant emissions of NO_X, SO_2, and mercury—will cost the electric utility industry $47.8 billion between the years 2007 to 2025.[5] As utilities enter another phase of emissions reductions, those costs will be reflected in customers' electric bills and must be borne equitably by all customers on the system.

Figure 7: **Power Plants Reduce Emissions Despite Increasing Electricity Demand**
1980-2004



1980 represents the base year. Graph depicts increases or decreases from the base year.

Sources: U.S. Department of Energy, Energy Information Administration (EIA), and U.S. Environmental Protection Agency (EPA)

Price Caps Set During Industry Restructuring Are Expiring

A major shift in the utility landscape began in the mid-1990s, as a number of states, especially those in the Northeast, Mid-Atlantic region, and the Midwest, along with California, moved to restructure portions of the retail electricity industry. Aiming to lower costs by stimulating competitive markets for the generation portion of customers' bills, these states moved away from the traditional model in which state regulators set the retail prices for power.

Today, 19 states and the District of Columbia have adopted programs for retail electric competition. One prominent hallmark of nearly every state that adopted such markets was this—as part of the gradual transition to competition, state policymakers decreed that customers' bills would be frozen, and in many cases reduced, typically for a period ranging from two to ten years. The first rate caps were put in place in 1997, and the last are set to expire in 2011.

Beginning in 2004, many of those rate freezes and reductions began to be phased out. The result is that many customers now perceive that their rates are being "increased," when in fact they are gradually reflecting the costs already incurred by utilities.

What Steps Are Electric Utilities Taking to Help Control Rising Prices?

Over the past decade, the electric utility industry has focused on improving the operations of its baseload generating fleet. Since 1995, coal and nuclear generation capacity factors—a measure of plant productivity—have increased by 15 and 17 percent respectively. Over the same period of time, operations and maintenance (O&M) costs have decreased by 17 percent for existing coal-based generators and 30 percent for nuclear generating units.

To help their customers manage their electricity costs and use energy wisely, electric utilities have taken a leading role in developing energy efficiency and demand response programs for residential, commercial, and industrial customers. Between 1989 and 2004, electric utility efficiency programs saved about 736 billion kilowatt-hours of electricity. That is enough electricity to power nearly 68 million average U.S. homes for one year. [To learn more about electric utility programs and incentives to improve energy efficiency and reduce energy, visit www.eei.org/wiseuse.]

Efforts like these have been, and will continue to be, key factors in helping to mitigate rising fuel costs and the need for new infrastructure investments.

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[5] U.S. Environmental Protection Agency, Office of Air and Radiation, October 2005.

Investing in America's Electric Future

Capital-intensive industries, such as the electric utility industry, often experience cycles of growth in which investments are made in new equipment and new facilities to meet current and future demand. Research shows that new capital investment, which tends to increase retail prices initially, will result in more stable prices in the future.

Electricity prices nationwide remained relatively stable from 1990 to 2000. Since 2000, utility operating costs have increased as utilities confront higher fuel costs and make investments in infrastructure and environmental improvements. Today, electric utilities are entering a new cycle of growth and investment, and a new era of ratemaking.

Clearly, electricity is an indispensable commodity that is crucial to our daily lives and to our nation's continued economic growth. And the costs needed to reinforce the nation's electric power system are worthy long-term investments. The bottom line is that we are living in a rising cost environment, and electricity prices have been a great deal for many years. Even with expected rate increases, electricity prices are projected to remain below the rate trends of other goods and services. In fact, the national average price for electricity today is significantly less than what it was in 1980, adjusted for inflation.

Of course, that is small comfort to customers who will be opening costlier electric bills in the coming months. And no one—utility, regulator, or customer—is eager to see electricity prices increase. The unavoidable reality, however, is that we all must address the fact that in order to ensure that electricity remains affordable and reliable, we must help shoulder the expense of reinforcing and upgrading our electricity infrastructure. It is the only way to be certain that electricity will be there when we need it, and at a price we can afford over the long term.

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